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Road safety performance evaluation and policy making by data envelopment analysis: A case study of provincial data in Iran

H.R. Behnood[a,*], E. Ayati[a], E. Hermans[b] and M.A. Pirayesh Neghab[c]

a. *Techno-Economic Road Safety Research Center, Department of Civil Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran.*
b. *Hasselt University, Transportation Research Institute (IMOB), Wetenschapspark 5 bus 6, 3590 Diepenbeek, Belgium.*
c. *Department of Industrial Engineering, Faculty of Engineering, Ferdowsi University of Mashhad, Mashhad, Iran.*

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Abstract. Considering the need to invest in road safety programs, an efficiency analysis on implemented countermeasures is required. The system presented in this study is designed to evaluate the efficiency related to measures annually implemented throughout 30 provinces of Iran, specifically in 2008 and 2009. The model calculates a relative inefficiency index for each province and in each year, using the Data Envelopment Analysis (DEA) method. Each province in each year is defined as a Decision Making Unit (DMU) in DEA analysis. The inefficiency index is defined as the proportion of the weighted sum of road fatality risk indices to the weighted sum of road safety performance indicators. The inefficiency rate for each DMU must be minimized by either decreased fatality indices and/or increased safety measures to an optimal extent. Using a dual model of the main DEA model for each DMU, a target setting task can be conducted by identifying the benchmarks as the leading entities. Moreover, some discussions are provided for the results concerning the efficient units and the two-year comparison analyses.

1. Introduction

A great amount of research and many government plans have been undertaken in various countries as a means to optimally implement road safety measures. Road safety management practitioners have always attempted to portray an explicit perspective in both quantitative and qualitative road safety evaluation criteria by setting distinct strategies.

In this study, a set of information about previously implemented road safety measures is applied to evaluate their efficiency effects in decreasing road fatalities. The system is designed to evaluate the performance related to measures annually implemented throughout 30 provinces of Iran, in two years, 2008 and 2009, following which a planning and decision making process is undertaken using requirements found as the output of the analysis. The model calculates a relative inefficiency index for each province and in each year using the Data Envelopment Analysis (DEA) method. The inefficiency index is defined as the proportion of the weighted sum of road fatality risk indices to the weighted sum of road safety performance indicators. The inefficiency index, as the final output of DEA analysis, is used as a criterion in evaluating the existing performances, as well as a tool for prospective planning efforts in the sense that

*. *Corresponding author. Tel.: +98 915 3143674*
E-mail addresses: hr.behnood@gmail.com (H.R. Behnood); e_ayati@yahoo.com (E. Ayati); elke.hermans@uhasselt.be (E. Hermans); pirayesh@um.ac.ir (M.A. Pirayesh Neghab)

a higher index represents an unsafe province in a given year.

The information used in this study is that forming the input and output data in DEA analysis. The information includes a set of road safety performance indicators, most of which are advised to have been collected by the Iranian Road Safety Commission [1]. According to some criteria (mentioned in Section 2), this study detects a subset of road safety measures defined in the IRSC report, which can suit the analysis framework of the study. The subset of measures considered for each region in this study includes: (1) police operation, (2) treated black spots, (3) freeways and highways, (4) speed cameras, (5) emergency medical services, and (6) road lighting projects. Having accounted fatality rates as road safety outcomes, a performance analysis is undertaken to evaluate how inefficiently road safety measures are in the regions. Indeed, entities which have the lowest inefficiency rates will represent successful provinces in the year under study. The inefficiency rate for each Decision Making Unit (DMU) must be minimized by either decreased fatality indices or increased safety measures to an optimal extent. Finally, for each DMU, a prioritization task can be conducted by identifying the benchmarks as the leading entities.

An early study in road safety usage of DEA was presented by Cook et al. [2] to prioritize highway accident sites. Afterwards, Odeck [3] used DEA to investigate target achievements of the operational units of the Norwegian Public Roads Administration (NPRA) charged with traffic safety services. In previous studies about combining road safety information in a performance index, the DEA approach was obviously found to be valuable in the road safety context, which results in a useful optimization problem [4]. According to the advantageous application of DEA, several road safety studies have utilized the approach as a performance evaluation method. Runde et al. [5] carried out a DEA model to evaluate traffic safety for five urban counties within a city in China. In 2009, a promising methodology to make road safety policies by DEA results was introduced through which a model was described as a means to set targets and prioritize road safety needs on the basis of a the benchmarking approach [6]. The prioritization technique in that study is the approach to be applied as the Data Envelopment Analysis Road Safety (DEA-RS) model in the current study. In 2009, a simple DEA framework for road safety priority settings was applied for different geographical areas in Bangladesh [7]. Shen et al. [8] presented a more comprehensive form of the analysis as a generalized multiple layer data envelopment analysis model for hierarchical structure assessment. They also adopted the DEA extensions in road safety risk evaluation and target setting by evaluating fatality rates in terms of exposure measures [9]. In the next section, a description of the road safety performance indicators is presented to figure out how input safety measures and output fatality risk indices are selected for the analysis. Section 3 provides some methodological issues to be described about data envelopment analysis. The DEA application to build up the DEA-RS model is presented in Section 4 with additional discussion on benchmarking and prioritization tasks, as well as further results made by the analysis. Finally, conclusions are summarized in Section 5.

2. Input and output indicators

Three main functions of indicators, as defined by Adriaanse [10], are: simplification, quantification and communication. By using indicators, we try to capture complex phenomena in relatively simple terms. Indicators generally use simplification to make complex phenomena quantifiable in such a manner that communication is either enabled or promoted. Furthermore, these indicators can be used to compare countries (or provinces as in the current study), to rank and to benchmark them [11]. In general, a Road Safety Performance Indicator (RSPI) is defined as any measurement that is causally related to accidents or injuries, used in addition to a count of accidents or injuries, to indicate safety performance or understand the process that leads to accidents [12]. The RSPIs can depict a clear image of investments, planning, traffic violation recordings, public training efforts, etc. to policy makers. Safety performance indicators refer to operator activities within a transport system, but need not be limited to them.

The RSPIs, defined as inputs of this study, can be categorized as implementation and policy performance indicators. The outputs are also defined as fatality risk indices that should be calculated on the basis of officially stated road fatality frequencies. However, some criteria apply to the selection of an appropriate set of indicators, based on the list of indicators introduced by the IRSC [1] in Iran:

- For each of the indices, at least one year of valid data for all provinces should be available. Furthermore, data from official reports that are annually issued by governmental agencies are important requirements.
- The indices, including valid data for all provinces, should be chosen for at least one year. Indices partially collected in some provinces or information adopted from lectures or meetings are not suitable for the analysis. The data should include information cited in official reports that are annually issued by governmental agencies.
- The data should be manageable and implementable

to be applied in planning and decision making tasks. These indicators are usually attributed to technical and infrastructural highway transportation indices but not behavioral and human factors. For example, indices like the rate of seat belts fastened, alcohol or drug impaired drivers, extra load violations by heavy vehicles, or speed violations are controlled by mediator plans, such as traffic public training or enforcement tasks, thereby, they cannot be directly implemented by the executive authorities. On the other hand, measures like removed black spots and the number of police stations per unit length of a region are the tasks that could easily be handled by executive agencies.

- Choosing a great amount of indices as input data can make the analysis procedure complicated and disorder the required balance between the inputs and outputs of the DEA analysis also. As an empirical criterion in DEA analysis, the following equation must be observed between the number of inputs and outputs [13]:

$$\text{Number of DMUs} \geq 3 \times (\text{Number of Inputs} + \text{Number of Outputs}).$$

  Otherwise, many DMUs will be located on the efficient boundary and their efficiency rate will be equal to 1.0. Thereby, the model resolution power will be reduced.

- The input data must be independent of each other. In other words, no indices used as analysis input data should be a function of another, so that no co-linearity exists in the data set.

Many studies have shown that the simultaneous implementation of a set of road safety measures can lead a system into sustainable form. An increase in an RSPI might not lead to any improvement in terms of final outcome regarding fatalities or injuries. Therefore, both SPIs and final outcome, collated according to SPIs, should be collected and analyzed. The combination of a set of SPIs might lead to very few fatalities [14].

According to illustrations regarding road safety performance indicators discussed in this section, the six indices attributed to six measures are introduced as the main input data to be used in the analysis:

- Police Operation (PO): the average number of highway police stations within each 100 kilometers.
- Treated Black Spots (BS): the average number of black spots treated within each 100 kilometers.
- Highways and Freeways (H_F): The combined index is the percentage of weighted sum of highway and freeway lengths to the total length of the roads. To this end, each road type is weighted by the road safety equivalent factor mentioned in the Highway Pavement Rehabilitation Manual of Iran [15].
- Speed Control Cameras (SCC): the average number of fixed speed cameras within each 100 kilometers.
- Emergency Medical Services (EMS): the average number of roadside stations serving the emergency medical services within each 100 kilometers,
- Road Lighting Projects (Li): the average length of road equipped with lighting poles within each 100 kilometers.

This study considers the above-mentioned indices as input values in DEA analysis, while the risk indices reflecting fatality rates compose the output values in the study. Table 1 shows all input and output data used as the applied indices in the analysis. Table 2 indicates a low co-linearity between input data using R^2 rates. Except for a few cases, very low co-linearity is observed between pairs of indicators.

The risk indices, as the output of DEA analysis, are fatality rates involving two aspects of road fatality risk: the risk per unit value of the mobility demand (FR1; fatality numbers per one million vehicle-kilometers traveled) and the risk per unit value of the road (FR2; fatality numbers per 100 kilometers of road). These two types of risk refer to all types of road in a region, as well as mobility demand, which includes the total vehicle-kilometers traveled. All data regarding road safety performance indicators (i.e. the indices referring to countermeasures) are adopted from the annual reports published by the Road Maintenance and Transportation Organization [16] in Iran. Besides, the data representing the fatality rates are adopted from the Iranian Road Safety Commission [1] at the Ministry of Roads and Transportation.

3. Data envelopment analysis

In recent years, Data Envelopment Analysis (DEA) has been known as a useful method to evaluate the performance of decision making units. Review studies of three decades of practices in DEA application have created a mature perspective on methodology developments in a variety of industrial and managerial activities [17,18]. The first concept of the DEA model was presented by Charnes, Cooper and Rohdes [19], known as the CCR model. The CCR model applies the proportion of the weighted sum of outputs (y) to the weighted sum of inputs (x) as a scale for the measure of efficiency of n decision making units. If each Decision Making Unit (DMU) includes m inputs and s outputs of production, the linear programming form of the DEA model to estimate the corresponding efficiency is as follows:

Table 1. DEA input and output data.

Year	Province	DMU	PO	BS	H_F	SCC	EMS	Li	FR1= F/VKT	FR2= F/L
	Azerbaijan-E	1	0.32	1.90	27.79	0.00	1.45	2.68	0.805	16.6
	Azerbaijan-W	2	0.26	1.39	7.53	0.00	0.84	2.67	1.228	18.2
	Ardebil	3	0.37	1.05	11.01	0.00	1.57	9.86	0.980	12.7
	Isfahan	4	0.28	1.47	60.57	1.62	1.44	2.13	0.587	16.9
	Ilam	5	0.28	0.35	3.05	0.00	1.40	0.14	1.531	8.9
	Booshehr	6	0.30	0.66	43.33	0.00	1.79	2.80	0.697	11.3
	Tehran	7	1.06	0.76	83.40	9.80	5.32	18.98	0.430	70.0
	Chaharmahal	8	0.28	1.59	4.28	0.00	1.59	3.53	1.519	10.8
	Khorasan-S	9	0.10	0.18	0.66	0.00	0.86	1.40	1.409	4.7
	Khorasan-Raz	10	0.29	1.03	24.48	0.00	1.59	2.78	0.772	16.9
	Khorasan-N	11	0.36	1.25	12.84	0.00	1.16	4.55	1.823	16.2
	Khoozestan	12	0.23	1.65	31.23	0.00	1.74	1.67	0.518	17.6
	Zanjan	13	0.43	2.80	41.83	0.00	2.01	4.24	2.130	21.9
	Semnan	14	0.54	1.14	60.59	0.00	2.08	5.65	1.176	22.5
2008	Sistan	15	0.16	0.41	0.66	0.00	1.08	0.45	1.376	11.2
	Fars	16	0.23	2.01	14.70	0.00	1.48	1.85	1.206	17.6
	Ghazvin	17	0.49	3.13	65.27	6.43	1.98	8.08	2.005	35.8
	Ghom	18	0.67	3.03	102.77	12.73	2.69	14.12	1.335	41.8
	Kurdistan	19	0.25	2.46	4.70	0.00	1.20	2.84	2.063	25.4
	Kerman	20	0.20	2.50	19.97	0.00	1.54	0.72	0.960	13.2
	Kermanshah	21	0.38	0.63	18.50	0.00	0.79	5.60	1.367	14.9
	Kohgiluyeh	22	0.27	0.82	2.33	0.00	2.01	2.19	2.337	10.1
	Golestan	23	0.36	2.63	21.43	0.00	2.63	13.95	1.569	31.9
	Gilan	24	0.48	2.55	30.63	0.00	1.78	7.96	1.896	37.3
	Lorestan	25	0.43	1.66	15.65	0.00	2.96	4.99	2.120	30.1
	Mazandaran	26	0.49	3.26	31.22	0.00	2.24	11.19	1.325	28.5
	Markazi	27	0.42	1.48	34.76	2.89	1.37	3.96	0.986	19.4
	Hormozgan	28	0.17	0.20	14.92	0.00	0.99	0.72	0.265	12.2
	Hamedan	29	0.30	1.14	44.14	0.00	1.50	2.58	1.650	28.2
	Yazd	30	0.21	0.31	19.63	0.00	0.82	1.47	0.433	7.6
Mean	0.35	1.51	28.46	1.12	1.73	4.86	1.283	21.0		
	Azerbaijan-E	31	0.32	1.23	27.93	0.00	1.65	3.85	0.771	16.7
	Azerbaijan-W	32	0.26	3.18	8.83	0.00	1.20	2.66	1.197	18.0
	Ardebil	33	0.37	7.32	12.78	0.00	1.64	10.23	1.031	14.1
	Isfahan	34	0.28	1.54	72.60	1.25	1.46	2.93	0.547	16.8
	Ilam	35	0.28	2.71	3.29	0.00	1.39	0.76	1.921	11.5
	Booshehr	36	0.29	2.92	48.96	0.65	1.75	4.09	0.669	12.7
	Tehran	37	1.05	3.84	88.29	8.66	5.79	20.92	0.338	60.0
	Chaharmahal	38	0.26	2.07	9.42	0.00	1.81	3.36	1.209	9.3
	Khorasan-S	39	0.10	0.31	0.90	0.00	0.96	1.40	1.456	4.7
	Khorasan-Raz	40	0.28	0.93	26.26	0.00	1.59	2.84	0.750	17.1
	Khorasan-N	41	0.36	3.57	15.78	0.00	1.34	4.83	2.210	23.0
	Khoozestan	42	0.23	3.49	32.55	0.00	1.78	3.26	0.532	17.4
	Zanjan	43	0.43	2.95	43.92	4.29	2.30	4.24	1.971	21.4
	Semnan	44	0.60	2.78	76.71	0.00	2.63	7.51	1.152	24.1
2009	Sistan	45	0.16	1.10	3.76	0.00	1.19	0.86	1.391	11.4
	Fars	46	0.22	2.02	19.14	0.00	1.50	1.97	1.120	17.1
	Ghazvin	47	0.48	3.14	72.66	8.27	2.25	13.12	1.875	35.1
	Ghom	48	0.65	2.94	104.97	12.68	2.61	17.16	1.344	42.5
	Kurdistan	4	90.25	5.23	8.49	0.00	1.64	2.84	1.771	22.4
	Kerman	50	0.19	1.79	24.68	0.94	1.60	1.79	0.853	12.2
	Kermanshah	51	0.37	1.99	18.63	1.21	1.04	6.01	1.500	16.1
	Kohgiluyeh	52	0.27	1.83	4.66	0.00	2.01	2.56	2.015	9.6
	Golestan	53	0.36	1.27	29.01	0.00	2.54	13.95	1.466	29.8
	Gilan	54	0.47	2.91	36.76	0.00	1.81	8.04	1.655	36.5
	Lorestan	55	0.43	7.64	19.76	0.00	3.21	6.21	2.460	32.8
	Mazandaran	56	0.48	3.91	33.80	0.00	2.56	12.07	1.464	32.3
	Markazi	57	0.41	3.68	45.92	3.64	1.38	4.75	1.138	24.3
	Hormozgan	58	0.17	4.81	23.23	4.37	0.99	0.78	0.263	12.1
	Hamedan	59	0.30	5.42	43.80	0.00	1.67	3.87	1.612	28.6
	Yazd	60	0.20	0.57	23.76	2.56	1.21	2.31	0.422	7.5
Mean			0.35	2.97	32.71	1.62	1.88	5.71	1.270	21.2

Table 2. Co-linearity check for input data (R^2).

Indicator	PO	BS	H_F	SCC	EMS	Li
PO	1.00					
BS	0.05	1.00				
H_F	0.53	0.03	1.00			
SCC	0.44	0.02	0.59	1.00		
EMS	0.74	0.07	0.34	0.29	1.00	
Li	0.73	0.08	0.41	0.41	0.60	1.00

$$\text{Max}: \theta_o = u_1y_{1o} + u_2y_{2o} + ... + u_sy_{so}. \quad (1)$$

Subject to:

$$v_1x_{1o} + v_2x_{2o} + ... + v_mx_{mo} = 1, \quad (2)$$

$$u_1y_{1j} + u_2y_{2j} + ... + u_sy_{sj} \leq v_1x_{1j} + v_2x_{2j} + ... + v_mx_{mj}$$

$$(j = 1, 2, ..., n)$$

$$v_1, v_2, ..., v_m \geq 0, \quad u_1, u_2, ..., u_s \geq 0. \quad (3)$$

By solving this program, the optimum value, θ_o^*, for the objective function and the optimum values, v_i^* and u_r^*, for the function coefficients can be estimated. The value, v_i^*, is the optimum weight for the input value, i, whose magnitude states the importance of that element. Also, the value, u_r^*, states a similar weight for the output, r. The practical form of the main road safety DEA model used in this study is shown by Eqs. (5) to (7) and described in Section 4.

4. Concepts and models

4.1. Data envelopment analysis road safety model

Road fatalities are the undesired outcome of mobility that should be minimized by road safety planning efforts. Policy makers who wish to reduce fatality risk by implementing a variety of road safety measures, still need to be conscious about the benefits motivated by each type of remedial action. As an alternative for the term 'efficiency', an 'inefficiency' analysis can best suit the essence of the proportion which contains the fatality rates in the nominator and road safety supplies in the denominator. On the basis of this concept, a mere increase in road safety production factors is not always a reason for an increase in inefficiency value. To this end, a frontier can be defined for fatality reduction, below which a set of possible combinations, a so called production possibility set of road safety measures, can be established. Using the applicatory DEA approach to evaluate the road safety performance in all provinces, it will be possible to calculate an inefficiency index that reflects the rate of changes in fatality outputs to changes in safety inputs. For doing so, the road safety inefficiency in each province and each year is defined in terms of input and output values, as follows:

- Input values include six road safety performance indicators defined at the end of Section 2.
- Output values include the risk of fatality captured in two types, involving the risk per mobility demand and the risk per unit road length.
- The inefficiency index in each DMU is to be defined as below:

$$II = \frac{\sum_{r=1}^{2} \text{WFI}_r}{\sum_{i=1}^{6} \text{WPI}_i}, \quad (4)$$

where II is the Inefficiency Index that must be minimized; WFI_r is the Weighted Fatality Index for risk index type, r; and WPI_i is the Weighted Performance Indicator for the ith input.

By such an equation, the decrease in inefficiency interpreted as an increase in road safety can be achieved in two ways, as below:

- By decreasing the fatality index; it may not be meaningful, unless, by comparing two different units, the unit with a lower fatality index and the same inputs (road safety measures) are less inefficient (or more efficient). Consider that fatality reduction is just the result that policy makers tend to.
- By increasing the road safety measures; road safety policy makers tend to improve safety by implementing several measures in an agenda.

Both these approaches will decrease inefficiency while still help reduce fatality outcomes. But an extent (i.e. frontier) exists up to which the inefficiency reduction trend stops. The following DEA model can best help us achieve such an extent:

$$\text{Min}\theta = u_1y_1 + u_2y_2 = \sum_{r=1}^{2} u_ry_r. \quad (5)$$

Subject to:

$$\sum_{i=1}^{6} v_ix_i = 1, \quad (6)$$

$$\sum_{r=1}^{2} u_ry_{rj} - \sum_{i=1}^{6} v_ix_{ij} \geq 0 \qquad (j = 1, 2, ..., 60) \quad (7)$$

$$v_i, u_r \geq 0.$$

The variable y_r in Eq. (5) represents the related fatality rates defined as two risk indices. Eq. (5) is the objective function to minimize the value of inefficiency rate, θ. The model implies the inefficiency to lie at a minimum rate of one. Thereby, the weighted outputs will always be greater than, or equal to, the weighted inputs as displayed in Eq. (10).

4.2. Benchmarking

Having found the inefficiency rates, less prosperous provinces in a given year can systematically be compared with leading ones. Best-performing DMUs are those finding an exact value of one for the inefficiency index. The comparison can lead us into setting benchmarks as a means to prioritize DMU-specific safety requirements. By doing so, a set of road safety measures are recommended that can best contribute to a province to achieve an inefficiency score equaling one. Thereby, the concept of benchmarking is used as an applicatory approach in the literature of performance evaluation analysis. The approach identifies reference entities for each individual inefficient DMU on the basis of duality theory [20]. By such a process, a province in a given year can even be a benchmark for the same province, but in the next year. Benchmarks for each inefficient unit are DMUs, the attributed constraints of which exactly equal zero in Eq. (10). In other words, benchmarks embody the constraints reflecting the DMUs, with an exactly equal weighted sum of inputs and weighted sum of outputs, so that the corresponding inefficiency equals one. To do so, the concept of the dual price is utilized. Dual price or, namely, shadow price, is the maximum price that management is willing to pay for an extra unit of a given limited resource [21]. The dual price attributed to each benchmark is earned by solving the dual model corresponding to the inefficient DMU under study. Table 3 illustrates an array of variables and coefficients embodied in both main DEA and dual models. Using the combinations in Table 2, the dual model is built up as follows:

$$\text{Max } \omega_0. \tag{8}$$

Subject to:

$$\sum_{j=1}^{6} oy_{rj}\lambda_j \le y_r \quad (r = 1, 2), \tag{9}$$

$$x_i\omega_0 - \sum_{j=1}^{60} x_{ij}\lambda_j \le 0 \quad (i = 1, ..., 6) \tag{10}$$

$$\omega_0, \lambda_j \ge 0.$$

In these equations, ω_0 is the objective value to be maximized in the dual model. The decision variable, λ_j, represents the dual price for the jth DMU under study, so that the values, $\lambda_j \neq 0$, reveal the applicable dual prices for benchmark units. Finally, using the experiences of Hermans et al. [6], target actions with corresponding values for road safety performance indicators in inefficient provinces can be calculated as below:

$$\text{Target}_{i,A} = \sum_{b=1}^{B} \left(\frac{\lambda_b}{II_A} \times x_{i,b} \right), \tag{11}$$

where:

$\text{Target}_{i,A}$	target value for input data, i, in inefficient unit, A;
B	number of benchmarks for inefficient unit, A;
λ_b	dual price for benchmark, b;
II_A	inefficiency index for inefficient unit, A;
$x_{i,b}$	existing value of input data, i, in benchmark, b.

Provided that the target is achieved, the inefficiency rate will be minimized as far as it equals 1.

Table 3. Variables and coefficients to build up the dual model.

Dual model		Main model						Right side value
		u_1	u_2	v_1	v_2	...	v_6	
Const. 1	λ_1	y_{11}	y_{21}	$-x_{11}$	$-x_{21}$	...	$-x_{61}$	≥ 0
Const. 2	λ_2	y_{12}	y_{22}	$-x_{12}$	$-x_{22}$	...	$-x_{62}$	≥ 0
.	.	.	.	.	.	...	.	.
.	.	.	.	.	.	...	.	.
.	.	.	.	.	.	...	.	.
Const. j	λ_j	y_{1j}	y_{2j}	$-x_{1j}$	$-x_{2j}$	...	$-x_{6j}$	≥ 0
.	.	.	.	.	.	...	.	.
.	.	.	.	.	.	...	.	.
.	.	.	.	.	.	...	.	.
Const. 60	λ_{60}	y_{160}	y_{260}	$-x_{160}$	$-x_{260}$	...	$-x_{660}$	≥ 0
Const. 61	ω_0	0	0	x_1	x_2	...	x_6	$= 1$
Right side value		$\le y_1$	$\le y_2$	≤ 0	≤ 0	...	≤ 0	

Having identified the targets, the needed changes in input values are determined. Notice that the targets and changes are not merely defined for input values but the output target and changes are set for fatality rates as well in the sense that the decrease in fatality rates can be estimated by such an analysis. In the next section, calculations are carried out for 30 provinces in two years, with the results discussed in term of benchmarking effects.

5. Results and discussion

This study covers the road safety performance data and the fatality risk indices available in all provinces of Iran (30 provinces) for two years (2008 and 2009). The solver add-in program in Microsoft Excel software was used as the tool to conduct the calculations for linear programming.

Having assigned the values $u_i(i = 1, 2)$ and $v_j(j = 1, ..., 6)$ as the decision variables of each DMU, the problem is solved having found the minimized inefficiency values. Resulted inefficiency values are shown in Table 4. Notice that four provinces of Ardebil, Ilam, Booshehr, and Yazd, in 2008, and eleven provinces of Ardebil, Isfahan, Booshehr, Tehran, Chaharmahal, Khorasan S., Semnan, Ghom, Kohgiluye, Hormozgan and Yazd, in 2009, found the least inefficiencies equal to 1. Thereby, in 2009, considerable progress was observed in the number of efficient provinces compared with the year 2008. This is earned by lower fatalities and more road safety implementations in 2009 in comparison with 2008. The average inefficiency value changed from 1.409 in 2008 to 1.307 in 2009. Thereby, a seven percent reduction in inefficiency occurred in the next year.

Given calculated inefficiency scores for each DMU, we can identify benchmarks for unsuccessful provinces and prioritize for road safety strategies afterwards. In the first step, the dual prices for benchmarks of a given DMU can be calculated once the benchmark identification is fulfilled. To do so, the zero valued constraints attributed to 60 DMUs are found as benchmarks whose corresponding dual prices are not equal to zero. The prices can be earned by solving the dual model specified for each DMU under study. The benchmarks and their attributed dual prices are shown in Table 3 for all 30 provinces in both years, 2008 and 2009.

Using the dual prices, targets can be set for each road safety measure to be prioritized in a given unsuccessful province. Using Eq. (11), targets for a given DMU are estimated as the sum of the product of duals and the attributed benchmarks' existing values totally divided by the inefficiency index in the DMU under study. In addition to the input values, outputs can also be targeted by the product of the duals and benchmarks' existing output values. This is the approach which could be utilized in road fatality target setting efforts. Table 5 illustrates the resulted targets for all DMUs. Consider that the targets for successful DMUs are just within the same values that currently exist.

Targets shown in Table 5 are those recommended for underperforming units in two years, so that a comparison analysis can be made for the inefficiency rates to explore how changes occurred in two years. However, two restricting subjects and regarded solutions proposed to overcome them can be deliberated here. The first is the concern about efficient units or benchmarks that have not found any unit to follow as a better performing one. Somehow, the benchmarks can also find a better situation in a special analytical context. The second issue relates to the two-year data comparison in the same province.

5.1. Efficient units analysis

Among the 30 provinces analyzed in two years, 4 provinces in 2008 and 11 provinces in 2009 are identified as the best-performing ones according to the least inefficiency rates as well as the benchmarking process shown in Table 4. Targets for all other 45 underperforming DMUs are adjusted to these 15 benchmarks, but the question is if the benchmarks themselves can follow a path to enhance the performances accordingly. The solution can be illustrated by defining a new special analytical context in which the benchmarks compete to achieve the lowest inefficiency rates in turn, so that the ones unable to do so are supposed to follow the new benchmarks generated in the context. For doing so, a new DEA process can be run for all 15 old benchmarks. Thereby, the new inefficiency values are set to find new benchmarks. For analysis of the 15 new DMUs, the existing data set implies that they again lie on the frontier, so that all inefficiency rates will again be equal to 1. On the other hand, a few inputs may be found which could have best helped them be the benchmarks in the initial analysis. Such a contribution can be shown by the individual shares of effects earned by the product of the input value and attributed weight $(v_i x_i)$ for each DMU. Once the shares are estimated for all data in all 15 old benchmarks, the highest share shows the greatest contributing factor and, thus, can be eliminated in the new DEA process. That is because the greatest contributing factors are the main reason for causing the mentioned DMUs to get efficient, and their magnitudes are just in a convincing situation. Thereby, less contributing factors have not been located at a convincing level and they can be analyzed in an independent environment. Effective factors for whole analysis are determined by averaging the shares for all 15 DMUs. Thereby, the overall shares for six input measures are 15% for PO, 9%

Table 4. Benchmarking and dual price calculations.

Year	Province	DMU	Inefficiency	Benchmarks (#DMU, Province, Year)														
				3 ARD (08)	5 ILM (08)	6 BOO (08)	30 YZD (08)	33 ARD (09)	34 ISF (09)	36 BOO (09)	37 TEH (09)	38 CHA (09)	39 KHS (09)	44 SEM (09)	48 GHM (09)	52 KOH (09)	58 HOR (09)	60 YZD (09)
2008	Azerbaijan-E	1	1.279					0.19		0.06								1.39
	Azerbaijan-W	2	1.974	0.58				0.21										1.04
	Ardebil	3	1.000	1														
	Isfahan	4	1.105						0.76	0.07		0.02		0.02				0.25
	Ilam	5	1.000		1													
	Booshehr	6	1.000			1												
	Tehran	7	1.079								1.13						0.18	
	Chaharmahal	8	1.131	0.17	0.3			0.07				0.3				0.23		
	Khorasan-S	9	1.088									0.18	0.63					
	Khorasan-Raz	10	1.452					0.04			0.06							1.68
	Khorasan-N	11	1.341	0.41	0.75	0.01		0.11										0.37
	Khoozestan	12	1.236								0.13						0.2	1
	Zanjan	13	1.369		0.31	1.18		0.4										
	Semnan	14	1.093				0.47				0.03							2.28
	Sistan	15	1.933		0.11							0.92						0.22
	Fars	16	1.819					0.33					0.2					1.5
	Ghazvin	17	1.590					0.29		0.16					0.05		0.58	3.61
	Ghom	18	1.004						0.05		0.01				0.73		0.53	0.46
	Kurdistan	19	2.809	0.83				0.71				0.36						0.21
	Kerman	20	1.293					0.31				0.21						0.91
	Kermanshah	21	1.151	0.57	0.37													0.58
	Kohgiluyeh	22	1.052													1.05		
	Golestan	23	1.375	1.29				0.2			0.2							0.07
	Gilan	24	1.980	0.3				0.37			0.12							2.8
	Lorestan	25	1.702									0.62						3.25
	Mazandaran	26	1.389	0.76				0.29		0.3	0.18			0.01				
	Markazi	27	1.184					0.05			0.04							2.19
	Hormozgan	28	1.445								0.14							0.52
	Hamedan	29	2.402			1.73				0.44				0.08				0.11
	Yazd	30	1.000				1											
2009	Azerbaijan-E	31	1.284					0.06			0.06							1.64
	Azerbaijan-W	32	1.878	0.04				0.74										0.95
	Ardebil	33	1.000					1										
	Isfahan	34	1.000						1									
	Ilam	35	1.195		0.55			0.38								0.13		
	Booshehr	36	1.000							1								
	Tehran	37	1.000								1							
	Chaharmahal	38	1.000									1						
	Khorasan-S	39	1.000										1					
	Khorasan-Raz	40	1.486					0.02			0.07							1.67
	Khorasan-N	41	1.800	0.07	0.69			0.79										0.65
	Khoozestan	42	1.096							0.01	0.06						0.65	0.8
	Zanjan	43	1.313					0.32		0.05							0.04	2.12
	Semnan	44	1.000											1				
	Sistan	45	1.830									1.1						0.15
	Fars	46	1.723					0.32				0.11						1.54
	Ghazvin	47	1.150	0.1				0.18							0.64			0.55
	Ghom	48	1.000												1			
	Kurdistan	49	1.814					1.17				0.34						0.36
	Kerman	50	1.208					0.16				0.18						1.12
	Kermanshah	51	1.23	0.38	0.41	0.02		0.21										0.59
	Kohgiluyeh	52	1.000													1		
	Golestan	53	1.276	1.33						0.01	0.16				0.07			
	Gilan	54	1.893	0.14				0.46			0.18							2.34
	Lorestan	55	1.441					1.26				0.46						1.43
	Mazandaran	56	1.439	0.73				0.43		0.31	0.21							0.07
	Markazi	57	1.380					0.25		0.4	0.06						0.24	1.26
	Hormozgan	58	1.000														1	
	Hamedan	59	1.783					0.65		1.32							0.21	
	Yazd	60	1.000															1

Table 5. Target setting in all DMUs.

Year	Province	DMU	Ineff.	Target values							
				PO	**BS**	**H_F**	**SC**	**EMS**	**Li**	**FR1**	**FR2**
2008	Azerbaijan-E	1	1.279	0.323	1.885	31.860	3.192	1.825	5.011	0.627	13.022
	Azerbaijan-W	2	1.974	0.255	1.386	17.117	1.351	1.271	5.203	0.620	9.167
	Ardebil	3	1.000	0.373	1.046	11.010	0.000	1.568	9.858	0.980	12.696
	Isfahan	4	1.105	0.286	1.495	61.426	1.641	1.539	3.316	0.541	15.586
	Ilam	5	1.000	0.279	0.349	3.050	0.000	1.397	0.140	1.531	8.869
	Booshehr	6	1.000	0.298	0.656	43.328	0.000	1.790	2.804	0.697	11.337
	Tehran	7	1.079	1.132	4.822	96.345	9.795	6.233	22.040	0.398	64.837
	Chaharmahal	8	1.131	0.278	1.624	6.702	0.000	1.598	3.566	1.348	9.560
	Khorasan-S	9	1.088	0.103	0.523	2.078	0.000	0.856	1.368	1.044	4.247
	Khorasan-Raz	10	1.452	0.286	1.018	31.487	3.324	1.679	3.818	0.530	11.502
	Khorasan-N	11	1.341	0.359	1.277	12.998	0.707	1.741	4.589	1.362	12.142
	Khoozestan	12	1.236	0.301	1.643	32.278	3.693	1.745	4.197	0.419	14.316
	Zanjan	13	1.369	0.430	2.784	41.784	0.000	2.340	5.440	1.249	15.909
	Semnan	14	1.093	0.536	1.424	60.407	5.584	3.025	6.023	1.074	20.471
	Sistan	15	1.933	0.162	1.070	7.361	0.292	1.079	1.872	0.711	5.788
	Fars	16	1.819	0.262	2.025	22.949	2.114	1.491	4.131	0.668	9.741
	Ghazvin	17	1.590	0.636	4.768	72.986	7.881	3.656	8.349	1.351	26.568
	Ghom	18	1.004	0.682	5.052	103.949	12.845	3.105	14.299	1.339	42.147
	Kurdistan	19	2.809	0.253	2.467	9.467	0.192	1.201	6.103	0.737	9.072
	Kerman	20	1.293	0.273	2.492	21.318	1.805	1.536	4.625	0.740	10.152
	Kermanshah	21	1.151	0.376	0.917	18.411	1.292	1.833	6.092	1.190	12.903
	Kohgiluyeh	22	1.052	0.274	1.824	4.648	0.000	2.006	2.554	2.011	9.576
	Golestan	23	1.375	0.568	2.633	26.246	1.390	2.615	13.901	1.140	23.073
	Gilan	24	1.980	0.474	2.564	43.014	4.151	2.600	7.941	0.958	18.755
	Lorestan	25	1.702	0.478	1.840	48.799	4.895	2.961	5.635	1.245	17.646
	Mazandaran	26	1.389	0.486	3.248	31.252	1.262	2.349	11.177	0.948	20.575
	Markazi	27	1.184	0.423	1.491	47.463	5.034	2.494	5.410	0.834	16.427
	Hormozgan	28	1.445	0.174	0.577	17.103	1.761	0.995	2.858	0.184	8.496
	Hamedan	29	2.402	0.298	1.127	43.826	0.237	1.754	3.126	0.682	11.637
	Yazd	30	1.000	0.205	0.308	19.627	0.000	0.822	1.472	0.433	7.583
2009	Azerbaijan-E	31	1.284	0.323	1.248	35.064	3.678	1.886	4.405	0.602	12.994
	Azerbaijan-W	32	1.878	0.257	3.194	17.292	1.297	1.291	5.411	0.640	9.610
	Ardebil	33	1.000	0.373	7.319	12.777	0.000	1.643	10.232	1.031	14.115
	Isfahan	34	1.000	0.278	1.542	72.602	1.253	1.456	2.934	0.547	16.813
	Ilam	35	1.195	0.277	2.686	5.971	0.000	1.384	3.595	1.251	9.611
	Booshehr	36	1.000	0.292	2.924	48.959	0.652	1.754	4.094	0.669	12.690
	Tehran	37	1.000	1.053	3.837	88.287	8.656	5.794	20.918	0.338	59.970
	Chaharmahal	38	1.000	0.259	2.070	9.418	0.000	1.811	3.364	1.209	9.314
	Khorasan-S	39	1.000	0.104	0.311	0.897	0.000	0.960	1.401	1.456	4.670
	Khorasan-Raz	40	1.486	0.280	0.919	31.036	3.289	1.650	3.719	0.504	11.405
	Khorasan-N	41	1.800	0.358	3.593	15.789	0.926	1.753	5.763	1.230	12.787
	Khoozestan	42	1.096	0.308	3.503	36.386	4.942	1.799	3.333	0.488	16.043
	Zanjan	43	1.313	0.432	2.960	44.045	4.297	2.443	6.402	0.965	16.344
	Semnan	44	1.000	0.601	2.780	76.711	0.000	2.630	7.513	1.152	24.117
	Sistan	45	1.830	0.172	1.291	7.609	0.210	1.188	2.211	0.761	6.211
	Fars	46	1.723	0.265	2.000	24.215	2.292	1.498	4.180	0.646	9.890
	Ghazvin	47	1.150	0.551	3.145	72.731	8.280	2.425	13.110	1.196	30.523
	Ghom	48	1.000	0.654	2.941	104.972	12.676	2.614	17.157	1.344	42.484
	Kurdistan	49	1.814	0.329	5.223	14.725	0.509	1.639	7.690	0.976	12.334
	Kerman	50	1.208	0.274	1.806	25.128	2.377	1.605	3.998	0.708	10.179
	Kermanshah	51	1.236	0.372	1.963	18.609	1.224	1.829	5.963	1.197	12.989
	Kohgiluyeh	52	1.000	0.274	1.828	4.658	0.000	2.011	2.559	2.015	9.598
	Golestan	53	1.276	0.559	1.755	28.687	1.786	2.518	13.871	1.142	23.182
	Gilan	54	1.893	0.444	1.805	39.393	3.994	2.495	5.761	1.093	18.680
	Lorestan	55	1.441	0.609	7.627	37.770	2.545	3.212	12.316	1.706	22.730
	Mazandaran	56	1.439	0.528	3.935	33.991	1.528	2.569	12.105	1.019	22.508
	Markazi	57	1.380	0.411	3.696	46.075	3.666	2.330	6.194	0.826	17.769
	Hormozgan	58	1.000	0.171	4.809	23.226	4.372	0.989	0.784	0.263	12.142
	Hamedan	59	1.783	0.373	5.400	43.644	0.998	2.015	6.854	0.902	15.972
	Yazd	60	1.000	0.201	0.569	23.763	2.564	1.205	2.310	0.422	7.466

for BS, 21% for H_F, 5% for SCC, 28% for EMS, and 22% for Li. The results show the EMS effects as the best contributing factor throughout the old benchmarks, so that it can be removed by analysis of competing benchmarks. Thereby, five inputs and two outputs (so, totally, seven data types) remain for analysis of 15 DMUs. The case would perfectly disorder the balance required to keep the inequality mentioned as the fourth prerequisite in selecting the indices in Section 2 ($15 < 3 \times 7$), so that many DMUs would still lie on the frontier line. Therefore, two more inputs are required to be removed from the analysis. The second and third high values of the shares belong to the road lighting effects by 22 percent and Highway/Freeway effects by 21 percent, respectively, removal of which would keep the balance in the data set, although located on a border edge ($15 \geq 3 \times 5$). Running the DEA for a total of five data types makes some DMUs earn the least inefficiency value equaling one and still remain lying on the frontier line. In such a case, some other DMUs find higher inefficiency values. The results found for analysis of 15 DMUs known as the old benchmarks, with a three-input two-output data set, are summarized in Table 6.

By new DEA analysis, seven new DMUs are identified as new benchmarks representing those having the best performance. Similarly, targets can be set for those that could not have succeeded, to appeal against the lowest inefficiency rates in the new process. Recall that in the recent prioritization run, no targets, thus no changes, are subjected to set for EMS, lighting, and Highway/Freeway effects in the analysis. Since there are still seven DMUs remaining as benchmarks, it might be possible to set a new analysis to rank them. However, notice that seven DMUs need no more than 2 data types to keep the balance in the data set ($7 \geq 3 \times 2$), in the sense that a maximum of one input and a maximum of one output would build up the data set in DEA analysis. As a rule of thumb, such an analysis will surely present far counterintuitive results, so that we accept those seven DMUs as the ultimate 'benchmarks of benchmarks'.

It must be noted that the Cross Efficiency Model (CEM) and the super-efficiency method are two conventional methodologies introduced to rank efficient units, none of which can be applied here, due to lack of compatibility with the scope of this study. The CEM method [22] ranks decision making units in lower efficiency (i.e. higher inefficiency) rates, so that much fewer DMUs will earn the exact efficient position. Thus, a different set of road safety inefficiency values are estimated, while disabled, to identify the objective targets by a benchmarking task. Moreover, using the CEM approach, the optimal input and output weights obtained from the basic DEA model may not be unique, and this makes the cross-efficiency analysis somewhat arbitrary and limited in applicability [9]. Besides, the Super-Efficiency (SE) method [23] ranks efficient DMUs below the lowest road safety inefficiency, and permits them to pass by the efficient frontier and possess an inefficiency rate of less than one. Inefficiency results by the SE method are shown for efficient units in Table 6. Comparing the results of the SE method with the new inefficiency rates shows that the lowest SE results cope with new benchmarks that have, again, earned a rate equal to 1. Such a result confirms the approach developed here. The super-efficiency method does not change the inefficiency values for under-

Table 6. Benchmarking, dual prices and target setting for old benchmarks.

Year	Province	Old DMU	Ineff. by SE method	New DMU	New ineff. rates	New benchmarks (#New DMU, Province, Year)							New target values[a]				
						1 ARD (08)	2 ILM (08)	4 YZD (08)	5 ARD (09)	8 TEH (09)	14 HOR (09)	15 YZD (09)	PO	BS	SCC	FR1	FR2
2008	Ardebil	3	0.905	1	1.000	1.000							0.37	1.05	0.00	0.98	12.70
	Ilam	5	0.927	2	1.000		1.000						0.28	0.35	0.00	1.53	8.87
	Booshehr	6	0.936	3	1.048	0.204		0.713				0.447	0.30	0.66	1.09	0.67	10.82
	Yazd	30	0.996	4	1.000			1.000					0.21	0.31	0.00	0.43	7.58
2009	Ardebil	33	0.507	5	1.000				1.000				0.37	7.32	0.00	1.03	14.12
	Isfahan	34	0.793	6	1.334				0.141	0.143		0.838	0.28	1.54	2.54	0.41	12.61
	Booshehr	36	0.843	7	1.078				0.355	0.043		0.685	0.29	2.92	1.97	0.62	11.78
	Tehran	37	0.539	8	1.000					1.000			1.05	3.84	8.66	0.34	59.97
	Chaharmahal	38	0.906	9	1.058	0.018	0.597		0.268				0.26	2.07	0.00	1.14	8.79
	Khorasan-S	39	0.995	10	1.392		0.468		0.037				0.10	0.31	0.00	0.54	3.36
	Semnan	44	0.980	11	1.002				0.161	0.081		2.274	0.60	2.78	6.52	1.15	24.05
	Ghom	48	0.903	12	1.170					0.020	2.353	1.703	0.65	10.57	12.68	1.15	36.32
	Kohgiluyeh	52	0.939	13	1.044		0.722		0.226				0.27	1.83	0.00	1.28	9.19
	Hormozgan	58	0.381	14	1.000						1.000		0.17	4.81	4.37	0.26	12.14
	Yazd	60	0.677	15	1.000							1.000	0.20	0.57	2.56	0.42	7.47

[a] :Targets for new efficient units are equal to the existing values so no changes are needed in related safety measures.

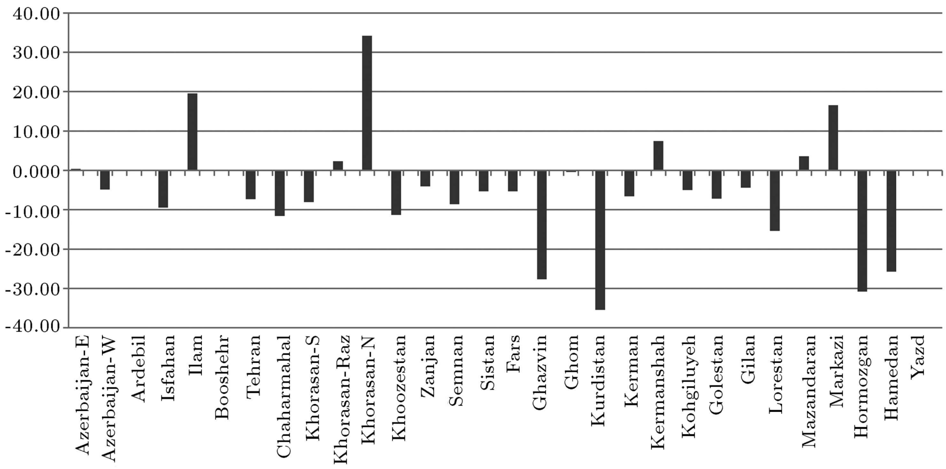

Figure 1. Percent of changes occurred in inefficiency rates in 2009 compared with 2008.

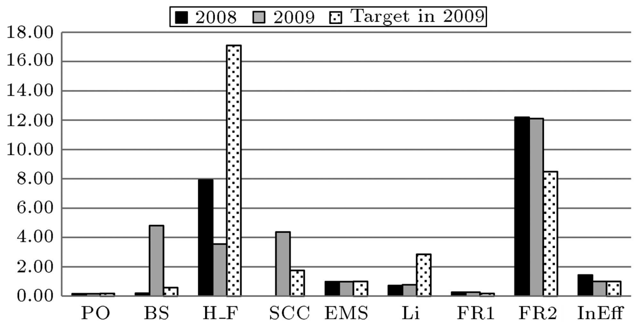

Figure 2. RSPIs and target values for Hormozgan province.

performing units, but is still disabled to set targets for best-performing DMUs, preferably in a competing context.

5.2. Two-year comparison

A variety of changing trends in two years can be observed in all provinces under study. The changes occurring in 2009 compared with 2008 are depicted in Figure 1. The columns show the decrease or increase in inefficiency values in percentages.

The upper columns above the zero axes represent the provinces that have not acted in the desired direction, since the inefficiency rates have grown. Amongst them, the province, Khorasan-N, has met a great increase in inefficiency (more than 30 percent). On the contrary, the lower columns beneath the zero axes indicate the relatively good performing provinces, which could have handled the inefficiency to some extent. Kurdistan is the most successful province among the relatively good performing ones.

For a further insight, Hormozgan is selected to be discussed as a province which has successfully reduced its inefficiency rate from a rather high value of 1.445 to the least value of 1. The column charts for the two-year implementations, as well as the target values in the province, are depicted in Figure 2. According to the target values shown in dotted columns, the second-year actual RSPIs are expected to be equal to the targets, while great distances are observed between the efficiently implemented and target values. Implemented measures in 2009 suggest a higher application of black spot remedial work and speed control cameras, as well as less H_F rates. On the other hand, target values advise higher rates of highway and freeways and lighting projects. Both implemented and target values would have led the province into a perfect efficient situation, but in two different ways. Therefore, the proposed targets achieved by the benchmarking process are not unique solutions for the policy making problem. In the real world, several ideas may be given as managerial decisions, based on existing limited resources, which may not make the targets earned in Table 4 as practical plans. To this end, utilizing a Decision Support System (DSS) can best help us test the outcomes achievable by several alternative decisions made to develop road safety measures. To do so, providing a DEA-based knowledge base can help us establish the DSS by means of a somehow expert system.

The DEA target set acts as a so called rigid framework of priorities that gives a unique set of information about the magnitude of road safety measures to be allocated, as well as the effectiveness of the recommendations. In fact, the flexibility and programmability of strategies due to resource limitations is a critical issue of concern. An expert system in the light of a reasoning approach enables users to define alternative strategies by exact amounts of measures to be assigned. Collecting a set of data in a few years, as a knowledge base of analysis, can lead us into a decision making system valid enough for all regions included in the study. Thus, one can use a single box of a Decision Making System (DMS) as a tool to be applied globally in prospective years.

Not only does the idea to build up a decision making system never conflict with the method used in this study, the DEA target setting can also significantly contribute to the enhancements in such a system. Indeed, such a decision making system should include targets set by the approach used in this study as exact recommendations throughout a set of decision making units. By doing so, a comprehensive knowledge base can be constructed that can best propose alternative options with clear outcomes.

6. Conclusion

This study endeavors to build up a Data Envelopment Analysis (DEA) process to evaluate road safety performances experienced in 30 Iranian provinces for two years, 2008 and 2009. Thereby, totally, 60 Decision Making Units (DMUs) are subjected to be used in the analysis. Six input values, as road safety measures, or so called road safety performance indicators, are introduced in the analysis to be assessed, versus two types of fatality rate used as risk indices. Besides, amongst the 60 DMUs provided, a group of best performing provinces, i.e. benchmarks, are explored that can open the path to other underperforming ones. To do so, the duality theory is applied, by means of which, a set of ideal targets is found for each individual DMU. As a result, 15 DMUs are identified as benchmarks for the others, so that 4 DMUs are adjusted in 2008 and the other 11 in 2009. Benchmarks, as the reference sets, help DMUs seek for the targets that bring them the lowest inefficiency score. Targets are estimated by means of dual prices, as well as the measures of existing values in corresponding benchmarks. As observed by the target set, no changes are needed in the existing data values in benchmarks. Target setting and required changes are estimated both for input road safety performance indicators (i.e. increase) and output fatality rates (i.e. decrease). This study is an extended application of the method developed by Hermans et al. [6], but on a national basis, carried out for all provinces in a single country in two successive years. The strategies made by such a process can be adopted either by the central government authorities or individually on a provincial basis. Discussion on results shows that some limitations still exist to count in the adopted target setting approach as an inclusive decision making system, due to the lack of alternatives, which can be replaced by unique targets in case of infeasibility.

Once the prioritization task is fulfilled, a new analytical context may be defined for 15 best performing DMUs, in the sense that they are involved in a new competing ranking effort. To this end, the input data that have already contributed the lowest inefficiency achievement are eliminated, in order to keep the balance in a data set, thus avoiding fewer DMUs to be located on the frontier. Considering the average product of input data and the attributed weights, defined as the shares affecting the benchmarks, three input data, including EMS, lighting facilities, and freeway effects, are removed in the new context. By doing so, eight DMUs from amongst the old 15 efficient ones would be ranked as the new underperforming entities, which can still enhance the efficiency rates regarding the new targets calculated for police operation, black spot treatments, and speed control cameras.

Another controversial discussion regarding results, concerns the two-year comparison analysis. The results show that targets achieved by the benchmarking process may not be a unique solution to improve efficiency, especially when constrained by some limited resources. For example, the targets set for Hormozgan province in 2008 are far different from the measures actually implemented in 2009, while both could have led to the lowest inefficiency rates. Thereby, some alternative practical decisions may be made to enhance efficiencies that can be supported by a Decision Support System (DSS). Accordingly, feasible outcomes may be observed by developing a DEA-based knowledge base that can help us establish the DSS by the means of a somehow expert system. Indeed, such a system should include the targets set by the approach used in this study, as the exact recommendations throughout a set of decision making units. Therefore, DEA benchmarking and target setting tasks can significantly contribute to the establishment of a comprehensive road safety decision making system.

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Biographies

Hamid Reza Behnood received a PhD degree in highway and transportation engineering from Ferdowsi University of Mashhad, Iran, where he had a significant role in establishment of the Techno-Economic Road Safety Research Center. His major fields of interest include road safety planning and economics using various techniques such as cost-benefit analysis, mathematical programming, statistical evaluations, data envelopment analysis, and fuzzy decision making.

Esmaeel Ayati received his MD degree in Road and Civil Engineering from Tehran University and his PhD degree in Road and Transportation Engineering from Aston University, UK. He is currently Full Professor in the Department of Engineering at Ferdowsi University of Mashhad, Iran, where he is Chief of the Techno-Economic Road Safety Research Center. His fields of interest include the safety of traffic and his research into evaluating the cost of traffic accidents is unique in Iran. His book, entitled "The Cost of Traffic Accidents in Iran", is the only valid reference publication in this area in Iran.

Elke Hermans graduated as a Commercial Engineer, in 2004, from the Limburg University Centre (now: Hasselt University), Belgium, where, until 2009, she worked as a doctoral researcher at the Transportation Research Institute. Her research interest includes the area of road safety, more specifically, the development of indicators and a methodology for developing a composite road safety performance index that can

be used for cross-country comparison. She attained her PhD degree in 2009 and has, since then, worked as Professor at the Transportation Research Institute/Bachelor & Master Programme, Transportation Sciences of Hasselt University, Belgium. Elke Hermans is author and co-author of various journal articles in accident analysis and prevention, transportation research records, knowledge-based systems, etc. and conference proceedings, such as the annual meeting of the Transportation Research Board, European Transport Conference, International Road Traffic and Accident Database Conference, and International Conference on Sensitivity Analysis of Model Output etc.

Mohammadali Pirayesh Neghab received his BS, MS and PhD degrees in Industrial Engineering from Sharif University of Technology, Tehran, Iran, in 2000, 2002 and 2008, respectively. Currently he is faculty member in the Industrial Engineering Department at Ferdowsi University of Mashhad, Iran. His current research interests include supply chain management, transportation planning and fuzzy decision making.