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# Providing a GIS-based Combined Model Applied to Evaluate Urban Environment Carrying Capacity in Shemiran City, Iran


## ABSTRACT

*Urban ecosystems evolve over time and space, as the outcome of dynamic interactions between Socio-economic and biophysical processes operating over multiple scales. If the urban population and human activities expand infinitely and exceed the "limit of urban capacity", local urbanites would no longer perceive prosperity, but be troubled by the overall deteriorations in Socio-economic and ecological aspects. On this basis, the present study aims to suggest a GIS-based model, combined of TOPSIS along with Fuzzy modeling, in GIS environ as a Spatial Decision Support System (SDSS), to evaluate Urban Environment Carrying Capacity. Suggested model was planned on basis of desirable and the maximum accepted limits of chosen indicators, used to determine Hot spots widths. The study area was Shemiran City (according to data collected at 2013) with 43%, 44% and 10% had Degree 2 (low pressure), Degree 3 (median pressure) and Degree 4 (Maximum pressure) of carrying capacity, respectively; also only 3% was at critical state. None of the studied districts has desirable degree of Carrying capacity.*


**Key words**: *Urban Environment Carrying Capacity (UECC); GIS- based Model; TOPSIS; GISFM; Evaluation; Shemiran City*


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## INTRODUCTION

Urban ecosystems evolve over time and space as the outcome of dynamic interactions between Socio-economic and biophysical processes operating over multiple scales (*Alberti 1999*). Cities are complex ecological systems dominated by humans. The human elements make them different from natural ecosystems in many ways. From an ecological perspective, urban ecosystems differ from natural ones in several respects; including their climate, soil, hydrology, species composition, population dynamics and flows of energy and matter (*Alberti 2008*).

With rapid urbanization across the world, many megacities have become showcases for a host of concomitant diverse urban problems. The "urban diseases" frequently besetting these cities include traffic congestion, housing shortage, lack of amenity, environmental pollution, and others, which has posed actual challenges and impediments for sustainable development (*Wei et al. 2015*). If the urban population and human activities expand infinitely and exceed the "limit of urban capacity", local urbanites would no longer perceive prosperity, but be troubled by the overall deteriorations in Socio-economic and ecological aspects. The immediate cause for these problems is the overdevelopment or over-concentration of population and Socio-economic activities in urban areas, which has greatly exceeded the inherent UCC (Urban Carrying Capacity) of cities (*Oh et al. 2002; Shi et al. 2013*).

In terms of urban planning, carrying capacity is the determined ability of the natural and artificial environment to support the demands of various uses (*Godschalk and Parker 1975*). In addition, carrying capacity is defined as the ability of natural and man-made systems to absorb population growth or physical development without serious decline or damage (*Schneider et al. 1978*). As a social science concept, carrying capacity is defined as the economic scale that the natural system of an area can sustain (*Lee 1999*). Furthermore, the urban carrying capacity can be defined as the level of human activities, population growth, patterns and extent of land use, physical development and etc., which can be sustained by the urban environment without causing serious degradation and irreversible damage (*Oh et al. 2005*).

These concepts is based on the assumption (*Kozlowski 1990*) that there are certain environmental thresholds that when exceeded can cause serious and irreversible damage to the natural environment. These approaches concerning carrying capacity can be useful when the thresholds are identified ahead of time. The determination of the capacity of urban space is straightforward when managing such human activities as population, traffic and land-use (*Lee et al. 2009*).

Environmental Carrying Capacity (ECC) is crucial to the speed and scale of a regional economic and Socio development and the continuous improvement of the ECC is a must for the sustainable development (*Zhang and Xu 2010*).

A review of several urban carrying capacity studies conducted in this field suggests that urban pressure indicators for studying urban sustainability consist of 8 main items including: air, energy, green areas, noise, transport, waste, water and territorial/demographic data (*European Commission-Eurostat 2001*). From 1996, ISTAT has collected the data related to 22 major Italian cities through environmental survey on major cities. The selected analytic framework is the well-known driving-pressures-state-impact-responses model, which is widely used for environmental indicators. In some cases, due to the lack of statistical data, indicators have been selected on the basis of availability and comparability criteria. Some of the main indicators were population density, possession of land, green space and transportation area, access to green space, emission of $CO_2$, $NO_x$, VOC, $PM_{10}$, Pb, water consumption per capita, sewage COD/BOD, soil contaminant, municipal waste per capita and energy consumption (*Tehrani and Makhdoum 2013*). *Godschalk and Axler* (*1977*) suggested soil, slope, vegetation, wetlands, scenic resources, natural hazards, air and water quality, and energy availability as factors affecting environmental carrying capacity. *Onishi* (*1994*) employed factors such as water supply, sewage, waste treatment, railway, road, and housing. *Liu* (*2012*) developed an UCC evaluation model whit 12 measurable indicators that focus on the physical factors, such as land, water, transportation and environment. *Tehrani and Makhdoum* (*2013*) employed factors such as natural state, population, resources consumption, waste/emission production and urban facilities. *Wei et al.* (*2015*) suggested key indicators that determine the UCC of an urban area are grouped into five main UCC components, i.e., environmental impacts and natural resources, infrastructure and urban services, public perception, institution setting and society supporting capacity.

Despite plenty of discussions and explanations, UCC still lacks a widely accepted definition and standardized assessment method (*Shi et al. 2013; Wei et al. 2015*).

Some of methods that directly or indirectly used to estimate the urban environment carrying capacity include: IPAT equation (*Chertow 2001*), energy analysis model (*Zhao et al. 2005*), ecological footprint model (*Du et al. 2006*), uni constraint model, graphical model, Pressure-State-Response model (*Guwahati 2012*) and spatial-Temporal models (*Tehrani and Makhdoum 2013*; *Wang et al. 2014*).

The present study addressed 28 indicators emphasizing on principal aspects of urban environment (ecological-economic-Socio) in 10 key subjects, including climate quality, underground water, earth shape, natural disasters, population; urban land use planning; consumption of matter and energy; production of wastes and traffic), in order to evaluate Urban Environment Carrying Capacity using a GIS-Based combined model.

## Study Area

Shemiran City, located at the center of Shemiranat County, the most northern point of Tehran Province-Iran. Stretched in 51° 23´ to 51° 32´ eastern longitude and 35° 46 ´to 35° 50´ northern latitude, the study area is located at Alborz slope of the south (**Figure 1**). Composed of 10 districts, totally 46 km$^2$, Shemiran City includes approximately 461,714 people (According to last statistics of 2013). Because of high divers natural, economic and Socio attractions, in two recent decades, population increased and as a result, constructions especially in mountain area, as well as the heights upper than 1,800 m, beside river valleys and faults, which consequently resulted in instability and irreversible damages.

## MATERIALS AND METHODS

This study applied a GIS-based model, combined of TOPSIS along with Fuzzy modeling, in GIS environ as a Spatial Decision Support System (SDSS), to evaluate Urban Environment Carrying Capacity. Combination of GIS with mentioned technique results in a useful tools in Spatial Planning (*Jankowski, 1995; Malczewiski, 1999*).

Suggested model was planned on basis of the desirable and maximum accepted limits of the selected indicators. However, due to difference of selected indicators, as well as their changes throughout the studied extent, evaluation of socio-economic and ecological Urban Environment Carrying Capacity is carried out separately, and results are compiled finally (**Figure 2**).

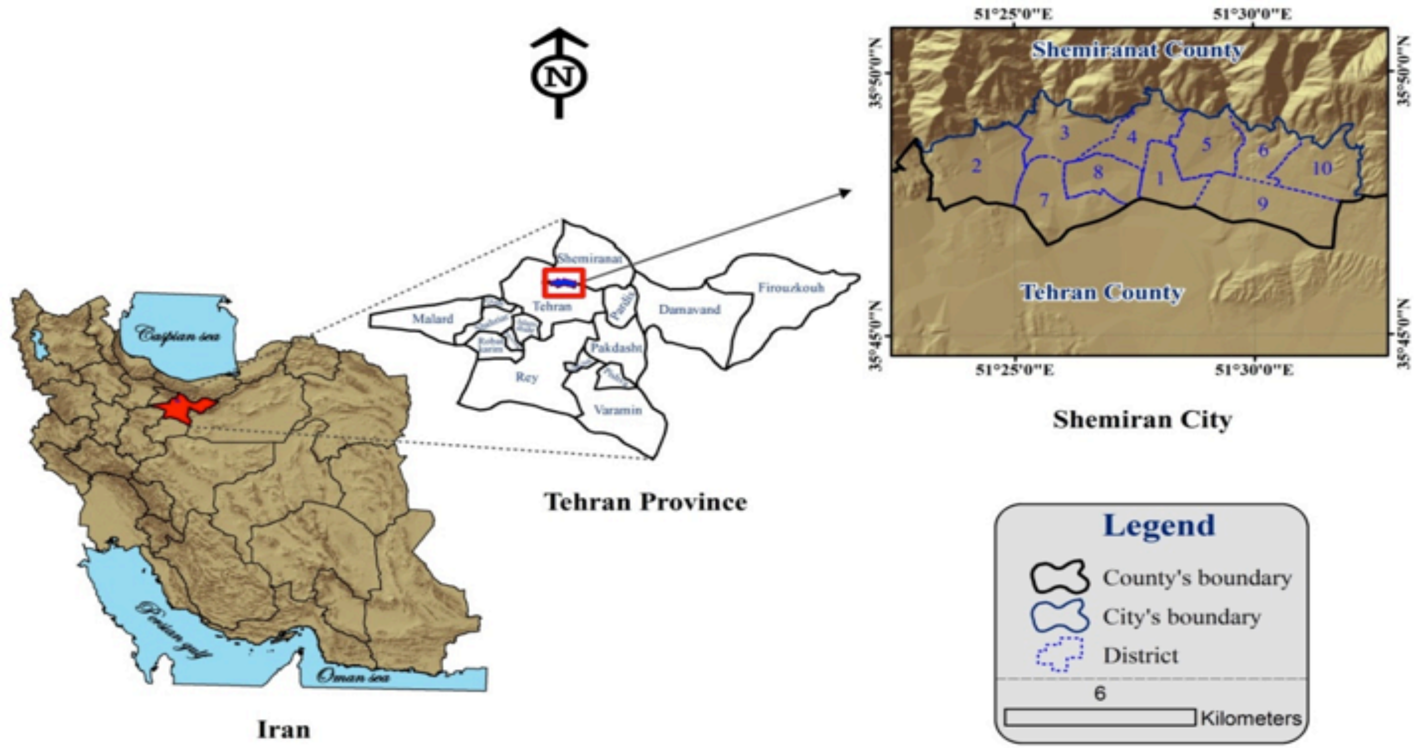


Figure 1. Location of Shemiran City, located in Tehran-Iran.

**Selecting the indicators of Urban Environment Carrying Capacity**

Throughout the study, according to DPSIR, a causal framework for describing the interactions between society and the environment was used to determine, develop and primary organization of selected indicators (*Godschalk and Axler 1977; Frank et al. 1997; Joardar 1998; European Commission-Eurostat 2001; Oh et al., 2005; Chennamaneni and Rao 2007; Li et al. 2009; Lee et al. 2009; Shen et al. 2011; Liu 2012; Tehrani and Makhdoum 2013; Wang et al. 2014; Wei et al. 2015*). In the mentioned model, extended form of DSR and PSR models, are classified in five separate groups: Driving forces: Pressures: States: Impacts: Responses. (*Kristensen 2004*). Applying such a framework seems to be appropriate in identification of the gap between current data, the whole indicators and general perception of the Environment-Human System (*Meadows 1998; UN 2007; Nees et al. 2007*). The following, according to direct relationship between driving forces and Pressures) of urbanism, as well as activities of natural and artificial (man-made) environ of urban environment, to choose the most appropriate indicators, Driving forces, Pressure and States were noticeably focused (**Table 1**). Eventually, 28 indicators emphasizing on principal aspects of urban environment in 10 key subjects were applied, in order to evaluate Urban Environment Carrying Capacity using a GIS-Based combined model (**Table 2**).

**Weighting of indicators**

Since diverse indicators (ecological and Socio-economic) play different role in imposing the pressure on urban ecosystem, as well as Urban Environment Carrying Capacity, hence evaluation process of indicators, on basis of standardized values is impossible and results would be inaccurate. To fix the problem, weighting to the indicators using multi-criteria decision-making methods is inevitable. To this regard, Analytical Hierarchy Process (AHP) is used with the help of Expert choice software (**Table 3**).

**Determination of desirable and maximum accepted limits of indicators, used to grading the carrying capacity**

The value of each indicator which lead to no changes or minimum changes and minimum Pressure or Disturbances in Urban environment is determined as Desirable Limit, which is noted by D1 (DCC= 1). Also, the value of indicators which is tolerated by Urban Environment as Maximum Pressure, before resulted in serious damages or irreversible changes, is determined as Maximum accepted limit of indicators and noted by D4. Overshooting the mentioned limit, cause destruction and irreversible changes (D5), which lead the Urban Environment to collapse. The grading of Carrying Capacity of the indicators (in 5 classifications) based on deterministic degrees applied in Socio-economic indicators, as well as their equal

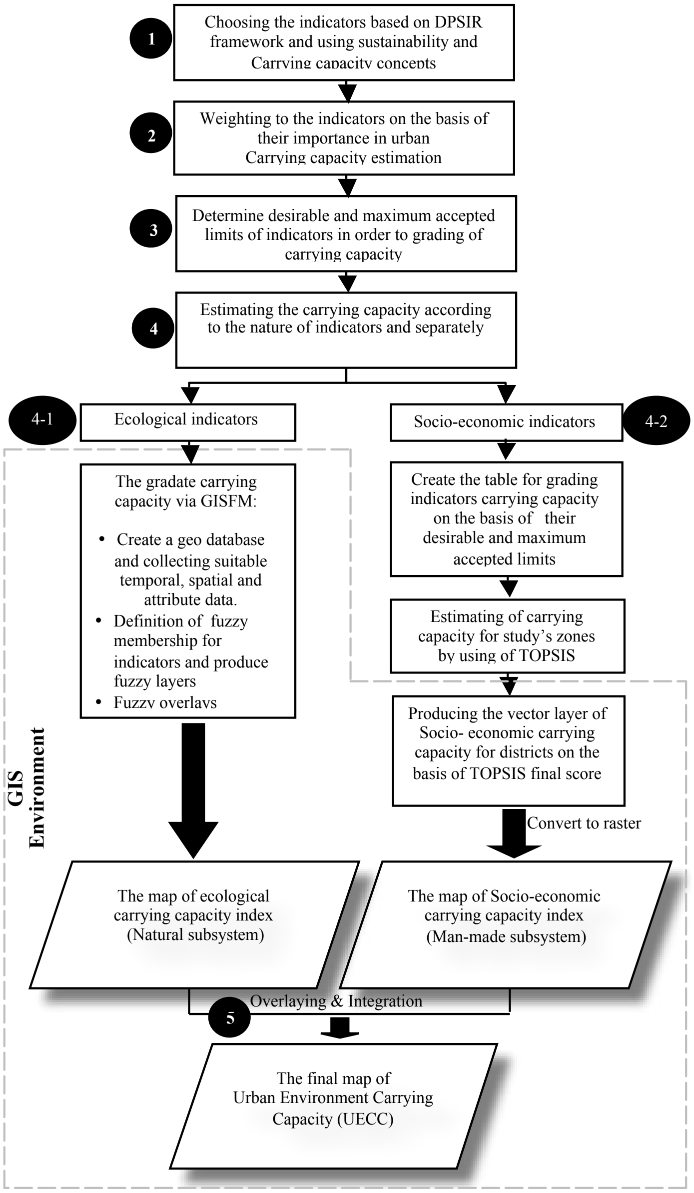


Figure 2. The flowchart of the UECC evaluation process.

fuzzy degree (used to ecological indicators) (**Table 4**).

It is worth to mention that, in general, indicators which have national or international standards (height, underground water depth, climate quality, population density, urban land use per capita), their desirable and maximum accepted limits are considered as basis of grading. For example, to grading the carrying capacity of ecological indicators of slope and height, ecologic model of urban development of Iran was used (*Makhdoum, 1999*) (**Table 5** and **6**).

**Evaluation of ecological and Socio-economic carrying capacity based on the nature of indicators separately**

**Evaluation of ecological carrying capacity by GISFM method**. As ecological indicators has Geospatial specification, and their changes are not limited to Districts limits, hence, to grading their carrying capacity and evaluation of ecological Urban Environment Carrying Capacity, Fuzzy model is applied in GIS environ, called as GISFM (GIS Fuzzy modeling).

GIS Fuzzy Modeling is considered as an appropriate procedure to prevent uncertainty and imprecision (*Badenko and Kurtener 2004; Amiri et al. 2013*) which is used in 4 steps:

1. Create a Geographical Database (GDB) in GIS environ

Collection, entry, storage and editing of attribute and spatial data related to indicators based on specified time limits (2003-2013) using ArcGIS$_{10.1}$

2. Creation of Raster layers of ecological indicators: profiting needed function of each indicator.

Table 1. The questionnaire sections.

| Criteria | Ref. |
|---|---|
| Linkage with environmental, economic and Socio issues. | [1] |
| Rich implications to the state of present conditions and link ultimate impacts with human activities. | [2] |
| Easy to quantify and reliably measurable. | [3] |
| Good data availability. | [4,5,6] |
| Understandable; simple enough to be understood by laypersons | [1] |
| Responsive; respond quickly and measurable to changes. | [1] |
| Systematic, comprehensive and spatial. | [7] |
| Principles | |
| • Ecosystem's carrying capacity concepts:<br>Entropy rate; changes in indicator's values during the time.<br>Source-sink capacity; the capacity of resources to supply urban ecosystem, as well as sinks to eliminate the wastes, and their interactions.<br>Urban metabolism analysis; flow of energy and material consumption. | [8] |
| • Sustainability concepts:<br>Access to the urban facilities; using spatial indicators of urban facilities.<br>Equity in sharing the environmental resources, cost and benefits; applying spatial indicators of resource consumption. | [8,9] |

Table 2. The indicators selected based on DPSIR framework and to consider carrying capacity and sustainability concepts.

| Main dimensions of urban environment | Key topic | Indicator | Type- in terms of "DPSIR" | The principles of selecting indicators (carrying capacity and sustainability concepts): Entropy rate | Source-sink equilibrium | Urban metabolism | Access to the urban facilities | Distribution of facilities and risks | Change in urban physical structure | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|
| Ecological (Natural subsystem) | Ambient air quality | PSI (Pollutant Standards Index) | S | ■ | | ■ | | | | [1,2,3,4] |
| | Groundwater | Groundwater depth | S | | ■ | | | | ■ | [5] |
| | Landform | Elevation | S | | | | | ■ | ■ | |
| | Disaster vulnerability | Slope | S | | | | | ■ | ■ | [5,6] |
| | | Earthquake vulnerability | S | | | | | ■ | ■ | |
| | | Flood vulnerability | S | | | | | ■ | ■ | |
| | | Gross population density | D | | ■ | | | | | Authors [5,7,8] |
| | Population | Population growth rate | D | ■ | | | | | | |
| | Urban land use: per capita | Residential | S | | | | | ■ | | |
| | | Educational | S | | | | | ■ | | [4,5,7,8, 9,10,11] |
| | | Health | S | | | | | ■ | | |
| | | Green space | S | | | | | ■ | | |
| | | Transportation network | S | | | | | ■ | | |
| | Urban land use: area | Build up/total area | S | | | | ■ | | | [5,8] |
| | | Green space/total area | S | | | | | | | |
| | | Transportation/total area | S | | | | ■ | | | |
| | | Water consumption | D | | | ■ | ■ | | | [5,8,11] |
| Socio-economic (Man-made subsystem) | Material consumption | Water consumption/ water resources | P | | ■ | | | | | |
| | | Water consumption rate | P | ■ | | | | | | [5] |
| | Energy consumption* | Gas consumption | D | ■ | | ■ | | | | |
| | Waste production | Gas consumption rate | P | | | | | | | |
| | | Electricity consumption | D | | | ■ | | | | [5,8,11] |
| | Traffic | Electricity consumption/ electricity resources | P | | ■ | | | | | |
| | | Electricity consumption rate | P | ■ | | | | | | [5] |
| | | Waste production | P | | | ■ | | | | [5,8,11] |
| | | Waste production rate | P | ■ | | | | | | [3,4,5,12] |
| | | Recycling rate | R | | ■ | | | | | |
| | | Traffic congestions | S | | ■ | | | | | [5,10,11] |

References: [1]. *Frank et al. 1997* [2]. *Lee et al. 2009*. [3]. *Li et al., 2009.* [4]. Shen et al., 2011. [5]. *Tehrani and Makhdoum 2013*. [6]. *Godschalk and Axler 1977*. [7]. *Wang et al. 2014*. [8]. *European Commission-Eurostat 2001*. [9]. *Deakin et al. 2007*. [10]. *Oh et al. 2005*. [11]. C*hennamaneni and Rao 2007*. [12]. *Joardar 1998*.

* Indicator "gas consumption/ gas resources" due to lack of data and uncertainty in Shemiran City share of Iran natural gas reserves has not been considered.

Table 3. The weights of selected indicators in UECC evaluation.

| Main dimensions of urban environment | The relative importance | Indicators | normalized weights | Overall inconsistency* |
|---|---|---|---|---|
| | | PSI (Pollutant Standards Index) | 0.052 | |
| Ecological (Natural subsystem) | 0.5 | Groundwater depth | 0.077 | |
| | | Elevation | 0.113 | |
| | | Slope | 0.226 | 0.03 |
| | | Earthquake vulnerability | 0.399 | |
| | | Flood vulnerability | 0.133 | |
| | | Gross population density | 0.049 | |
| | | Population growth rate | 0.146 | |
| | | Residential per capita | 0.009 | |
| | | Educational per capita | 0.009 | |
| | | Health per capita | 0.009 | |
| | | Green space per capita | 0.018 | |
| Socio- economic (Man-made subsystem) | 0.5 | Transportation per capita | 0.009 | |
| | | Build up/total area | 0.005 | |
| | | Green space/total area | 0.005 | |
| | | Transportation/total area | 0.009 | |
| | | Water consumption | 0.053 | |
| | | Water consumption/water resources | 0.213 | |
| | | Water consumption rate | 0.106 | |
| | | Gas consumption | 0.012 | |
| | | Gas consumption rate | 0.023 | |
| | | Electricity consumption | 0.011 | 0.04 |
| | | Electricity consumption/electricity resources | 0.021 | |
| | | Electricity consumption rate | 0.037 | |
| | | Waste production | 0.021 | |
| | | Waste production rate | 0.085 | |
| | | Recycling rate | 0.043 | |
| | | Traffic congestions | 0.107 | |

Table 4. Degree of carrying capacity according to crisp and fuzzy degrees and their definition.

| | Degree of Carrying Capacity (DCC) | | | | |
|---|---|---|---|---|---|
| | $D_1$ | $D_2$ | $D_3$ | $D_4$ | $D_5$ |
| Crisp or Deterministic degrees | 1 | 2 | 3 | 4 | 5 |
| Fuzzy degrees domain | 0 - 0.2 | 0.2 - 0.4 | 0.4 - 0.6 | 0.6 – 0.8 | 0.8 - 1 |
| Color ramp | | | | | |
| Associated pressure | None -very low | Low | Medium | High | Very high |
| Meaning | Desirable limit = Safe level of indicator that causes minimum change or damage | Level of indicator that causes low change or damage | Level of indicator that causes medium change or damage | Maximum accepted level of indicator = Level of indicator that causes high change or damage | Critical limit= exceeding from maximum acceptable level that beyond it, irreversible changes or degradations will occur |

3. Fuzzification of Raster layers based on desirable and maximum accepted limits:

Using this procedure, values of input layers is calibrated using proper Fuzzy functions (according to expertise within 0-1 intervals) in ArcGIS software.

Indeed, in mentioned step, Fuzzy membership is defined, and then carrying capacity of indicators is gradated in 0-1 intervals. Maximum membership shows the

Table 5. Gradation the carrying capacity of ecological indicators based on desirable and maximum limits, and using fuzzy functions.

| Ecological indicators | Measuring unit | Degree of Carrying Capacity (DCC) and Fuzzy degrees domain | | | | | Type of fuzzy membership function |
|---|---|---|---|---|---|---|---|
| | | $D_1$ 0 – 0.2 None – very low pressure | $D_2$ 0.2 – 0.4 Low pressure | $D_3$ 0.4 – 0.6 Medium pressure | $D_4$ 0.6 – 0.8 High pressure | $D_5$ 0.8 - 1 Very high pressure | |
| PSI | - | X≤50 | 50<X≤100 | 100<X≤200 | 200<X≤300 | 300<X | Fuzzy large |
| Groundwater depth | m | | X>20 | | X= 20 | 20>X | Fuzzy small |
| Elevation | m | 400≤X≤1200 | | 1200<X≤1800 | | | User defined |
| Slope | Degree | X≤6 | | 6<X≤9 | | 1800<X | Linear-S shape |
| Earthquake | Zoning | X= 1 | | 1<x<5 | | 9<X | Linear |
| vulnerability | | X= 1 | | | | X= 5 | |
| Flood vulnerability | Zoning | | | 1<x<5 | | X= 5 | Linear |

maximum pressure and critical state (D5) and Zero presents zones without Pressure (D1). Gradating the carrying capacity of ecological indicators based on desirable limit and maximum accepted limit, as well as Fuzzy functions (**Table 5**).

It is worth mentioning that to zoning the studied area respected to natural disasters (Flood and earthquake vulnerability), following measures were done:

First, considering effective criteria (including: earth-made factors and type of stone and soil, potential landslides, earthquake history, type and size of faults in the study area) vulnerability map was prepared in 5 domains: resistant, low vulnerability, median vulnerability, high vulnerability, very high vulnerability. Afterwards, using linear Fuzzy Function, 1 to 5 values were transformed to 0 to 1 values. So that, Zero Pixels shows None-very low pressure ($D_1$) and 1 Pixels shows very high pressure state ($D_5$), and also 0 to 1 values represents pressure increment on ecosystem and reduction of tolerable capacity of environment.

4. Overlaying of Fuzzy layers of indicators and preparation the map of ecological Carrying Capacity index

In this step, resulted weights are applied instead of operators of Fuzzy sum, Fuzzy product and Fuzzy gamma, in order to improve evaluation process accuracy (**Table 3**). To this aim, Fuzzy layers were combined in Weighted Sum manner which is a Fuzzy Weighted Linear Combination (FWLC). As a result, the map of ecological carrying capacity index of the studied area (Shemiran City) is achieved.

**Evaluation of Socio-economic Carrying Capacity using TOPSIS method**. Since, Socio-economic Indicators (such as: gross population density, material and energy consumption, etc.,) are separable based on studied districts (Urban districts), and so it is possible to consider a deterministic number for each district, then, to evaluate Socio-economic Urban Environment Carrying Capacity of each district TOPSIS technique is applied. Firstly presented by *Hwang and Yoon* (*1981*), mentioned above Technique is widely used in multi-criteria decision-making. In ideal point method, all options are classified based on their distance to ideal point, which could be a hypothetical point, achieved as a consequent of total variables. Basis definition of TOPSIS extremely insists on the minimum distance between selected options and positive ideal points, and the maximum distance between selected options and negative ideal points (*Chen and Tsao 2008*).

Hereby, it should be mentioned that, in the present study, not only positive ideal point does not represent desirable condition, but only it has been considered as the maximum pressure (D5), or critical state of transition from Tolerance threshold; whereas, negative ideal point represents desirable condition (D1). Indeed, negative and positive directions (+ and -) shows increment or reduction of pressure on urban ecosystem. Briefly, this section of the study consists of following steps:

1. Preparation of classification Table for Socio-economic Indicators of Carrying Capacity: on basis of desirable and maximum accepted limits (**Table 6**), and then calculation, as well as determination of carrying Capacity of Indicators for each districts of the study area.

2. Formation of TOPSIS decision-Making Matrix: composed of 10 options (Districts of the studied area) and 22 Socio-economic indicators. Carrying capacity of all indicators is given to the matrix, on basis of the studied districts. All scores are standardized in 1 to 5 intervals, so that there is no need to no-scaling of decision-making matrix.

Table 6. Gradation the carrying capacity of Socio-economic indicators based on desirable and maximum limits.

| Socio-economic Indicators | Measuring unit | Degree of Carrying Capacity (DCC); (Deterministic degrees) | Description |
|---|---|---|---|
| Gross population density | Person $ha^{-1}$ | $D_1 \le 50 < D_2 \le 70 < D_3 \le 90 < D_4 \le 110 < D_5$ | Human population density is the most important indicator that should be considered in estimating the environmental carrying capacity of an urban ecosystem. For this purpose, 50 persons $ha^{-1}$ (*Tehrani and Makhdoum 2013*) and 110 persons $ha^{-1}$ (EEAC, 2002) were introduced as minimum desirable and maximum accepted limits, respectively. To calculate the values of DCC for the indicator of population growth rate (and other indicators that indicate the rate of changes), the data of indicators were collected between the years of 2003 to 2013. The data were applied in the exponential growth function with (n = 10).Maximum and minimum level of the DCC's of urban land-use and facilities indicators were determined considering the international and national standards and existing constrains in the study area. |
| Population growth rate | % | * | |
| Residential per capita | $m^2$ $person^{-1}$ | $D_1 \ge 50 > D_2 \ge 30 > D_3 \ge 10 > D_4 \ge 2 > D_5$ | |
| Educational per capita | $m^2$ $person^{-1}$ | $D_1 \ge 5 > D_2 \ge 3 > D_3 \ge 2 > D_4 \ge 1 > D_5$ | |
| Health per capita | $m^2$ $person^{-1}$ | $D_1 \ge 1.5 > D_2 \ge 1.25 > D_3 \ge 1 > D_4 \ge 0.75 > D_5$ | |
| Green space per capita | $m^2$ $person^{-1}$ | $D_1 \ge 15 > D_2 \ge 9 > D_3 \ge 6 > D_4 \ge 3 > D_5$ | |
| Transportation per capita | $m^2$ $person^{-1}$ | $D_1 \ge 25 > D_2 \ge 20 > D_3 \ge 10 > D_4 \ge 5 > D_5$ | |
| Built area/ total area | % | $D_1 \le 50 < D_2 \le 60 < D_3 \le 70 < D_4 \le 80 < D_5$ | |
| Transportation network/ total area | % | $D_1 \ge 25 > D_2 \ge 20 > D_3 \ge 10 > D_4 \ge 5 > D_5$ | |
| Green space/ total area | % | $D_1 \ge 15 > D_2 \ge 10 > D_3 \ge 5 > D_4 \ge 3 > D_5$ | |
| Water consumption | $m^3$ $ha^{-1}$ $yr^{-1}$ | $D_1 \le 2738 < D_2 \le 5992 < D_3 \le 9246 < D_4 \le 12500 < D_5$ | Calculating the intervals of DCC for indicators of energy and material consumption are totally different from other indicators and is as follows:<br>1. The desirable limit of indicators was obtained by multiplying the maximum level of consumption or standard (water, electricity & gas) per capita by the minimum desirable population density per unit area (here 50 p $ha^{-1}$),<br>2. The maximum accepted limits were determined with considering the resource constrains or availability in the study area. Finally values were converted to the DCC degrees.Some of the maximum consumption per capita of indicators obtained from existing standards or tariffs in Iran, are as follows:<br>• Maximum desirable water consumption: 150 l $d^{-1}$ per person = 54.75 $m^3$ $yr^{-1}$ per person<br>• Maximum gas consumption: 6000 $m^3$ $household^{-1}$ $yr^{-1}$<br>• Maximum electricity consumption: 3000 $m^3$ $household^{-1}$ $yr^{-1}$. Household size in Shemiran City = 3 (2013).<br>• Maximum waste production: 500 g $d^{-1}$ per person= 0.182 t $yr^{-1}$ per person |
| Total water consumption/ Supply** | % | $D_1 \le 15 < D_2 \le 30 < D_3 \le 60 < D_4 \le 90 < D_5$ | |
| Water consumption rate | % | * | |
| Gas consumption | $m^3$ $ha^{-1}$ $yr^{-1}$ | $D_1 \le 100000 < D_2 \le 140000 < D_3 \le 180000 < D_4 \le 220000 < D_5$ | |
| Gas consumption rate | % | * | |
| Electricity consumption | Kwh $ha^{-1}$ $yr^{-1}$ | $D_1 \le 50000 < D_2 \le 88200 < D_3 \le 126400 < D_4 \le 164600 < D_5$ | |
| Total electricity consumption/ Supply** | % | $D_1 \le 15 < D_2 \le 30 < D_3 \le 60 < D_4 \le 90 < D_5$ | |
| Electricity consumption rate | % | * | |
| Waste production | t $ha^{-1}$ $yr^{-1}$ | $D_1 \le 9 < D_2 \le 21.33 < D_3 \le 33.66 < D_4 \le 46 < D_5$ | |
| Waste production rate | % | * | |
| Recycle ratio | % | $D_1 \ge 90 > D_2 \ge 60 > D_3 \ge 30 > D_4 \ge 15 > D_5$ | |
| Traffic congestions | Zoning | $D_1 = 3,\ 3 < D_2 \le 5 < D_3 \le 7 < D_4 < 9,\ D_5 = 9$ | DCC intervals of traffic congestion indicator were determined by applying the data obtained from Shemiran traffic control center. In these maps, traffic volume was categorized to three transport network: highway, major and minor streets, and from 1= without traffic to 3= very heavy traffic. Traffic congestion zoning for each district was carried out based on gradating to the vector layers (highways, major streets and minor streets) in GIS environment, then overlaying with each other. As 3= without traffic state (D1) and 9= very heavy traffic state (D5). |

* Indicator's growth rate and its DCC were calculated separately in each district.
$D_1$: DCC= 1

3. Weighting to indicators: in this step, normalized weights of previous step (**Table 3**) were used.

4. Calculation of weighted no-scaling matrix: weight matrix (W) is a n×n matrix. Weights are placed on Main diameter, and outside main diameter are zero. Weighted Matrix (V) is as follows (*Chang et al. 2012*):

$$V_{m\times n} = [r_{ij}]\times W_{n\times n} \tag{1}$$

Where, $r_{ij}$= each element of matrix which is located in a defined rows and columns. And W= weight of Socio-economic indicators.

5. Finding positive and negative ideals:

In general, according to positive and negative effect of each indicator on ultimate objective, best and worst values for each indicator is determined by following Formula. In other words, for each indicator (matrix columns), in weighted no-scaling matrix, maximum numerical value is represented as $A_i^+$ (maximum pressure) and minimum numerical value is represented as $A_i^-$ (minimum pressure).

$$A^+ = \{(\max_i v_{ij} | j \in J^+), (\min_i v_{ij} | j \in J^-)\} = \{v_1^+, v_2^+, \dots, v_n^+\} \tag{2}$$

$$A^- = \{(\min_i v_{ij} | j \in J^+), (\max_i v_{ij} | j \in J^-)\} = \{v_1^-, v_2^-, \dots, v_n^-\} \tag{3}$$

(*Chang et al. 2012*)

$J^-$ and $J^+$ represent positive and negative indicators in decision-making process.

6. Calculation of Euclidean distance of each option from $A_i^+$ and $A_i^-$: distance of each district from maximum and minimum pressure was calculated as follow: (*Chang et al. 2012*)

$$d_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2} \tag{4}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2} \tag{5}$$

7. Identification of relative closeness of available options regarding $A_i^+$ (maximum pressure): calculated, as follow and then Gradating is done based on largest to smallest relative closeness.

$$cl_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{6}$$

Numerical value of relative closeness (Cl) in each studied district shows state of socio-economic carrying capacity of investigated indicators. This value, which is defined in 0 to 1 intervals as a Fuzzy value, the more closer to 1, presents the higher pressure and consequently lower carrying capacity. And the more closer to zero, presents lower pressure and higher carrying capacity.

8. Formation of digital layer of Socio-economic carrying capacity index: to local display of gained results of previous step, digital layer of Socio-economic carrying capacity index, was created based on achieved values (Cl) in GIS environ, at first as vector, and then to overlaying withthe map of ecological carrying capacity index, it is transformed to Raster layer.

**Overlaying and combination of Socio-economic and ecological carrying capacity maps**

In this step, map of Socio-economic and ecological carrying capacity index is combined considering equal weight (**Table 3**) and ultimate map of Urban Environment Carrying Capacity (UECC) is prepared.

## RESULTS AND DISCUSSION

According to represented method, in order to evaluate ecological carrying capacity of Shemiran City, Fuzzy layers of carrying capacity of ecological indicators were gradated based on determined limits and threshold in 0 to 1 intervals (**Figure 3**). Results of combination of layers by applying the relevant weighting coefficients, produced a map of ecological carrying capacity index of Shemiran City (**Figure 5-a**). In these maps, zero score represents lack of pressure state, or desirable state of carrying capacity ($D_1$), and 1 represents maximum pressure or critical state ($D_5$). To evaluate socio-economic carrying capacity of the studied for each districts separately, 22 Socio-economic indicators were chosen, and degree of carrying capacity (DCC) was determined after calculation indicators values, (**Table 7**). The weighted decision-making matrix and distance of options (districts) from maximum and minimum pressure and also relative closeness to maximum pressure is tabulated (**Table 8**).

According to Fuzzy results (CLi column) (**Table 8**) and in comparison with thresholds and degree of Carrying Capacity (DCC) (**Table 4**), it can be presumed that amongst 10 districts of the studied are districts 8 and 3, with 0.8454 and 0.8055 fuzzy scores, respectively. Regarding the socio-economic indicators investigated in 2013, it showed a carrying capacity degree of 5 ($D_5$), and were gradated in critical state (transition from tolerance threshold). Moreover, district 4, with Fuzzy score 0.2334 and carrying

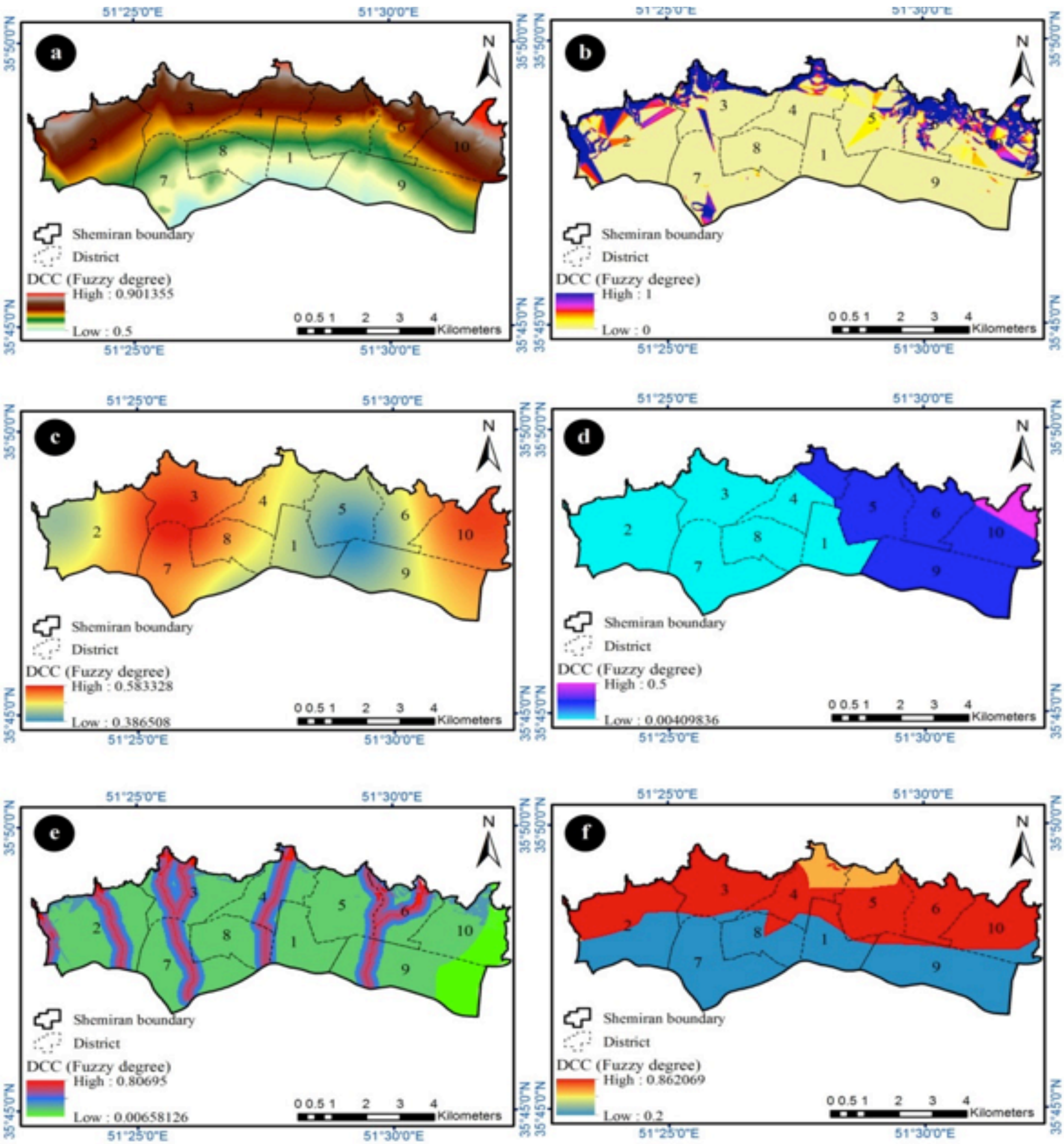


Figure 3: Fuzzy layers of gradated carrying capacity of ecological indicators, prepared via GISFM: a. Elevation, b. Slope, c. Pollutant standards index (PSI), d. Groundwater depth, e. Flood vulnerability, f. Earthquake vulnerability.

capacity degree 2 ($D_2$), was in low pressure condition and related to other districts profited more desirable state in 2013. Investigating the indicators of carrying capacity separately for each district (**Table 7**), principal factors of desirable and undesirable states for carrying capacity is determined. For instance, studying related indicators such as (relative density of population, as well as growth rate of population; health per capita; water consumption and water consumption rate; Gas consumption and Gas consumption rate; electricity energy consumption and waste production), district 8 was in transition from tolerance threshold state. Hence, to improve and revival of carrying capacity in the mentioned district, control of pressure of indicators is of the highest importance (**Figure 4**).

Table 7: Calculated values and determined DCC of Socio- economic indicators in Shemiran's districts.

| Socio-economic Indicators | Measuring unit | Degree of Carrying Capacity (DCC); (Deterministic degrees) | Values and DCC for Study's Districts (Shemiran's districts) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Gross population density | Person ha$^{-1}$ | $D_1 \leq 50 < D_2 \leq 70 < D_3 \leq 90 < D_4 \leq 110 < D_5$ | V:80.14 D:3 | V:82.49 D:3 | V:172.44 D:5 | V:69.74 D:2 | V:88.48 D:3 | V:136.20 D:5 | V:99.48 D:4 | V:172.40 D:5 | V:58.62 D:2 | V:99.85 D:4 |
| Population growth rate | % | * | V:2.31 D:4 | V:0.7 D:4 | V:5.90 D:5 | V:0.33 D:3 | V:1.14 D:4 | V:7.02 D:5 | V:1.94 D:5 | V:1.69 D:5 | V:4.87 D:4 | V:4.87 D:5 |
| Residential per capita | m$^2$ person$^{-1}$ | $D_1 \geq 50 > D_2 \geq 30 > D_3 \geq 10 > D_4 \geq 2 > D_5$ | V:58.41 D:1 | V:52.14 D:1 | V:23.51 D:3 | V:57.56 D:1 | V:36.94 D:2 | V:14.06 D:3 | V:49.10 D:2 | V:33.75 D:2 | V:18.61 D:3 | V:22.05 D:3 |
| Educational per capita | m$^2$ person$^{-1}$ | $D_1 \geq 5 > D_2 \geq 3 > D_3 \geq 2 > D_4 \geq 1 > D_5$ | V:2.10 D:3 | V:17.87 D:1 | V:0.57 D:5 | V:5.07 D:1 | V:1.94 D:4 | V:3.02 D:2 | V:2.01 D:3 | V:1.75 D:4 | V:0.88 D:5 | V:1.44 D:4 |
| Health per capita | m$^2$ person$^{-1}$ | $D_1 \geq 1.5 > D_2 \geq 1.25 > D_3 \geq 1 > D_4 \geq 0.75 > D_5$ | V:0.18 | V:0.84 | V:0.86 | V:1.10 | V:0.15 | V:3.17 | V:0.66 | V:0.31 | V:1.85 | V:0.13 |
| Green space per capita | m$^2$ person$^{-1}$ | $D_1 \geq 15 > D_2 \geq 9 > D_3 \geq 6 > D_4 \geq 3 > D_5$ | D:5 V:15.05 | D:4 V:22.93 | D:4 V:4.27 | D:3 V:22.58 | D:5 V:16.06 | D:1 V:33.52 | D:5 V:10.10 | D:5 V:4.52 | D:1 V:9.45 | D:5 V:29.97 |
| Transportation per capita | m$^2$ person$^{-1}$ | $D_1 \geq 25 > D_2 \geq 20 > D_3 \geq 10 > D_4 \geq 5 > D_5$ | D:1 V:13.37 | D:1 V:47.28 | D:4 V:9.65 | D:1 V:3.69 | D:1 V:27.54 | D:1 V:16.84 | D:2 V:11.88 | D:4 V:13.26 | D:2 V:15.19 | D:1 V:10.27 |
| Built area/total area | % | $D_1 \leq 50 < D_2 \leq 60 < D_3 \leq 70 < D_4 \leq 80 < D_5$ | D:3 V:64.19 | D:1 V:64.09 | D:4 V:65.61 | D:5 V:64.61 | D:1 V:58.18 | D:3 V:31.59 | D:3 V:65.85 | D:3 V:67.50 | D:3 V:74.33 | D:3 V:33.77 |
| Transportation network/total area | % | $D_1 \geq 25 > D_2 \geq 20 > D_3 \geq 10 > D_4 \geq 5 > D_5$ | D:3 V:10.72 D:3 | D:3 V:23.86 D:2 | D:3 V:16.69 D:3 | D:3 V:2.85 D:5 | D:2 V:24.37 D:2 | D:1 V:22.94 D:2 | D:3 V:11.82 D:3 | D:3 V:22.88 D:2 | D:4 V:8.91 D:4 | D:1 V:10.26 D:3 |
| Green space/ total area | % | $D_1 \geq 15 > D_2 \geq 10 > D_3 \geq 5 > D_4 \geq 3 > D_5$ | V:12.06 D:2 | V:19.07 D:1 | V:7.39 D:3 | V:15.75 D:1 | V:14.22 D:2 | V:45.66 D:1 | V:10.05 D:2 | V:7.80 D:3 | V:5.54 D:3 | V:29.93 D:1 |
| Water consumption | m$^3$ ha$^{-1}$ yr$^{-1}$ | $D_1 \leq 2738 < D_2 \leq 5992 < D_3 \leq 9246 < D_4 \leq 12500 < D_5$ | V:7313 D:3 | V:7528 D:3 | V:15735 D:5 | V:6364 D:3 | V:8074 D:3 | V:12428 D:4 | V:9078 D:3 | V:15732 D:5 | V:5349 D:2 | V:9111 D:3 |
| Total water consumption/ Supply** | % | $D_1 \leq 15 < D_2 \leq 30 < D_3 \leq 60 < D_4 \leq 90 < D_5$ | V:0.3 D:1 | V:0.76 D:1 | V:0.1 D:1 | V:0.32 D:1 | V:0.46 D:1 | V:0.53 D:1 | V:0.66 D:1 | V:0.68 D:1 | V:0.48 D:1 | V:0.6 D:1 |
| Water consumption rate | % | * | V:2.84 D:4 | V:1.22 D:4 | V:6.45 D:5 | V:0.85 D:3 | V:1.66 D:4 | V:7.57 D:5 | V:2.47 D:4 | V:2.22 D:5 | V:5.41 D:4 | V:5.41 D:5 |
| Gas consumption | m$^3$ ha$^{-1}$ yr$^{-1}$ | $D_1 \leq 90500 < D_2 \leq 126700 < D_3 \leq 162900 < D_4 \leq 199100 < D_5$ | V: 145069 D:3 | V: 149325 D:3 | V: 312125 D:5 | V: 126240 D:2 | V: 160159 D:3 | V: 246529 D:5 | V: 180062 D:4 | V: 312043 D:5 | V: 106109 D:2 | V: 180720 D:4 |
| Gas consumption rate | % | * | V:7.50 D:5 | V:5.81 D:5 | V:11.27 D:5 | V:5.42 D:5 | V:6.27 D:5 | V:12.44 D:5 | V: 7.12 D:5 | V:6.85 D:5 | V:10.18 D:5 | V:10.19 D:5 |
| Electricity consumption | Kwh ha$^{-1}$ yr$^{-1}$ | $D_1 \leq 50000 < D_2 \leq 88200 < D_3 \leq 126400 < D_4 \leq 164600 < D_5$ | V: 80148 D:2 | V: 82500 D:2 | V: 172445 D:5 | V: 69746 D:2 | V: 88485 D:3 | V: 136204 D:4 | V: 99482 D:3 | V: 172399 D:5 | V: 58624 D:2 | V: 99845 D:3 |
| Total electricity consumption/ Supply** | % | $D_1 \leq 15 < D_2 \leq 30 < D_3 \leq 60 < D_4 \leq 90 < D_5$ | V:0.23 D:1 | V:0.58 D:1 | V:0.76 D:1 | V:0.25 D:1 | V:0.35 D:1 | V:0.40 D:1 | V:0.50 D:1 | V:0.51 D:1 | V:0.36 D:1 | V:0.45 D:1 |
| Electricity consumption rate | % | * | V:3.88 D:4 | V:2.24 D:3 | V:7.52 D:5 | V:1.87 D:3 | V:2.69 D:4 | V:8.65 D:5 | V:3.91 D:4 | V:3.25 D:5 | V:6.48 D:3 | V:6.48 D:5 |
| Waste production | t ha$^{-1}$ yr$^{-1}$ | $D_1 \leq 9 < D_2 \leq 21.33 < D_3 \leq 33.66 < D_4 \leq 46 < D_5$ | V:39.9 D:4 | V:32.98 D:3 | V:42.07 D:4 | V:34.78 D:4 | V:38.6 D:4 | V:27.9 D:3 | V:40.66 D:4 | V:54.84 D:5 | V:15.59 D:2 | V:15.73 D:2 |
| Waste production rate | % | * | V:3.2 D:5 | V:2.17 D:4 | V:1.87 D:5 | V:-0.23 D:4 | V:3.34 D:5 | V:4.73 D:4 | V:0.75 D:4 | V:0.55 D:4 | V:6.8 D:4 | V:6.8 D:4 |
| Recycle ratio | % | $D_1 \geq 90 > D_2 \geq 60 > D_3 \geq 30 > D_4 \geq 15 > D_5$ | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 | V:20 D:4 |
| Traffic congestions | Zoning | $D_1=3$, $3<D_2 \leq 5 < D_3 \leq 7 < D_4 < 9$, $D_5=9$ | V:6 D:3 | V:6 D:3 | V:6.2 D:3 | V:5.5 D:3 | V:4.5 D:2 | V:4 D:2 | V:8 D:4 | V:7.5 D:4 | V:4.5 D:2 | V:4.5 D:2 |

V= Value & D= DCC

*Growth rate of indicator and degree of carrying capacity for each district of the studied area separately.

** Due to having common provider source for Shemiran city and Tehran City, the ratio of consumption to source was reported very small for Shemiran City.

Table 8. Weighted decision- making matrix, and distance to maximum and minimum pressure and CI for each district.

| Districts | Socio-economic indicators | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gross pop'n density | Pop'n growth rate | Residential per capita | Educational per capita | Health per capita | Green space per capita | Transportation per capita | Buildup/ total area | Transportation/ total area | Green space/ total area | Water consumption | Water consumption/ water resources | Water consumption rate |
| 1 | 0.147 | 0.584 | 0.009 | 0.027 | 0.045 | 0.018 | 0.027 | 0.015 | 0.015 | 0.018 | 0.159 | 0.213 | 0.424 |
| 2 | 0.147 | 0.584 | 0.009 | 0.009 | 0.036 | 0.018 | 0.009 | 0.015 | 0.01 | 0.009 | 0.159 | 0.213 | 0.424 |
| 3 | 0.245 | 0.730 | 0.027 | 0.045 | 0.036 | 0.072 | 0.036 | 0.015 | 0.015 | 0.027 | 0.265 | 0.213 | 0.530 |
| 4 | 0.098 | 0.438 | 0.009 | 0.009 | 0.027 | 0.018 | 0.045 | 0.015 | 0.025 | 0.009 | 0.159 | 0.213 | 0.318 |
| 5 | 0.147 | 0.584 | 0.018 | 0.036 | 0.045 | 0.018 | 0.009 | 0.01 | 0.01 | 0.018 | 0.159 | 0.213 | 0.424 |
| 6 | 0.245 | 0.730 | 0.027 | 0.018 | 0.009 | 0.018 | 0.027 | 0.005 | 0.01 | 0.009 | 0.212 | 0.213 | 0.530 |
| 7 | 0.196 | 0.730 | 0.018 | 0.027 | 0.045 | 0.036 | 0.027 | 0.015 | 0.015 | 0.018 | 0.159 | 0.213 | 0.424 |
| 8 | 0.245 | 0.730 | 0.018 | 0.036 | 0.045 | 0.072 | 0.027 | 0.015 | 0.01 | 0.027 | 0.265 | 0.213 | 0.530 |
| 9 | 0.098 | 0.584 | 0.027 | 0.045 | 0.009 | 0.036 | 0.027 | 0.02 | 0.02 | 0.027 | 0.106 | 0.213 | 0.424 |
| 10 | 0.196 | 0.730 | 0.027 | 0.036 | 0.045 | 0.018 | 0.027 | 0.005 | 0.015 | 0.009 | 0.159 | 0.213 | 0.530 |
| $A_i^+$ | 0.245 | 0.730 | 0.027 | 0.045 | 0.045 | 0.072 | 0.045 | 0.02 | 0.025 | 0.027 | 0.265 | 0.213 | 0.530 |
| $A_i^-$ | 0.098 | 0.438 | 0.009 | 0.009 | 0.009 | 0.018 | 0.009 | 0.005 | 0.01 | 0.009 | 0.106 | 0.213 | 0.318 |

Table 8. (cont.).

| Districts | Socio-economic indicators | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gas consumption | Gas consumption rate | Electricity consumption | Electricity consumption rate | Electricity consumption /electricity resources | Waste production | Waste production rate | Recycling rate | Traffic congestions | $d_i^+$ (Maximum pressure) | $d_i^-$ (Minimum pressure) | $CL_i$ |
| 1 | 0.036 | 0.115 | 0.022 | 0.084 | 0.037 | 0.084 | 0.425 | 0.172 | 0.321 | 0.2664 | 0.2455 | 0.4795 |
| 2 | 0.036 | 0.115 | 0.022 | 0.063 | 0.037 | 0.063 | 0.340 | 0.172 | 0.321 | 0.4308 | 0.2244 | 0.3424 |
| 3 | 0.06 | 0.115 | 0.055 | 0.105 | 0.037 | 0.084 | 0.425 | 0.172 | 0.321 | 0.1099 | 0.4553 | 0.8055 |
| 4 | 0.024 | 0.115 | 0.022 | 0.063 | 0.037 | 0.084 | 0.340 | 0.172 | 0.321 | 0.4368 | 0.1330 | 0.2334 |
| 5 | 0.036 | 0.115 | 0.033 | 0.084 | 0.037 | 0.084 | 0.425 | 0.172 | 0.214 | 0.3251 | 0.2220 | 0.4057 |
| 6 | 0.06 | 0.115 | 0.044 | 0.105 | 0.037 | 0.063 | 0.340 | 0.172 | 0.214 | 0.2516 | 0.4089 | 0.6190 |
| 7 | 0.048 | 0.115 | 0.033 | 0.084 | 0.037 | 0.084 | 0.340 | 0.172 | 0.428 | 0.1881 | 0.3995 | 0.6798 |
| 8 | 0.06 | 0.115 | 0.055 | 0.105 | 0.037 | 0.105 | 0.340 | 0.172 | 0.428 | 0.0888 | 0.4857 | 0.8454 |
| 9 | 0.024 | 0.115 | 0.022 | 0.063 | 0.037 | 0.042 | 0.340 | 0.172 | 0.214 | 0.3778 | 0.1876 | 0.3318 |
| 10 | 0.048 | 0.115 | 0.033 | 0.105 | 0.037 | 0.042 | 0.340 | 0.172 | 0.214 | 0.2734 | 0.3838 | 0.5840 |
| $A_i^+$ | 0.06 | 0.115 | 0.055 | 0.105 | 0.037 | 0.105 | 0.425 | 0.172 | 0.428 | | | |
| $A_i^-$ | 0.024 | 0.115 | 0.022 | 0.063 | 0.037 | 0.042 | 0.340 | 0.172 | 0.214 | | | |

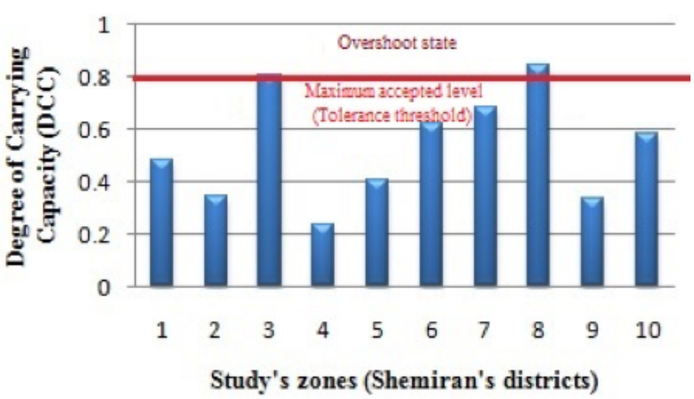


Figure 4. Comparison of Socio-economic carrying capacity of Shemiran's districts (in 2013).

The map of carrying capacity index contains the ecological index, socio-economic carrying capacity and also ultimate map of Urban Environment Carrying Capacity (UECC)(**Figure 5**).

## CONCLUSION AND RECOMMENDATIONS

Urban Environment Carrying Capacity as an applied index in urban environment management play crucial role in achieve to sustainable urban development in developing countries. In the present study, to evaluate Urban Environment Carrying Capacity, a GIS-based model was presented as Spatial Decision Support System. In this model, to increment of the accuracy of gradating, as well as evaluation of carrying capacity according to applied indicators, GISFM method and TOPSIS technique were combined. To test the mentioned model, Shemiran City located in Iran was investigated. Results showed that according to data collected in 2013, no district in the studied area was determined in desirable state (without pressure). From whole studied area, 43% , 44% , 10% and 3% achieved carrying capacity degree 2 (D2); Degree 3 ($D_3$); Degree 4 ($D_4$) (maximum accepted pressure); degree 5

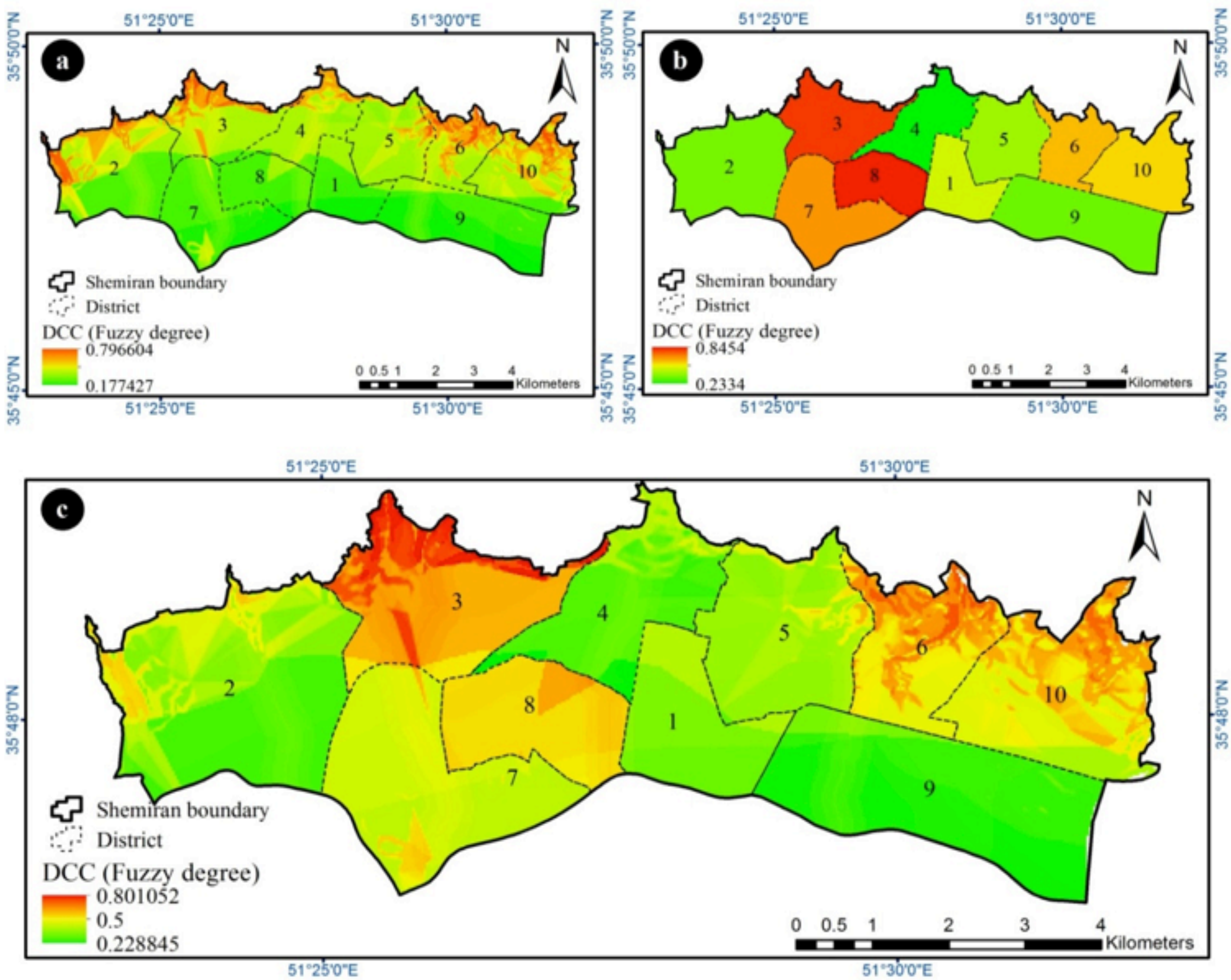


Figure 5. The maps of carrying capacity: (a) Ecological carrying capacity index, (b) Socio- economic carrying capacity index (c) The final map of Urban Environment Carrying Capacity (UECC) of Shemiran City (in 2013).

($D_5$) or critical state of transition from tolerance threshold. Determined critical districts, called as Hot Spots, are the spaces where, in addition to limits of ecological carrying capacity resulted from physical structures and natural specifications of the studied area, were reported higher than accepted limits of pressure, regarding population density and related activities. These districts lack of needed capacity for future development, and as a result, constructions, as well as population settlement have to be restrained. Meanwhile, to prevent critical state of districts with maximum accepted pressure, in addition to debarment of construction in open lands, continuous monitoring in terms of introduced indicators is necessary.

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