

Research Paper: Evaluation of Decision-making Units in Reducing Traffic Accidents Using Data Envelopment Analysis



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ABSTRACT

Background: Road accidents are one of the most important causes of death and severe bodily injuries and financial damages, and its social, cultural, and economic consequences have severely threatened human societies. The purpose of this study was to use Data Envelopment Analysis (DEA) to measure the efficiency of provincial traffic police in reducing accidents in 2018 and determining the amount of optimal input resources of each provincial unit.

Materials and Methods: The model used in this research had three inputs, including the level of equipment at the disposal, the level of the approved provincial budget, and the level of manpower at the disposal. It also had two outputs, including the score of reduction of casualties and the score of reduction of deaths in traffic accidents. The “returns to scale” was considered as a variable model, and the input model was an axial-type model. The DEAP software was used for data analysis.

Results: The highest decrease in deaths in traffic accidents (in 2018) was related to Fars Province with 119 people, and the highest decrease in the number of injured cases was related to Khorasan Razavi Province with 1495 people. The RAHVAR Police (Traffic Police of Iran) in Tehran Province had the highest level of input resources, including manpower, equipment, and approved budget. Performance measurement for 2018 showed that out of 31 provinces studied, 10 provinces had a good performance and 21 provinces had acted inefficiently. The research results showed that the proper allocation of resources could push all units to the brink of efficiency.

Conclusion: The trend of accidents in Iran is declining. Most of the RAHVAR Police units operate at an inefficient level, which by increasing their efficiency, the number of accidents can be reduced with a greater slope.

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1. Introduction

The increasing number of vehicles and road users is one of the important and wide-ranging issues with various and complex dimensions [1]. Traffic accidents are one of the new public health problems worldwide and are considered as one of the most important causes of death, physical disability, and hospitalization, which have significant economic and social consequences [2]. In the coming years, traffic accidents are expected to become the second leading cause of death in high-income and middle-income countries [3]. Research shows that by 2020, the number of deaths due to traffic accidents will reach more than 2 million people worldwide, mostly in developing countries [4].

According to the World Health Organization, if the precautionary measures are not taken to reduce the current trend of accidents, the share of traffic accidents in mortality will increase to more than 67% [5]. Reducing the number of accidents as well as the severity of accidents should be considered and prioritized by the officials of the countries for their planning. Data show that 9 people die per 10,000 vehicles on the road in the world, while in Iran, 37 people die per 10,000 vehicles [6].

Human, technical, regulatory, and other factors are effective in the occurrence of accidents [7]. The most important factor in the occurrence of traffic accidents that has been addressed in various research is the human factor. One of the factors influencing the reduction of accidents is the improvement of drivers' supervision, which is the responsibility of the RAHVAR Police.

RAHVAR Police supervisory bodies can reduce the number of accidents by enacting appropriate rules, better monitoring, and training drivers [8]. One of the most important decisions in various organizations, including supervisory and service organizations is the efficient, appropriate, and fair allocation of financial resources to increase the efficiency of organizational units [9]. Targeted allocation of resources to the provincial units of the RAHVAR Police (as the administrator of monitoring and reducing accidents in Iran) can lead to better performance of this organization.

Furthermore, evaluating the efficiency of the provincial RAHVAR Police units allows them to be ranked in terms of efficiency in managing traffic accidents, and can be an indicator to identify the shortcomings of the provincial units and improve them. Given that the main responsibility for reducing accidents lies with the RAHVAR Police if

they can act effectively, both the accidents will decrease and the general health of the community will increase, because they harm the individual and the community, as well.

Data envelopment analysis (DEA) has been widely used by researchers as a technique for ranking decision-making units [10-13]. In his study, which measured the efficiency of RAHVAR Police units, Zangunejad described the efficiency of the decision-making units of each province but did not provide a model for the proper allocation of resources for RAHVAR Police [14].

DEA is effective in a system, and in addition to ranking and measuring performance, shows the correct allocation of resources between decision-making units. Jabbarzadeh and Sufi used DEA only to rank the police bases [15].

DEA has been used in RAHVAR Police for ranking and measuring the efficiency index, and no research has yet been done to determine the appropriate amount of resources available to the RAHVAR Police units

In this study, using DEA, in addition to measuring the efficiency of provincial RAHVAR Police in reducing accidents in 2018, the amount of optimal input resources of each provincial unit will be determined.

2. Materials and Methods

This descriptive and analytical study was of a comparative type, which used the data of injured and dead people in traffic accidents and the level of financial resources available for provincial units to measure the efficiency and estimate the appropriate resources needed by each province. The statistical population of this study was all the injured and dead cases in traffic accidents by provinces in 2018 received from the Iranian Legal Medicine Organization and the RAHVAR Police.

The purpose of this research was to measure the efficiency of RAHVAR Police; therefore, only the statistical data of accident deaths were mentioned because the supervision of RAHVAR Police as a response system was considered effective in reducing accidents and deaths in the country. The number of those who were injured or died due to vehicle defects or unsafe roads was not mentioned in this study.

Due to the confidentiality of the resources available to the RAHVAR Police, with the permission of the NAJA (Iranian Disciplinary Force) RAHVAR Police, the available indicators of each of the provincial RAHVAR Police were scored on a 0-100 index. The DEA tool was

used to estimate the efficiency and optimal allocation of input resources for each province. The efficiency of the decision-making units in this research was determined by the input and output values.

The efficiency value was between 0-1; number one indicated an efficient unit. The DEA model used in this study was the “variable returns to scale” model with 3 inputs and 2 outputs. The inputs of this model included the level of equipment available, the level of approved organizational budget, and the level of human resources available, whereas the outputs of this model included the reduction of traffic accident casualties and the reduction of traffic accident deaths.

The permit to review the level of resources available to the decision-making units was obtained from the RAHVVAR Police, and considering its several aspects, with the cooperation of NAJA Research and Development staff, three input variables entitled “provincial approved budget level”, “level of human resources available”, and “level of equipment available” were used as input variables to measure the efficiency of decision-making

units. For example, the amount of equipment available included a number of factors, such as the number of traffic enforcement cameras, the number of police vehicles, the quality of the police equipment, and surveillance and security devices. Based on the collection method of these resources, a level was considered for each province from 1-100, varied according to the amount of resources available in the studied provinces.

To measure the reduction in the number of traffic accident casualties, the base number was considered to be 2000. When the number of injured cases decreased, the decreased number was added to 2000, and when the number of injured cases increased, the increased number was subtracted from 2000. The base number for those killed in traffic accidents was 500.

After measuring the efficiency for 2018, the appropriate input to reach the efficiency limit was estimated and the correct form of resource allocation between units was determined. Considering that in this study the inputs of NAJA provincial units were centrally determined by the General Staff of NAJA and at a certain level, and on

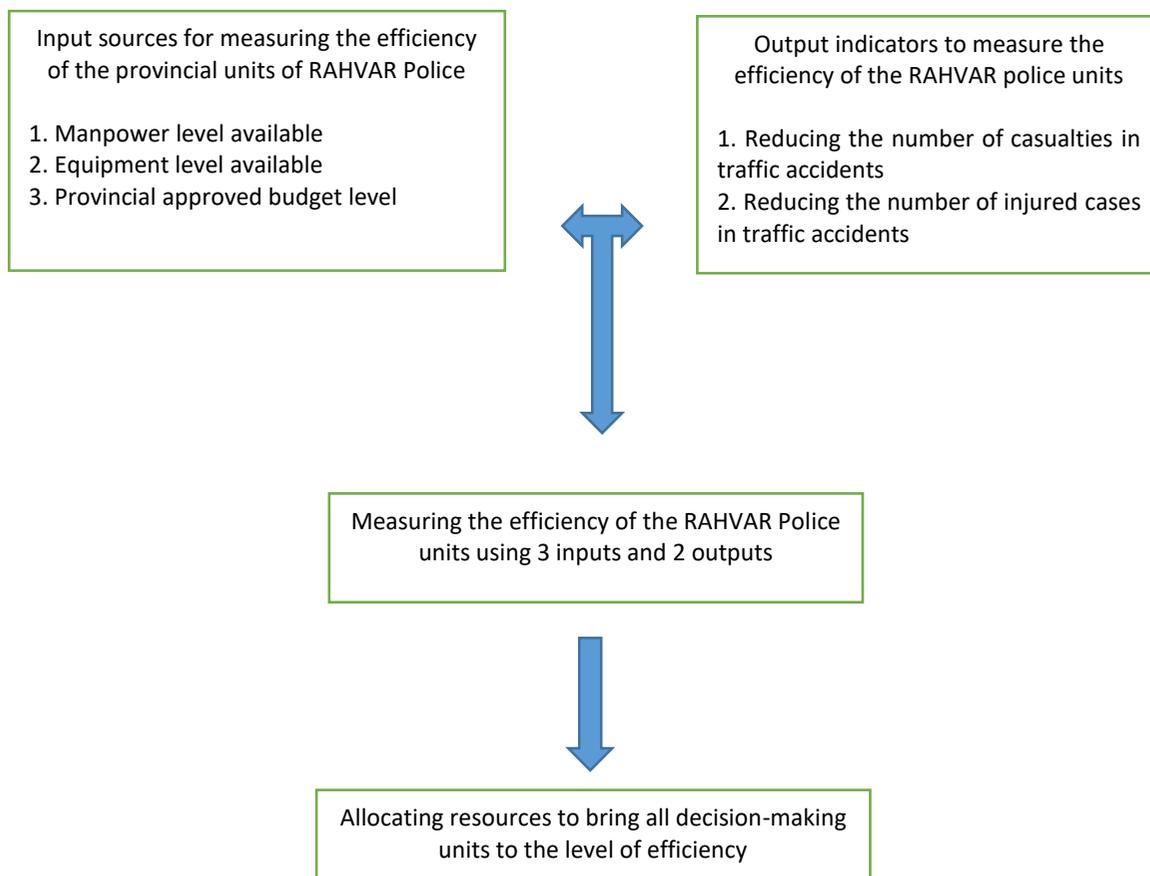


Figure 1. Stages of the research flowchart

the other hand, considering that the objective of NAJA is to develop and provide better services to people, the emphasis of the management of this assemblage was more on the amount of services based on the input sources of the provincial units of NAJA.

The model used in this study was input-oriented. Also, the DEA model with the assumption of variable returns to scale or the model of Banker, Charnes, and Cooper (BCC) was used.

To measure the validity of the instrument and check whether the input and output sources could be a suitable tool for measuring the efficiency of decision-making units, the opinions of professors and experts, including 10 faculty members with relevant fields were used. The experts confirmed the validity of the input and output sources. Because the study used real-world data and hospital performance data, it was not relevant to investigate the reliability of the study. Figure 1 shows a step-by-step flowchart of the research and performance measurement using DEA.

3. Results

The statistical data of injured and dead cases in traffic accidents in 2018 showed that compared with 2017, the number of people injured in traffic accidents decreased by 5.2% and the number of deaths in traffic accidents decreased by 2.7%. The highest number of reduction in deaths in traffic accidents in 2018 was related to Fars Province with 119 cases, whereas the highest number of reduction in casualties was related to Khorasan Razavi Province with 1495 cases. The total number of casualties in 2017 and 2018, the rate of decrease and increase in statistical data, and the scores of the provincial RAHVVAR Police are provided in Table 1.

Based on the available manpower, equipment, and approved budget, a level from 1 to 100 was determined for each province because of the involvement of many factors at each level available to the provincial police. The level available to each province is presented in Table 2. RAHVVAR Police of Tehran Province had the highest level of input resources, including manpower, equipment, and approved budget.

After measuring the inputs of the provincial units of RAHVVAR Police in each province based on the levels of the approved budget, manpower, and equipment in 2018, using input and output resources, including the index of a decrease and an increase in traffic accident victims and the index of an increase and a decrease in traffic accident casualties, the efficiency of each province was measured (Table 3).

Performance measurement in 2018 showed that out of 31 provinces studied, 10 provinces had a good performance. Also, 21 out of 31 provinces studied, had acted inefficiently in 2018, which indicates the need to review the allocation of resources in the RAHVVAR Police units. The mean efficiency of all decision-making units in this study for 2018 was 0.637.

In DEA, decision-making units were divided into two categories of efficient and inefficient, and units with an efficiency of higher than 0.5 were identified as units with moderate efficiency, and those with an efficiency below 0.5 were identified as units with severe inefficiency [13]. Among the inefficient units, 8 units had a performance above 0.5%, which indicates their average efficiency index, but 13 provinces had an efficiency of 0.5, which indicates a serious waste of resources in these provinces. Also, among the efficient units, the number of references to achieve efficiency is given in Table 4.

Appropriate allocation of the input resources for inefficient provinces to reach the efficiency limit was based on the reference provinces and lambda coefficients. The amount of input resources of the provinces and the desired amount of resources to reach the efficiency limit are provided in Table 5. The available input resources are shown on the left side of the arrows and the desired input resources are shown on the right side of the arrows.

4. Discussion

Every year, a large number of people lose their lives in Iran due to traffic accidents and natural disasters, and a significant number of these people are injured in accidents. The aim of this study was to use DEA to measure the efficiency of the RAHVVAR Police units involved in reducing accidents and estimate available resources to reach the efficiency limit.

The results of this study showed that the number of people injured and dead in traffic accidents in Iran is declining. Reducing the number of accidents is a good indicator of the correct direction of accident management in the country, which can improve the unfavorable situation of the number of people killed and injured in traffic accidents.

In the research by Erfanpour et al. (2016), the incidence of accidents in Khorasan Province as one of the tourist destinations in Iran was declining [16]. Also, in a study by Ghorbani et al. (2012), accidents in Khuzestan Province had a decreasing trend [17]. Hosseinzadeh et al. investigated the trend of changes in traffic accidents in

Table 1. Total number of casualties and scores of RAHVAR Police

Province	Losses of 2017	Losses of 2018	The rate of a Decrease and an Increase in 2018	RAHVAR Police Score Regarding Death Rate Based on 500 Cases in 2018	Total Number of People Injured in 2017	Total Number of People Injured in 2018	The Rate of Decrease and Increase in 2018	RAHVAR Police Scores Regarding Casualties Based on 2000 Cases in 2018
East Azarbaijan	885	886	1	499	15492	15437	-55	2055
West Azarbaijan	622	548	-74	574	9410	9352	-58	2058
Isfahan	477	405	-72	572	9626	8922	-704	2704
Ardabil	160	172	12	488	4201	4324	123	1877
Alborz	249	232	-17	517	8800	8654	-146	2146
Ilam	199	238	39	461	2965	2549	-416	2416
Bushehr	289	287	-2	502	3429	3623	194	1806
Tehran	1352	1295	-57	557	37943	35631	-312	2312
Chaharmahal and Bakhtiari	262	232	-30	530	5300	5672	372	1628
South Khorasan	240	247	7	493	3536	4262	726	1274
Khorasan Razavi	1272	1265	-7	507	25798	24303	-1495	3495
North Khorasan	299	234	-65	565	4382	4469	87	1913
Khuzestan	811	1172	361	139	17639	17503	-136	2136
Kermanshah	475	452	-23	523	10172	11071	899	1101
Kohgiluyeh	183	197	14	486	5032	4921	-111	2111
Gilan	341	312	-29	529	9648	9973	325	1675
Golestan	286	274	-12	512	9026	8429	-597	2597
Mazandaran	414	432	18	482	1624	17437	1196	804
Lorestan	442	460	18	482	8680	7513	-1167	3167
Qazvin	186	175	-11	511	4972	4545	-427	2000
Qom	223	151	-72	572	9273	9420	147	1853
Kurdistan	221	206	-15	515	4717	4469	-248	2248
Fars	1445	1326	-119	619	24252	23778	-474	2474
Kerman	212	200	-12	512	6304	5284	-1020	3020
Markazi	488	376	-112	612	5884	5968	84	1916
Hamedan	389	336	-53	553	6646	5737	-909	2909
Hormozgan	331	369	38	462	2871	3414	543	1457
Yazd	223	269	46	454	2521	2624	103	1897
Zanjan	216	222	6	494	3254	3142	-112	2112
Semnan	201	219	18	482	2514	2715	201	1799
Sistan and Baluchestan	196	182	-14	514	2647	2345	-302	2302

Table 2. The level of input resources of RAHVAR Police in the provinces

Province	Provincial Approved Budget Level	Manpower Level Available	Equipment Level Available	Death Output	Injured Output
East Azarbaijan	33.16	33.17	32.07	499	2055
West Azarbaijan	41.14	32.20	28.21	574	2058
Isfahan	52.17	40.12	50.10	572	2704
Ardabil	17.14	15.21	15.12	488	1877
Alborz	24.12	20.15	52.31	517	2146
Ilam	11.09	17.12	18.19	461	2416
Bushehr	17.14	15.16	17.19	502	1806
Tehran	100	100	100	557	2312
Chaharmahal	32.14	21.23	32.14	530	1628
South Khorasan	13.19	14.12	10.07	493	1274
Khorasan Razavi	70.51	61.17	72.25	507	3495
North Khorasan	12.14	9.25	10.27	565	1913
Khuzestan	64.14	64.32	59.81	139	2136
Kermanshah	60.21	59.41	52.12	523	1101
Kohgiluyeh	7.86	10.13	11.09	486	2111
Gilan	50.51	22.13	22.36	529	1675
Golestan	42.14	23.45	44.14	512	2597
Mazandaran	62.61	42.14	64.15	482	804
Lorestan	26.24	14.25	24.97	482	3167
Qazvin	34.12	26.16	28.76	511	2000
Qom	23.17	21.12	29.12	572	1853
Kurdistan	13.14	15.02	14.72	515	2248
Fars	60.12	34.14	42.12	619	2474
Kerman	11.13	10.09	13.14	512	3020
Markazi	16.10	22.41	41.16	612	1916
Hamedan	22.34	23.19	30.30	553	2909
Hormozgan	34.82	24.51	32.12	462	1457
Yazd	28.80	20.12	32.71	454	1897
Zanjan	27.40	26.14	20.13	494	2112
Semnan	22.20	20.14	40.12	482	1799
Sistan and Baluchestan	9.84	15.05	28.17	514	2302

Table 3. Performance of the RAHVAR Police units in 2018

Province	Performance Level	Efficiency
East Azarbaijan	Inefficient	0.334
West Azarbaijan	Inefficient	0.59
Isfahan	Inefficient	0.627
Ardabil	Inefficient	0.684
Alborz	Inefficient	0.473
Ilam	Inefficient	0.808

Province	Performance Level	Efficiency
Bushehr	Inefficient	0.629
Tehran	Inefficient	0.163
Chaharmahal	Inefficient	0.436
South Khorasan	Good performance	1
Khorasan Razavi	Good performance	1
North Khorasan	Good performance	1
Khuzestan	Inefficient	0.182
Kermanshah	Inefficient	0.198
Kohgiluyeh	Good performance	1
Gilan	Inefficient	0.458
Golestan	Inefficient	0.417
Mazandaran	Inefficient	0.22
Lorestan	Good performance	1
Qazvin	Inefficient	0.365
Qom	Inefficient	0.549
Kurdistan	Inefficient	0.766
Fars	Good performance	1
Kerman	Good performance	1
Markazi	Good performance	1
Hamedan	Good performance	1
Hormozgan	Inefficient	0.377
Yazd	Inefficient	0.46
Zanjan	Inefficient	0.536
Semnan	Inefficient	0.475
Sistan and Baluchestan	Good performance	1

Table 4. The number of efficient units

Province	Number
South Khorasan	2
Khorasan Razavi	1
North Khorasan	21
Kohgiluyeh	10
Lorestan	1
Fars	4
Kerman	12
Markazi	2
Hamedan	3
Sistan and Baluchestan	1

Table 5. Input and input target values

Province	Input 1	Input 2	Input 3
East Azarbaijan	33.16 → 11.072	33.17 → 9.525	32.07 → 10.708
West Azarbaijan	41.14 → 21.568	32.2 → 14.183	28.21 → 16.639
Isfahan	52.17 → 32.693	40.12 → 24.733	50.1 → 31.396
Ardabil	17.14 → 11.731	15.21 → 9.334	15.12 → 10.348
Alborz	24.12 → 11.397	20.15 → 9.521	52.31 → 10.914
Ilam	11.09 → 8.957	17.12 → 10.117	18.19 → 11.778
Bushehr	17.14 → 10.775	15.16 → 9.531	17.19 → 10.531
Tehran	100 → 16.31	100 → 13.405	100 → 16.31
Chaharmahal	32.14 → 12.14	21.23 → 9.25	32.14 → 10.27
South Khorasan	13.19 → 13.19	14.12 → 14.12	10.07 → 10.07
Khorasan Razavi	70.51 → 70.51	61.17 → 61.17	72.25 → 72.25
North Khorasan	12.14 → 12.14	9.25 → 9.25	10.27 → 10.27
Khuzestan	64.14 → 11.656	64.32 → 9.469	59.81 → 10.869
Kermanshah	60.21 → 11.914	59.41 → 9.296	52.12 → 10.313
Kohgiluyeh	7.86 → 7.86	10.13 → 10.13	11.09 → 11.09
Gilan	50.51 → 12.329	22.13 → 10.129	22.36 → 10.234
Golestan	42.14 → 11.516	23.45 → 9.769	44.14 → 12.043
Mazandaran	62.61 → 12.14	42.14 → 9.25	64.15 → 10.27
Lorestan	26.24 → 26.24	14.25 → 14.25	24.97 → 24.97
Qazvin	34.12 → 12.061	26.16 → 9.316	28.76 → 10.496
Qom	23.17 → 12.73	21.12 → 11.21	29.12 → 14.871
Kurdistan	13.14 → 10.061	15.02 → 9.82	14.72 → 11.271
Fars	60.12 → 60.12	34.14 → 34.14	42.12 → 42.12
Kerman	11.13 → 11.13	10.09 → 10.09	13.14 → 13.14
Markazi	16.1 → 16.1	22.41 → 22.41	41.16 → 41.16
Hamedan	22.34 → 22.34	23.19 → 23.19	30.3 → 30.3
Hormozgan	34.82 → 12.14	24.51 → 9.25	32.12 → 10.27
Yazd	28.8 → 12.14	20.12 → 9.25	32.71 → 10.27
Zanjan	27.4 → 11.958	26.14 → 9.401	20.13 → 10.786
Semnan	22.2 → 10.555	20.14 → 9.576	40.12 → 10.574
Sistan and Baluchestan	9.84 → 9.84	15.05 → 15.05	28.17 → 28.17

Qazvin Province and reported that the rate of accidents in this province has been almost unchanged [18].

Assessing the efficiency of RAHVAR Police units in 2018 showed that 30% of its units were at an efficient level and 70% were inefficient. This shows the need to reconsider the proper allocation of resources among RAHVAR Police units for better control and supervision of the drivers. The results of this study showed that DEA was an effective tool for measuring the efficiency of decision-making units.

Alinejad and Khalili (2017) in their research showed that DEA was a suitable tool to measure the efficiency of hospitals [19]. Fazeli et al. used DEA as a tool to measure the efficiency of hospitals in Ilam and indicated that this method was acceptable in measuring efficiency when there are many decision-making units [20].

Given that the reference units are currently identified, it is suggested that an analysis of the experiences and reference actions be performed, and resources be allocated to the follower provinces to reduce the accident rate. Different bodies are involved in road safety and accidents. In this study, only the RAHVAR Police was investigated. Involv-

ing other effective bodies to make a more accurate assessment of the allocation of provincial resources is suggested.

The limitations of this study were as follows:

- It was very difficult to receive information from the introduced experts due to their busy schedule and in some cases, their conservatism;

- The administrative process for obtaining a permit to receive statistical data from the police was a long procedure;

- Due to the involvement of many cases in measuring performance and selecting input indicators, the available level was used instead of the actual values.

Ethical Considerations

Compliance with ethical guidelines

All ethical principles are considered in this article.

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Authors' contributions

All authors contributed in preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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