Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 14	No. 4	pp. 973-978	2015

Original Research Paper

Application of D Numbers to the Environmental Impact Assessment of Highway

Leila Sepahvand
Department of Management and Planning, Graduate Faculty of Environment, University of Teheran, Teheran, Iran

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 03-07-2015
Accepted: 15-08-2015

Key Words:
EIA
Highway
D numbers
Dempster-Shafer theory

ABSTRACT

Environmental impact assessment (EIA) is an important technique to ensure that possible effects of developmental projects have been fully identified and calculated for environment, and also its main purpose is accurate predicting, identifying and analysing the all positive and negative impacts on the natural and human environment. Assessment of the environmental impact requires a method or methods to do it. Due to the lack of sufficient knowledge, potential effects of projects are qualitative for nature, and they cannot be numerical exactly. One way to overcome this problem is using different types of uncertainty on EIA process. The theory of D numbers is a new provision of unreliable information and it is developed version of Dempster-Shafer theory. In this research, an assessment of environmental impact arising from the construction and operation of Ghomeishlou highway has been evaluated using D theory of numbers.

INTRODUCTION

Environmental impact assessment (EIA) is an important technique to ensure that possible effects of developmental projects in environment have been fully identified and calculated (Sharafi et al. 2008), and its main purpose is accurate predicting, identifying and analysing all positive and negative impacts on the natural and human environment. Assessment of environmental impact requires a method or methods to do it. In this regard, the method which has been presented by Leopold and his colleagues for assessing environmental impacts, can be considered as a first action in response to this requirement. Also after them, many different methods have been developed and introduced for environmental impact assessment, by increasing knowledge and awareness of researchers in this field, with the conducted advancements in the field of IT, that each of them has their own unique flaws and advantages. Although experts have made introduction of several methods for assessing the effects of environmental effects, but considerable point is the lack of a worldwide methodology that can be applied in all the environmental conditions. Also, due to the lack of technical information, and need of training and gaining experience in expert judgment about the effects of projects on the environment, the possibility of achieving such a methodology is low (Jabarian 2011). Currently, several methods for environmental assessment have been developed such as: Life Cycle Assessment (LCA)(Stiel & Teuteberg 2014) is envelopment analysis of data (DEA)(Sueyoshi & Goto 2012) and Rapid assessment matrix (RIAM) (Li et al. 2014).

Since assessment of environmental impact is multidimensional and also a complex process with several criteria and operators, therefore it needs the use of a multi criteria decision making techniques (Wang et al. 2006). Dempster-Shafer evidence theory has been applied to consider the uncertainty caused by lack of knowledge and information, or the inability of experts to provide accurate judgement during expert judging in the EIA process. Because of inadequate knowledge and cognition, potential effects of projects are qualitative in nature and cannot be determined numerically exactly. A way to overcome this problem is using different types of uncertainty in the EIA process. Till now several theories have been presented associated with uncertainties, including fuzzy set theory, rough set theory and Dempster-Shafer theory. Among these theories, Dempster-Shafer theory has the advantage of expressing uncertainty directly, and in this theory the concept of basic probability assignment (BAP) is used to represent uncertain information (Dempster 1967, Shafer 1976). As Dempster has mentioned, Dempster-Shafer theory has some limitations that assuming independent and separate sources of evidence is the most important one (Jahankhah et al. 2009), existence of exclusive hypotheses, and the condition of completeness in a set of numbers (Deng 2012, Deng et al. 2013), that these characteristics provide restricted conditions for application of this theory. Theory of D numbers is a new one providing the unreliable information, and also a developed theory of Dempster-Shafer and has not the limitations of Dempster-Shafer theory. The purpose of this paper is to assess the environmental impacts of construction and operation of Ghomeishlou highways using D number theory.

MATERIALS AND METHODS

D Numbers: This theory is defined as follow:

Table 1: Valuation of environmental impacts.

Description	Numerical rating
Very good effect	+5
Good effect	+4
The medium effect	+3
Weak effect	+2
Trivial effect	+1
No effect	0
Slight destruction	-1
Weak destruction	-2
Medium destruction	-3
Excessive destruction	-4
Too high destruction	-5

Definition 1: Suppose that Ω is a finite non-empty set, D numbers are as follows:

$$D: \Omega \rightarrow [0,1] \qquad D(\emptyset)=0 \quad \Sigma_{B\subseteq\Omega} D(B) \leq 1 \qquad ...(1)$$

That, ø is an empty set and B is a subset of Ω. Defining the D numbers is as the same as the definition of sum function, but it should be noted that, 1) It is not necessary to parameters of Ω set should be mutually incompatible with each other, 2) the completeness condition has been removed from all D numbers. Indeed if it is $\Sigma_{B\subseteq\Omega} D(B) = 1$ information is complete and also if it is $\Sigma_{B\subseteq\Omega} D(B)$ it said that the information is rudimentary.

Assume that a highway has been evaluated in the scale distance of {1-100} and detection framework is represented by experts as following:

$m(a_1)=0/2 \quad m(a_2)=0/7 \quad m(a_1+a_2+a_3)=0/1$

that a1=[0.40] and a_2=[41.70] a_3=[71.100]. Elements of $(a_1+a_2+a_3)$ set do not have any similarities so this set is a diagnostic framework. If another expert use the numbers D for expression evaluation as below:

that $D(b_1) = 0/2$ and $D(b_2) = 0/6$ $D(b_1+b_2+b_3) = 0/1$ that b_1= [0/45] b_2=[38/73] and b_3=[61/100] are as it mentioned.

This set is not determined as a detection framework because and also because $D(b_1)+ D(b_2)+ D(b_1+b_2+b_3) <1$ and information is rudimentary, the elements of set $(b_1+b_2+b_3)$ are incompatible with each other. Example presented above illustrates the difference between the translation and D numerals. For every separated D numerals $\Omega = b_1,b_2,\ldots,b_i,\ldots,b_n\}$ and $b_i \neq b_j$ if $i \neq j$ special form of D is represented as below:

$D(b_1)=v_1 \quad D(b_2)=v_2 \ldots\ldots D(b_i)=v_i \ldots\ldots D(b_n)=v_n \quad ...(2)$

Or it is written at this form:

$D=\{(b_1,v_1),\ldots.(b_i,v_i),\ldots,(b_n,v_n)\}$

$\sum_{i=1}^{n} vi \leq 1$ that $v_i>0$

Definition 2: Stability of contribution so that if there are two D number as following:

$D_1=\{(b_1,v_1),\ldots.(b_i,v_i),\ldots,(b_n,v_n)\}$and $D_2 = \{(b_n,v_n), \ldots., (b_i,v_i),\ldots.,(b_1,v_1)\}$

$D_1 \leftrightarrow D_2$

Definition 3: If D={(b1,v1),….(bi,vi),…,(bn,vn)} combination of D will be as bellow: (Deng et al. 2014).

Table 2: The integration of assessment results.

Environmental Factor	Expert judgments	Weight Factor	Environmental Factor	Expert judgments	Weight Factor
Microkelima	(-1,1)	0.06	Groundwater consumption	(-1,0.6)(-2,0.2)	0.07
Air quality	(-1,1)	0.07	Soil erosion	(-1,0.5)(-1,0.4)	0.08
Sound	(-2,0.5)(-2,0.5)	0.06	Soil characteristics	(-2,0.8)(-1,0.2)	0.05
Flood regime	(-1,1)	0.00	Soil stabilization	(-2,0.2)(-3,0.8)	0.05
Surface Water Quality	(-2,0.6)(-3,0.4)	0.06	Drainage	(-1,0.6)(-2,0.4)	0.06
Groundwater quality	(-3,0.4)(-2,0.6)	0.06	Shape of Land	(-3,0.1)(-4,0.9)	0.06
Surface water consumption	(-1,1)	0.06	Ground water level	(-2,0.9)(-1,0.1)	0.08

Table 5: The sum of weighting in different environments for assessing the environmental impact of Qomaishloo highway.

	Socio-economic environment (1/3)	Biological environment (1/3)	The physical environment (1/3)
Construction phase	+6.01	-19.46	-12.56
Operational phase	+7.65	-26.68	-10.24

Table 6: Final impact assessment of Ghomeishlou highway.

	Socio-economic environment.	Biological environment	The physical environment
Overall assessment	+4.55	-15.38	-7.60

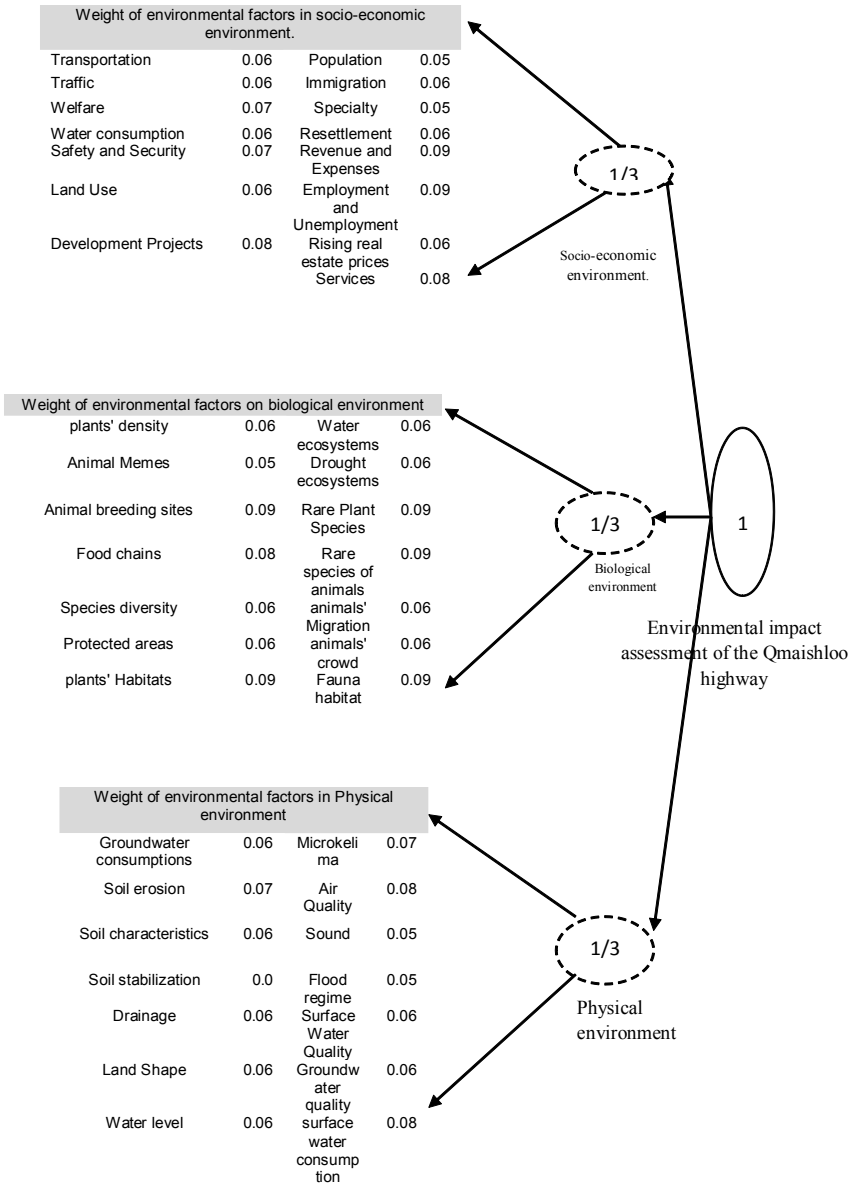

Fig. 1: Weights of factors in each level.

$$I(D) = \sum_{i=1}^{n} bivi \qquad ...(3)$$

$$\sum_{i=1}^{n} vi \le 1 \quad \text{That} \quad R\ b_i \in$$

Forming hierarchical structure model to assess the environmental impacts of highway: Construction of a highway can have significant and comprehensive impact on the environment, including the biological, socio-economic and physical environments. While some factors are more important than others, so building a hierarchical structure is necessary to survey the environmental impact of highway. In this paper, the factors used to assess the environmental impact of highway have been derived directly from Falahatkar et al. (2010).

Assigning weight for each factor: At this stage factors related to the physical, biological, economic and social environment are recognized and evaluated moderately. Weight of each factor is determined by the relative importance of that factor at each level. At the next step we must determine a standard assessment, that experts determine effectiveness of any construction activity and exploitation of highway on the environment based on that. For example, in this paper the applied standard for environmental impact assessment of highway Ghomeishlou is Leopold matrix. In this matrix a little value is considered to assess the effect of activation on the environmental factor which is normally between 1 and 10 by the suggestion of Leopold. But according to proposed model of Makhdoom (1990) every household will be evaluated according to Table 1 that contains numbers from -5 till +5 which means too much damaging effect, +5 number means very good and number zero means the no effect (Table 1).

Calculating consolidated showing of the evaluation factors: Suppose that there are 10 experts in desired assessment, If 5 expert assess effect too well and four of them assess it at average level, Showing this assessment by D numbers is in the form of (5,0/5) (3,0/4) Table 2.

To provide the assessment results of the physical environment as D numbers, it is necessary to use an operation on D numbers for process evaluation results. Evaluation results of physical factors which are written as D numbers are summed as real numbers. For example, the physical environment for assessing the environmental impact of the highway is shown in Fig. 1. Evaluation results

Table 3: The part of results of evaluation of biological effects in operation stage of Ghomeishlou highway by experts.

activiies / Environmental factors	Landscape	Salt pouring	Snow removal	Landscaping	Hiring	Accidents and Disasters	Transportation of hazardous waste
Water ecosystems							
Drought ecosystems	(+3,0.6) (+4,0.4)	(-3,1)	(-2,1)	(+3,0.5) (+,0.5)		(-2,1)	(-3,0.5) (-4,0.5)
Rare Plant Species	(+2,0.5) (+4,0.5)	(-5,1)		(-3,0.3) (-4,0.7)		(-2,1)	(-3,0.8) (-4,0.2)
Rare species of animals	(+2,0.2) (+5,0.8)	(-3,1)		(-3,0.3) (-4,0.6)		(-2,0.5) (-3,0.5)	(-3,0.1) (-4,0.9)
animals' Migration	(-2,1)	(-3,0.9) (-4,0.1)				(-3,1)	(-3,0.5) (-4,0.5)
animals' crowd							
Fauna habitat	(+3,0.6) (+5,0.4)	(-4,0.9) (-5,0.1)		(-2,1)	(-2,0.1) (-4,0.9)	(-4,-1)	(-3,0.3) (-4,0.7)
Habitats of plants	(+3,0.3) (+5,0.7)	(-4,0.5) (-5,0.5)	(-2,1)	(-2,0.1) (-5,0.9)		(-3,1)	(-3,0.5) (-4,0.5)
Density of plants	(+3,0.5) (+5,0.5)	(-4,0.4) (-5,0.6)		(-3,0.9) (-5,0.1)		(-3,1)	(-2,0.6) (-4,0.4)
Animal Memes	(-3,0.1) (-1,0.9)	(-3,0.5) (-4,0.5)		(-3,0.3) (-4,0.7)		(-4,1)	(-3,0.2) (-4,0.8)
Animal breeding sites	(-3,1)	(-3,0.1) (-4,0.9)		(-3,0.3) (-5,0.5)		(-4,0.5) (-2,0.5)	(-3,0.6) (-4,0.4)
Food chains	(-3,0.5) (-4,0.5)	(-3,0.2) (-4,0.8)		(-3,1)		(-3,0.5) (-2,0.4)	(-3,0.5) (-5,0.5)
Species diversity	(-3,0.5) (-2,0.3)	(-4,1)		(-3,0.5) (-5,0.5)		(-4,0.2) (-5,0.8)	(-4,0.3) (-5,0.7)
Protected areas	(-3,0.4) (-5,0.6)	(-2,1)	(-2,1)	(-2,0.3) (-3,0.7)		(-2,1)	(-2,0.5) (-4,0.5)

Table 4: The part of conclusion of factors in evaluation biological effects in operation stage of Ghomeishlou highway.

activiies / Environmental factors	Green spaces	pouring Salt	Snow removal	Landscaping	Hiring	Accidents and Disasters	Carrying hazardous waste
Water ecosystems Drought ecosystems							
Rare Plant Species	+0.2	-0.18	-0.12	-0.21		-0.12	-0.21
Rare species of animals	+0.27	-0.45		-0.23		-0.18	-0.29
animals' Migration	+0.4	-0.27		-0.3		-0.22	-0.35
animals' crowd	-0.12	-0.19				-0.18	-0.21
Fauna habitat							
Habitats of plants	+0.34	-0.37		-0.18	-0.34	-0.36	-0.33
Density of plants	+0.27	-0.4	-0.18	-0.42		-0.27	-0.31
Animal Memes	+0.24	-0.28		-0.19		-0.18	-0.17
Animal breeding sites	-0.06	-0.23		-0.2		-0.2	-0.19
Food chains	-0.18	-0.23		-0.26		-0.18	-0.2
Species diversity	-0.28	-0.3		-0.24		-0.21	-0.32
Protected areas	-0.13	-0.24		-0.24		-0.29	-0.28
sum	-0.25	-0.12	-0.12	-0.16		-0.12	-0.18

based on formula (3) are combined together as following:

Microkelima=I= [(-1, 0.6), (-2, 0.2)] = [(-1×0.6) + (-2×0.2)] = -1

Air Quality =I= [(-1, 0.5), (-1, 0.4)] = [(-1×0.5) + (-1×0.4)] = -0.9

Sound =I= [(-2, 0.8), (-1, 0.2)] = [(-2×0.8) + (-1×0.2)] = -1.8

Flood regime =I= [(-2, 0.2), (-3, 0.8)] = [(-2×0.2) + (-3×0.8)] = -2.8

Surface Water Quality =I= [-1, 0.6), (-2, 0.4)] = [(-1×0.6) + (-2×0.4)] = -1.4

Groundwater quality =I= [(-3, 0.1), (-4, 0.9)] = [(-3×0.1) + (-4×0.9)] = -3.9

Calculating total environmental impact: Suppose that F contains *n* sub factors represented as follows:

f_i, i = 1,2, ..., n. the weight of each sub factor is shown as w_i and the result of evaluation is f_i, R_i, environmental impact of total factor of F is shown RF and is calculated as follows:

$$RF = \sum_{i=1}^{n} wiRi \quad ...(4)$$

CASE STUDY

Ghomeishlou highway in Iran is 25 km far from Isfahan Province, and isolated from Axis 4 of Mourchekhort region and continues to the south, after cutting off the Aligudarz main road in West of Najaf Abad and crossing over the Isfahan-ZobAhan highway in neighbourhood of Gavpirneck and also after confluence with the Zayanderud river at the distance of 6 km from Mobarakeh Steel Complex-Sepahan Cement Factory ends. According to experts, by construction of this highway, about 10 to 15 kilometres of Ghomeishlou wildlife shelterhad been isolated, and this area is endangered by the construction of the highway. In order to demonstrate the application of D number theory in assessment of environmental impact of Ghomeishlou highway, first a hierarchical structure model was formed for this highway. Secondly, weighting and evaluation factors were done by experts. Due to the high volume of data evaluation by experts, in this article summary of biological environment is given in Tables 3 and 4.

RESULTS AND CONCLUSION

The results show that due to the passage across this highway of Ghomeishlou Wildlife Sanctuary, and damage to environment, implementation of this plan is rejected. Biological environment is undergoing the greatest negative impact of this project. While the socio-economic environment receives the lowest negative effects (Tables 5 and 6).

In this paper, a new method is proposed for assessing environmental impacts of the highway. In the proposed method, D numbers have been used for expression of uncertainty in environmental impact assessment for highway. This method can be applied in other fields such as risk assessment, waste management, and crisis management etc.

REFERENCES

Deng, X., Hu, Y., Deng, Y. and Mahadevan, S. 2013. Supplier selection using AHP methodology extended by D numbers. Expert Systems with Applications, 41(1): 156-167.

Deng, X., Hu, Y. and Deng, Y. 2014. Bridge condition assessment using D numbers. The Scientific World Journal, 1-11.

Deng,Y. 2012. D numbers: theory and applications. Journal of Information and Computational Science, 9(9): 2421-2428.

Jabarian Amiri, B. 2011. Comparison of evaluation methods of environmental impacts by using numerical taxonomy analysis, Natural Environment Journal, 64(3): 325-335.

Jafari, A., Mafi Gholami, D. and Mahmoudi, M. 2010. Environmental impacts assessment (EIA) of the Oshtorankooh protected area by using the degradation model. Environmental Studies Journal, 1(1): 13-22.

Jahankhah, M., Moshiri, B., Delawari, M. and Zare, M. 2009. Development of intuitive argument theory in multi-criteria decision-making methods in spatial dependence data. Control Journal, 3(3): 63-52.

Li, W., Xie, Y. and Hao, F. 2014. Applying an improved rapid impact assessment matrix method to strategic environmental assessment of urban planning in china. Environmental Impact Assessment Review, 46: 13-24.

Makhdoom, M. 1990. Environmental Impacts Assessment, Master Plan (Phase I), National Company of Agroindustrial and Livestock in Pars, Consulting Engineers of Comprehensive Iran, Report No. 28.

Sharafi, M., Makhdoom, M. and Ghafourian Bloori Mashhad, M. 2008. Environmental impact assessment of automobile manufacturing factory by making a case study: constructing automobile manufacturing factory in west of Takestan. Journal of Environmental Sciences, 4: 2-27.

Stiel, F. and Teuteberg, F. 2014. Measuring the environmental impact of IT/IS solution-A life cycle impact modeling approach. Environmental Modellig & Software, 56: 94-104.

Sueyoshi, T. and Goto, M. 2012. Data envelopment analysis for environmental assessment: Comparison between public and private ownership in petroleum industry. European Journal of Operational Research, 216(3): 668-678.

Wang, Y. M., Yang, J. B. and Xu, D. L. 2006. Environmental impact assessment using the evidential reasoning approach. European Journal of Operational Research, 174(3): 1885-1913.