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Development of an Innovative Model for Environmental Impact Assessment of Urban Projects

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Abstract: In this study, a innovative model was developed for impact assessment for urban development project. The proposed model has the capability of zoning the impacts according to integration of vulnerability for the selected environmental factors within impacts criterion in this study. The main process for this model consists of identification of urban development project activities, determination and zoning of impacts intensity, calculation of environmental vulnerability factor and decision making on proposed alternatives. The integration of results for the mentioned stages will determine the final assessment zoning. This model was applied to urban development plan in district-22 of Tehran municipality (Iranian capital city) as a case study. The results indicate that the model was applicable for zoning of impacts according to the characteristics of affected environmental and ecological factors as well as determining major impacts units. Meanwhile, this model was capable to select alternatives of urban development plan for decision makers. Finally planners will find out the necessary mitigation measures which should be implemented in each impact unit.

Key words: EIA, environmental vulnerability, urban development, impact intensity, impact importance, district-22 of Tehran municipality

INTRODUCTION

Environmental Impact Assessment (EIA) is considered as a necessary instrument for environmental management[1-4]. Generally, assessment methods in EIA will determine unique values for different impacts, which are derived from integration of activities for the proposed project and characteristics of environmental factors[2-5]. These methods are almost applied within the site projects. It is necessary to mention that the methods in described site projects focus on the activities which take place in a limited area, while the activities of wide area projects are distributed in a widespread area. As characteristics of the environmental factors may vary within the study area of the widespread projects, impact assessment methods should have the capability to integrate the impacts according to this variation. Therefore, site projects impact assessment methods are not quite suitable for EIA of wide area projects. In EIA of wide area project, decision making about separate activities will not result to a unique assessment, therefore some environmentalists use regional environmental impact assessment approaches for wide area projects such as urban development plans. Considering the fact that still this method does not have the capability for quantification of environmental factors vulnerability into the projects impacts[1].

To cover the aforementioned gap in wide area projects many attempts have been taken. In this regard overlay methods are largely derived from town and country planning landscape architecture and land capability assessment. They generally rely on a set of maps, sometimes referred to as sieve maps of a locality where a development is proposed[1]. By overlaying environmental factors layers a composite view can be developed systematically but the output shows the composition of baseline environment without any integration capability with the project impacts. Overlay methods do not separate direct and indirect impacts, give no indication of the probability of an impacts occurring and do not do much to show causal relationship. In this study a new model is developed for impacts assessment of urban development projects, using district-22 of Tehran municipality (within 6 zones) development plan as the case study, by integration of the predicted impacts into environmental factors vulnerability zones resulted from overlay method (Fig. 1 and 2).

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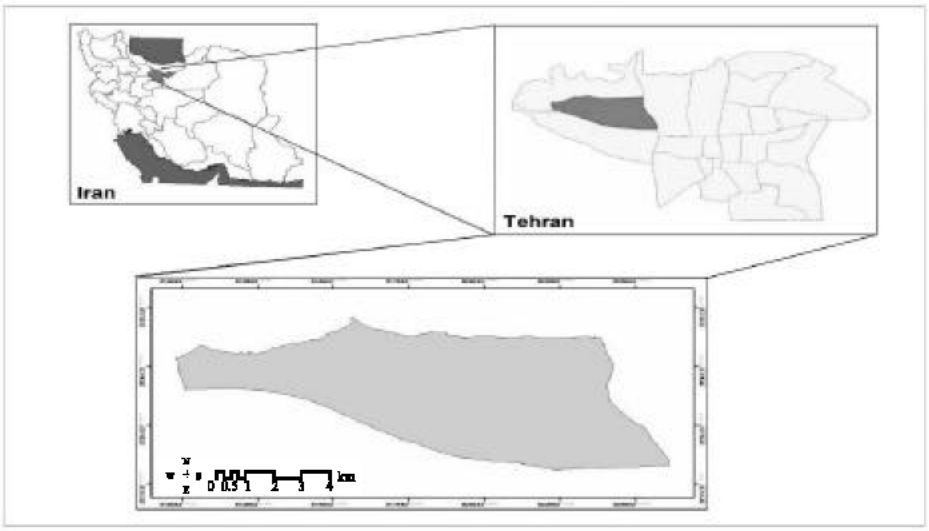

Fig. 1: Location of the studied area (district-22 of Tehran municipality)

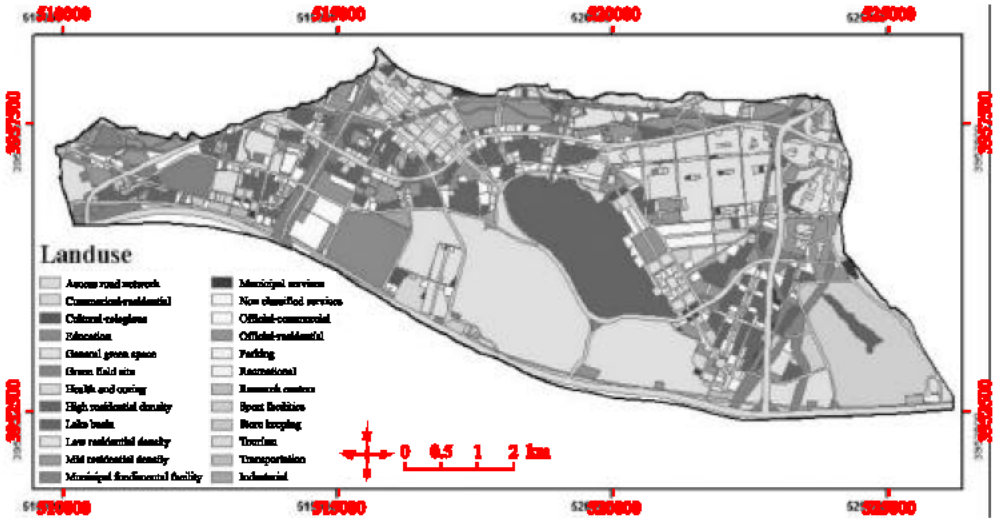

Fig. 2: Urban development plan in the studied area

MATERIALS AND METHODS

This study has been done at the district-22 municipality of Tehran, in 2004. Four indices are used for impacts assessment in urban development projects. These indices are environmental factors vulnerability with respect to urban development impacts, impact intensity, impact nature and importance of environmental factors. In order to zone the impacts, the study area is divided into specific impact units (37 units) (Fig. 3). These units have been determined on the basis of both density and various land uses considered in the development plan for district-22 of Tehran municipality. District-22 of Tehran municipality with an area of 10,000 ha. is a development project for decentralization and organizing of activities in the north west of Tehran which is capital of Iran with population of about 7 millions[6-9]. Proposed process of impact assessment for urban development EIA is indicated in Fig. 4.

Ecological impact assessment

Ecological vulnerability: Ecological vulnerability is dependent upon the ecological characteristic of the unit area[10-11]. In this study, vulnerability of environmental factors including groundwater, soil properties, vegetation and wildlife habitats have been determined separately on the basis of the layers capability in absorption of the proposed urban activities impacts. Hence for each factors,

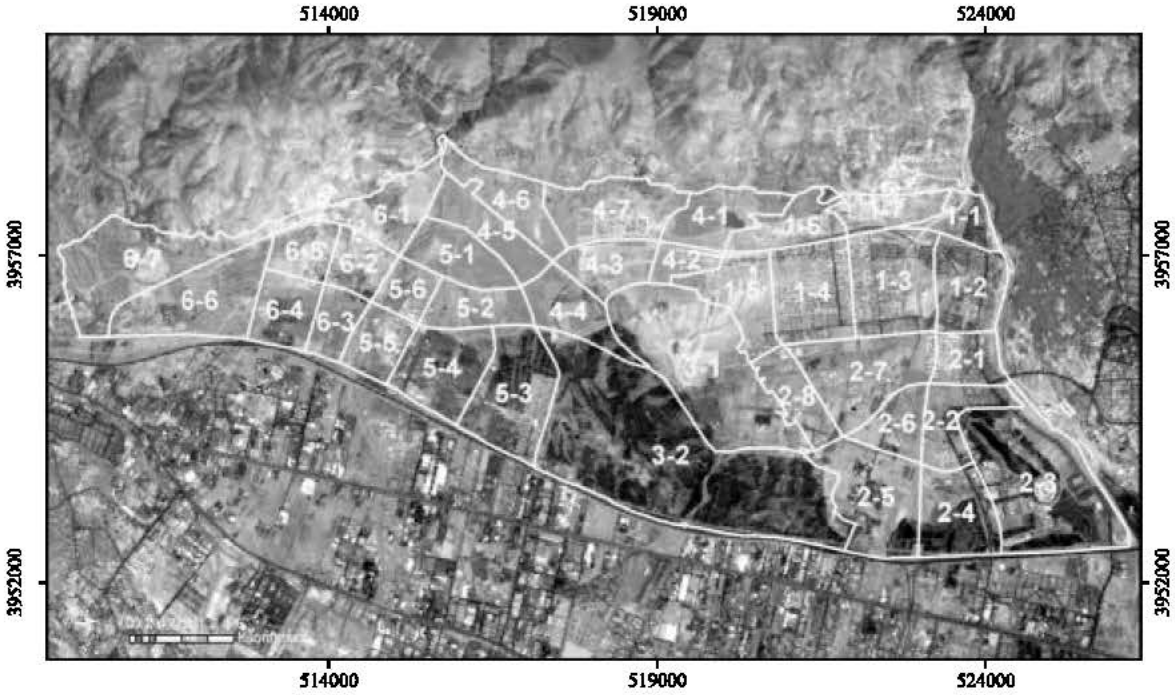

Fig. 3: Impact units of the studied area

Table 1: Selected ecological factors and vulnerability criteria

Environmental factors	Vulnerability criteria
Ground water	Nitrate
Soil property	Infiltration
Air quality	PM_{10}, CO
Vegetation	Rare spices
Wild life habitat	Habitat value

one criterion should be determined. In order to simplify the study and regarding data scarcity, five major environmental factors which have more relation to urban development impacts were selected as shown in Table 1.

In this regard, main specified impacts have been initially determined and then environmental vulnerability for these factors has been calculated in accordance to the related impacts of each impact unit within the studied area. Vulnerability of each environmental factor is different in the studied area and therefore, there should be classifications to organize these factors for further assessments of the impact units. Following steps are accomplished after determination of vulnerability criteria for each factor; vulnerability factor demonstrates quantity of intrinsic vulnerability of selected criteria for each factor. The degree consists of a four level classifications from 1 to 4 that show the lowest vulnerability to the highest, respectively. As there would be different vulnerability in each impact unit, following equation is used for calculations of the final vulnerability layers[12]:

$$V_{ef} = \left[\sum_{i=1}^{n} VC.A_i / \sum A_i\right]_j \quad (1)$$

Where:

V_{ef} : Vulnerability of ecological factor in each sub zone
Vc_i : Level of vulnerability of class I of ecological factor
A_i : Area of class I of ecological factor
j : Number of sub zone

Importance of ecological factors: Since the importance of ecological factors is not the same in the studied area, of Analytical Hierarchy Process (AHP) method has been used to determine weighting of ecological factors[13]. The importance of each factor is multiplied to its vulnerability in each impact unit and the final value of vulnerability will be resulted.

Impacts intensity: Impact intensity is defined as extent of environmental changes as a result of project activities[2]. In order to quantify the impacts intensity, those activities of the urban development that have common characteristics should be classified into distinctive levels such as residential, transportation, commercial, recreational and services. The professional points of views of the expert have been used for determination and quantification of impact intensity of the activities on each class of environmental factors, by using questionnaire prepared for this reason according to the

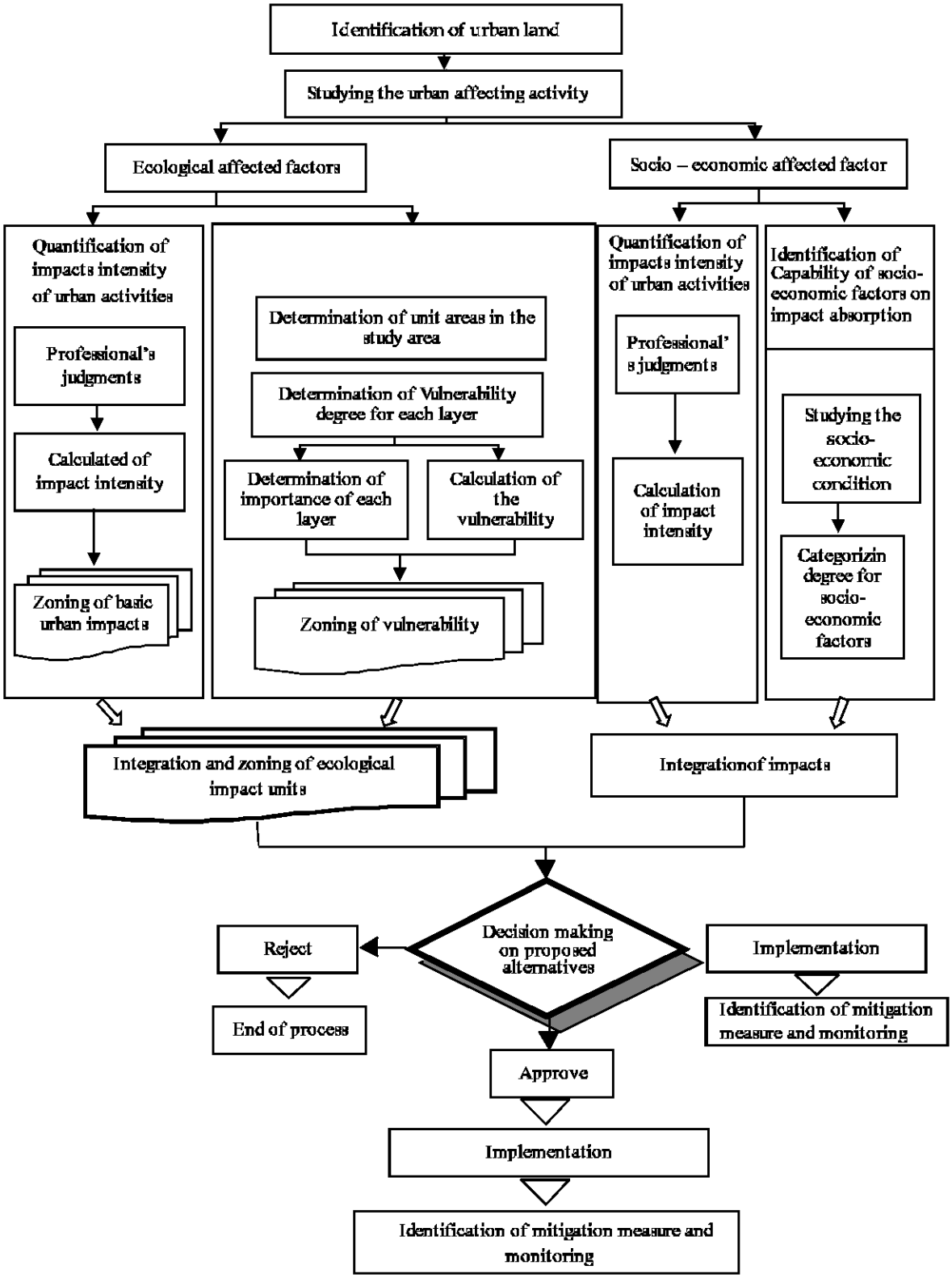

Fig. 4: The proposed environmental impact assessment process

urban development characters. Scale of +1 to +4 for positive impacts and -1 to - 4 for negative impacts is suggested for quantification of impacts so that the lowest intensity in each dimension is marked as 1 and the highest will be 4. Since area of impact units are important, it should be considered in the impacts intensity determination and therefore following equation is developed and suggested for integration of impact unit area to calculate basic environmental impact intensity:

$$I_{lu} = \left[\sum_{i=1}^{n} IC.A_i / \sum A_i\right]_j \quad (2)$$

Where:

I_{lu} : Basic environmental impact intensity of activities in the sub zones
I_c : Impact intensity of I activity
A_i : Area of activity I
j : Number of the sub zone

Final ecological assessment: In order to calculate and introduce various zones of ecological impacts, results of impacts intensity and vulnerability are integrated by using the following proposed equation relevant to each environmental factor:

$$I_e = \left[\sum_{i=1}^{n} I_{lu} \cdot V_{ef}\right]_j \quad (3)$$

Where:

I_e : Impacts on ecological factors
I_{lu} : Impacts intensity of proposed urban land use
j : Number of sub zone
V_{ef}: Vulnerability of environmental factor

Socio-economic impacts analysis: Socio-economic impacts assessments of urban development plans are different from natural environment assessment and therefore aforementioned equations could not be used for socioeconomic environment. Therefore, although four assessment indices (importance, intensity, impacts nature and capability of socio-economic factors on impact absorption) were used for socioeconomic environment, the proposed models for determination of impacts intensity and vulnerability are different in this environment.

Capability of socio-economic factors on impact absorption: In order to determine the capability of socio-economic factors on impact absorption, suitable questionnaires were prepared and filled in by the residents of the region within the studied area. According to socio-economic characteristics of the studying area, more important parameters such as unemployment, economical condition, transportation, services and green space have been considered in this study (SPSS Software ver.10 has been used for statistical analysis). The shortage of parameters has been defined as main criteria for categorizing the capability of socio-economic factors on impact absorption. The categorizing degree consists of a four level grade classification from 1 to 4, which stands for the lowest impact absorption to the highest, respectively. Therefore by using the results of questionnaires, highest degree has been allocated to the parameters which have the most shortage.

Impacts intensity: For identification of impacts intensity, the classified urban activities, which were explained before are used for filling the questionnaires that were designed on the basis of the project and also socioeconomic characteristics of the studied area.

Importance of socio-economic factors: Analytical Hierarchy Process (AHP) has been used for weighting the importance of socio-economic factors. The next step after determination of these four indices is to multiply them to calculate the final socioeconomic score. The results of impact assessment of natural environment could be summarized with the socioeconomic environment. By using this model, there could be a final score for urban development projects which is adjusted exactly to the relevant detailed conditions of environmental factors in proposed location of the project within the studying area. Hence if there would be different alternatives for an urban development project, the quantitative impacts analysis makes a good support for final decision-making.

RESULTS

In order to study the applicability of the proposed model, this model has been applied in district-22 of Tehran Municipality as the case study. For this application the model is used in two main categories, ecology and socio economy each of them has their own branches.

Ecological impacts assessment: Although five ecological factors are used in ecological impact assessment, the results and output maps are only presented for two most important factors, groundwater and vegetation.

Groundwater: One of the most important water resources in district-22 (especially for drinking water) is groundwater resources. Therefore groundwater vulnerability with respect to contamination analysis is very important.

In order to calculate intrinsic groundwater vulnerability, there are many different models such as

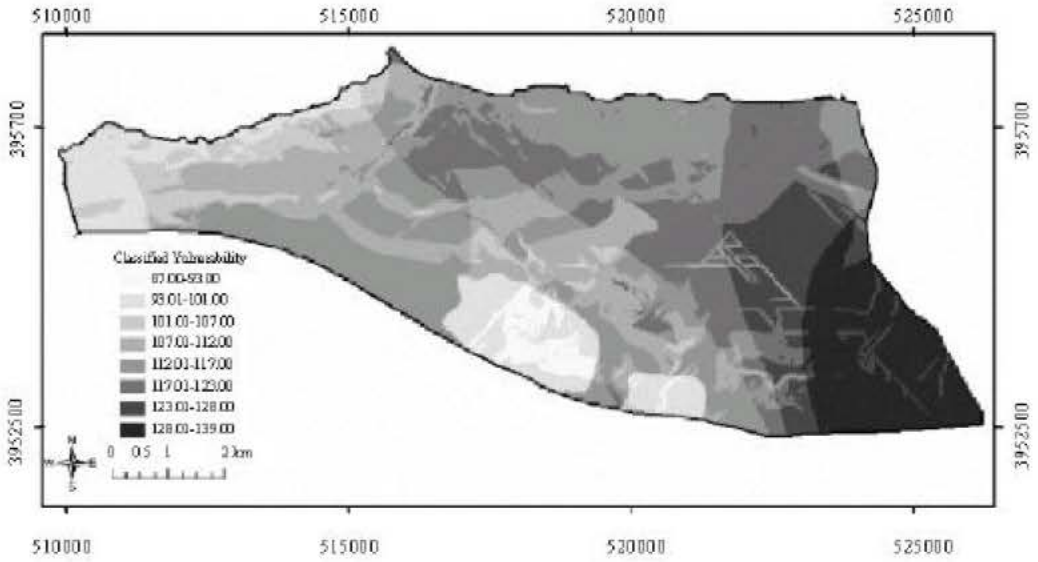

Fig. 5: Groundwater vulnerability of the studied area

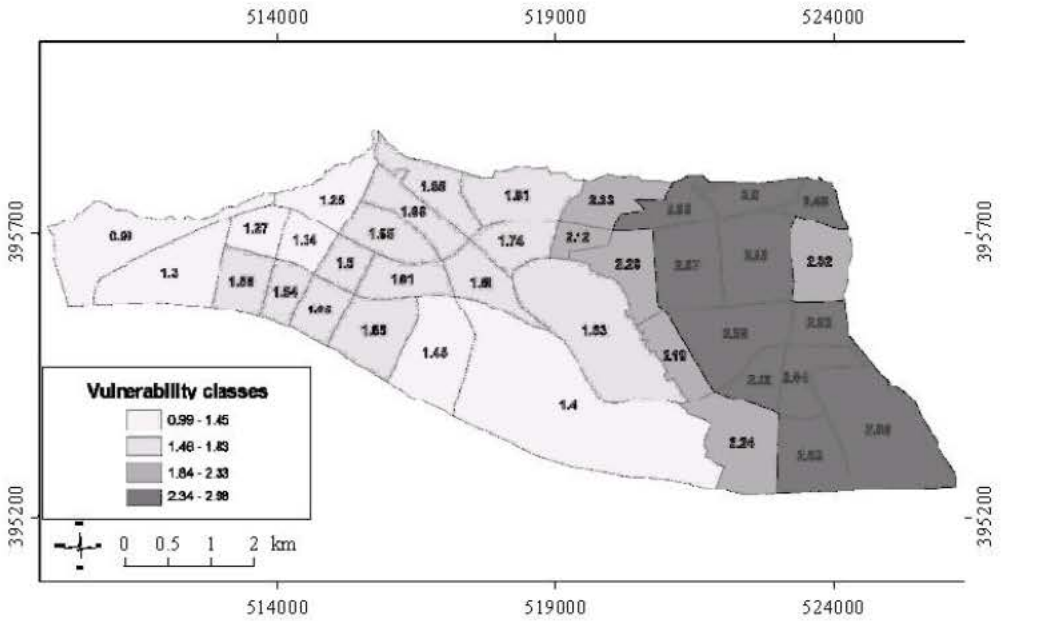

Fig. 6: Groundwater vulnerability of studied area in impact units

AVI, GODS and DRASTIC. The groundwater vulnerability studies for district 22 of Tehran Municipality were conducted through Drastic method (Fig. 5), since it was more compatible to the characteristics of urban areas[14].

The resulted groundwater vulnerability will determine the dominant vulnerability in each of the impact units, through Eq. 1 with respect to importance of this layer. The defined zones of the impacts units show that east and southeast area of the studying area have the highest vulnerability while the west and northwest areas have the Least (Fig. 6). Impacts of the activities on groundwater have been calculated through Eq. 2. For this reason, map of activities in the district urban development master plan has been prepared and then the results derived from impacts intensity of various activities were added to descriptive data table of Arc view Software. In other words, intensity score of impacts on groundwater is considered.

Final impact assessment on the groundwater is calculated with integration of impacts intensity (output of Eq. 1) into the vulnerability (output of Eq. 2) by using Eq. 3, (Fig. 7).

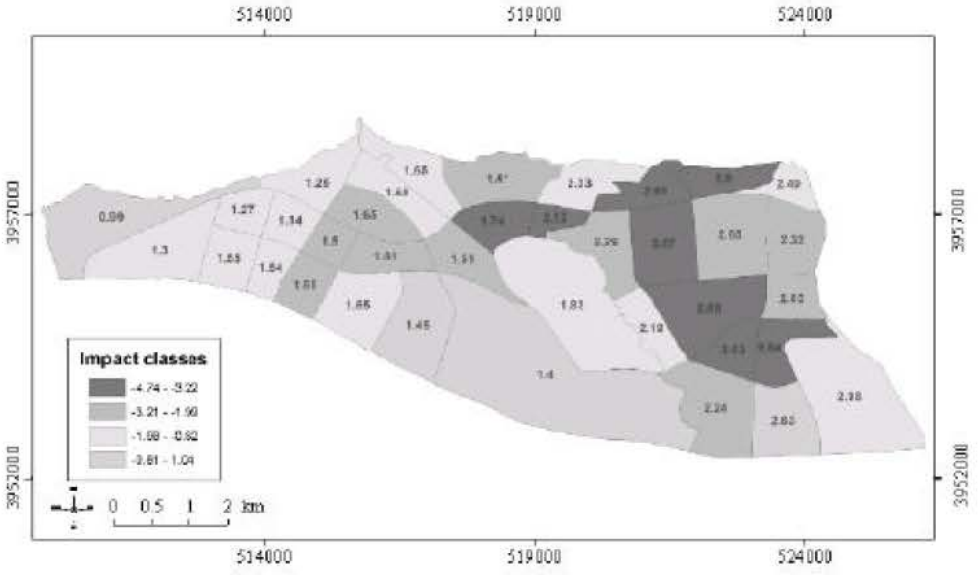

Fig. 7: Impact classification of urban development plan on ground water

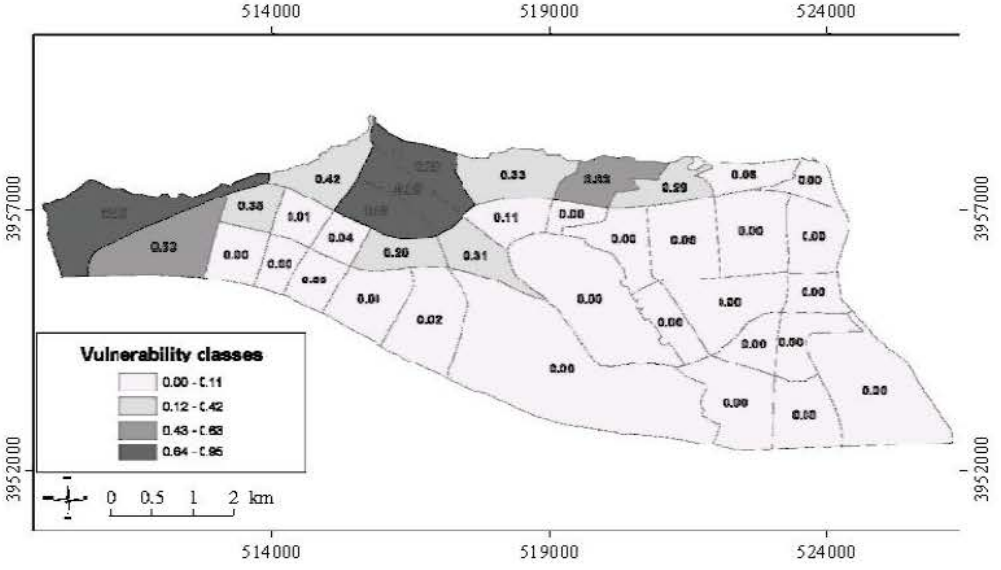

Fig. 8: Vegetation classification of the studied area in impact units (On the basis of IUCN Red List class)

As it is shown in Fig. 3, the impact units of eastern areas in the studying area such as 1-4, 2-7, 2-6, 2-2 and 4-3 have all received more impacts than other parts of the area.

Vegetation: Considering soil destruction and land use alteration which are resulted from urban development project in the studying area, vegetation removal is unavoidable. The most ordinary criteria for studying the vulnerability of vegetation in development projects is vegetation density, but as the result of vegetation scarcity in the region after the project implementation (due to the project operation), this criteria could not be used for vulnerability assessment of vegetation. Hence in this study distribution of rare species within the region has been independently considered as vital criteria (Fig. 8).

Vegetation analysis in studying area indicates that most species are in LR (Low Risk) category and some of the species in northern part of this area are in VU (Vulnerable) category with respect to IUCN Red List classes[1,5]. In order to calculate the impact intensity on vegetation, basic impacts have been determined,

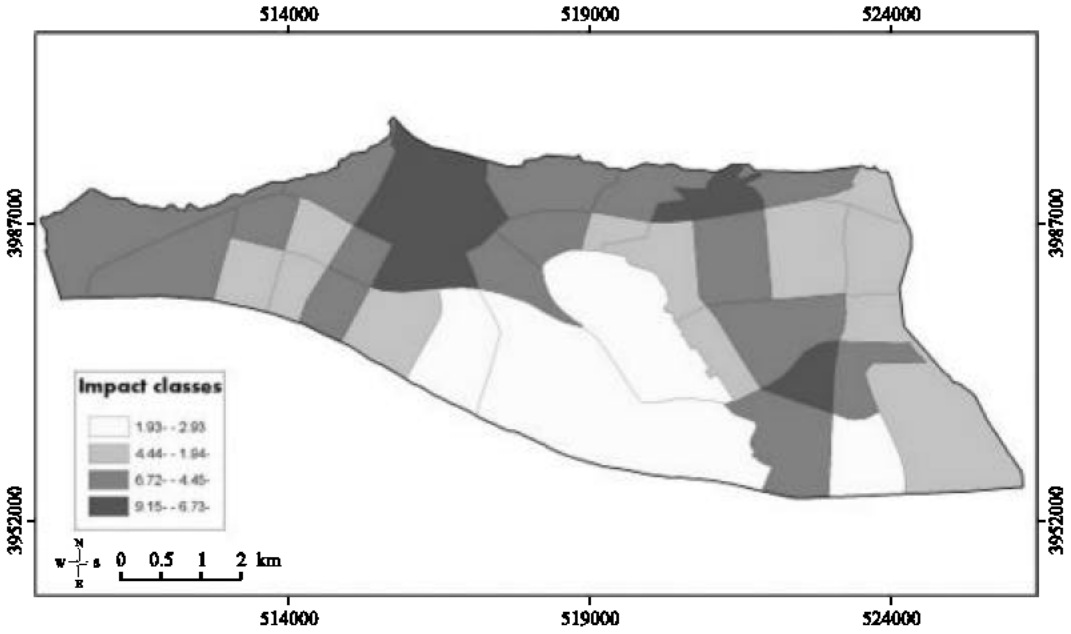

Fig. 9: Final Impact classification of urban development plan in impact units

Table 2: Results of professional judgments on impacts of the project land uses on vegetation

Urban land uses	Score of impact intensity
Residential	4.0
Transportation	4.0
Services and health	4.0
Commercial	4.0
Green spaces	3.0
Lake	4.0
Recreation	3.5

Table 3: Shortage of socio-economic condition on the basis of public view points

Socio-economic factors	importance	Zone 1 (%)	Zone 2 (%)	Zone 5 (%)	Zone 6 (%)
Employment	0.36	40	19.0	17.0	24
Economic condition	0.21	40	12.5	12.5	21
Infrastructure	0.08	48	16.0	12.0	24
Transportation	0.11	40	17.0	20.0	33
Green space	0.04	32	13.0	22.0	33
Services	0.16	50	16.0	8.0	26

Table 4: Conclusion of environmental impacts for the project

Affected environment	Score (with coefficient for any affected environment, 0.21, 0.6 and 0.72)
Physico-chemical environment	-25.81
Biological environment	-2.30
Socio-economic environment	+105.82
Total	+77.61

according to Table 2. Taking into account scores of impacts intensity on vegetation provided in Table 2, the impacts scores are integrated with the impact unit areas through Eq. 2 to introduce various zones of impacts in the studied area. Results of impacts intensity zoning derived from Eq. 2, along with the outputs of Eq. 1 through Eq. 3 would introduce final assessment of impacts on vegetation. Results of this assessment in district 22 urban development plan shows that northern parts of the district such as 4-6, 4-5, 5-1, 6-1 and 6-7 are more affected with respect to other parts of the studying area.

Socio-economic impacts assessment: On the basis of this study, population of the residential areas is about 100,000 which are more concentrated in east and northeast of the district. According to the studies and the results of the questionnaires, socio-economic conditions are not the same in different zones of the studied area (Table 3). It is necessary to mention that there is no residential area in zones 3 and 4.

Therefore, according to these shortages and importance of each factor and intensity of impacts, impacts of the project on socio-economic environment within the studying area have been determined. The results indicate that zone 1 will receive most positive impacts from the project.

For final ecological assessments in the studying region, all of the impacts zoning maps will be overlaid and integrated with each other and as a result, the final impacts scores are obtained (Fig. 9).

Table 4 also demonstrates the environmental impacts computed separately for affected environments. Therefore, the application of the proposed model and further computation of its score into classes of categories for affected environment, will assess the environmental impacts of urban development projects in the study

area. Furthermore while there are different alternatives for urban developments plans, this model as a quantitative tool for EIA, not only will support decision-makers to assess alternatives and select the best option but also the results will address planners to focus on specific mitigation measures for each impact units with respect to environmental vulnerability and environmental impacts of the urban development plan. Therefore the following advantages could be achieved at the same time by using the new proposed model for environmental impact assessment of the urban development projects:

- Impacts zoning for each environmental factors
- Calculation and zoning of accumulative impacts on the basis of the allocated impact of the environmental factors within the study area
- Quantification and reduction of expert judgments in assessment of the impacts
- Introduction of environmental vulnerability into environmental impacts assessment
- Optimization and leading the mitigation measures according to the results of impacts zoning

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