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Efficiency Assessment Based on Data Envelopment Analysis for Occupational Accidents and Diseases in Furniture Industry of Turkey

Procjena učinkovitosti turske industrije namještaja primjenom analize omeđivanja podataka o broju nezgoda na radu i profesionalnih bolesti

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ABSTRACT • *In this study, the provinces in which enterprises operate heavily in the Turkish furniture industry were subjected to an efficiency assessment using the data envelopment analysis (DEA) method based on work accidents and occupational diseases. The data related to the furniture industry was obtained from the Social Security Institution (SSI) and the Ministry of Labor and Social Security (MoLSS). The number of operating businesses and the number of employees insured in each province were evaluated as inputs for the analysis. The total number of workplace physicians and other health personnel in each province, the number of workplace physician and occupational safety centers and A, B, and C-class occupational health and safety specialists were used as outputs. The number of employees who experienced work accidents and occupational diseases, deaths resulting from work accidents and occupational diseases, total temporary disability periods, the number of beneficiaries, and the number of those receiving permanent disability income in each province were evaluated as undesirable outputs. The data was analyzed using the DEA method by modeling the undesired outputs in 6 different ways, and the efficiency of each province was determined. It was seen that Model 6 gave the most ideal results in DEA efficiency assessments. Aydın, Çanakkale, Diyarbakır, Eskişehir, Malatya, Muğla, Trabzon and Zonguldak were determined as the most effective provinces in terms of occupational health and safety. The results were evaluated along with the literature, and recommendations were presented.*

KEYWORDS: *DEA; data envelopment analysis; non-parametric evaluation methods; work accident and occupational health; furniture industry*

SAŽETAK • *U ovom je istraživanju primjenom metode analize omeđivanja podataka (DEA) na temelju broja nezgoda na radu i profesionalnih bolesti napravljena procjena uspješnosti pokrajina u kojima intenzivno posluju*

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poduzeća turske industrije namještaja. Podatci vezani za industriju namještaja dobiveni su od Zavoda za socijalnu skrb i Ministarstva rada i socijalne skrbi Turske. Ulazni podatci za analizu bili su procijenjeni broj operativnih poduzeća i broj zaposlenika u svakoj pokrajini, a izlazni podatci sadržavali su ukupan broj liječnika medicine rada i drugoga medicinskog osoblja u svakoj pokrajini, broj centara za zaštitu na radu te broj stručnjaka zaštite na radu A, B i C klase. Kao nepoželjni izlazni podatci za analizu u svakoj su pokrajini uzeti u obzir broj zaposlenika koji su doživjeli nezgodu na radu i/ili oboljeli od profesionalne bolesti; broj smrti uzrokovanih nezgodama na radu i/ili profesionalnom bolešću; ukupno trajanje privremene nesposobnosti za rad, kao i broj korisnika te onih koji primaju trajnu invalidninu. Podatci su analizirani uz pomoć DEA metode (analize omeđivanja podataka) modeliranjem neželjenih izlaza na šest različitih načina te je određena učinkovitost svake provincije. Pokazalo se da je model 6. dao optimalne rezultate u procjeni učinkovitosti DEA metodom. Utvrđeno je da su Aydın, Çanakkale, Diyarbakır, Eskişehir, Malatya, Muğla, Trabzon i Zonguldaku najuspješnije pokrajine u smislu zdravlja i sigurnosti na radu. Rezultati su analizirani usporedno s literaturom te su dane preporuke za moguća poboljšanja.

KLJUČNE RIJEČI: *analiza omeđivanja podataka (DEA); neparametarske metode evaluacije; nezgoda na radu; turska industrija namještaja*

1 INTRODUCTION
1. UVOD

Occupational health and safety (OHS) is an essential element of the business world. At this point, occupational accidents and diseases (OADs) are an issue that particularly concerns employees in many sectors. Sectors such as manufacturing, production, mining, construction, transportation, underground and underwater contain many risks for employees. The issue of OADs is not only a matter of concern for employees, but also affects and concerns employers, the relatives for whom the employee is responsible, and the government. In Turkey, this issue has been taken more seriously since the adoption of the Occupational Health and Safety Law No. 6331 in 2012 within the framework of the European Union (EU) adaptation laws. Although the law contains important provisions for workplaces and employers to take serious measures regarding OHS and to protect employees, and provides for serious sanctions for non-compliance, the rates of OADs in Turkey are still at low levels. According to Serin *et al*. (2015), in terms of the manufacturing sector, Turkey takes the first place in Europe and second in the world when rankings are examined according to the frequency of occupational accidents. This situation shows the necessity of analyzing occupational accidents seriously in Turkey (Akyüz *et al*., 2016).

During work life, OHS has a priority that requires a national-level effort involving not only preventive measures taken by employers at the workplace but also contributions from employees and the government. Therefore, as in other countries, various regulations have been implemented and will continue to be implemented in Turkey to continuously improve the working conditions, ensure effective participation of employees in OHS efforts, and plan national-level education on this subject. To measure the effectiveness of such regulations and see their impact, it is necessary to look at the indicators of countries' performance in this area. Statistical data on OHS and its changes and distribution over the years are essential elements of the business world.

Data on OADs in Turkey are recorded and published by the Social Security Institution (SSI). Until 2013, only accident data for incidents that occurred and were closed within the year were published. However, with the implementation of heavy sanctions for those who fail to report accidents, particularly following Law No. 6331, all reported accidents have been published since 2013. However, it is an issue to be considered that these statistical data only cover the reported OADs. According to Kurttekin and Taçgın (2019), it is known that many occupational accidents are not reported or recorded due to insufficient control and inspection. In addition, identifying occupational diseases is also quite difficult because most occupational diseases emerge either in advanced age or after the worker's retirement, so they are not considered as occupational diseases and are not recorded. Therefore, the accuracy of the data obtained from SSI statistics is accepted as a limitation of the research.

The furniture industry is one of the leading subsectors within the manufacturing industry. According to Magezi and Okan (2023), the Turkish furniture industry has made good use of the opportunities in the last ten years and has become competitive in EU. There are 21,758 businesses in the sector, with 154,829 insured employees (SSI, 2019). Furniture companies are mainly classified as dangerous and highly dangerous based on their risk group. The sector includes many hazardous tools such as cutting, drilling, carving, and crushing equipment, as well as many chemicals that threaten human health, such as wood dust and formaldehyde, paint, and thinner. In addition, there are many heavy tasks and workloads during production and assembly that can harm the musculoskeletal system of workers.

There are many different studies on the subject in the literature. Koç *et al*. (1998) examined OADs in the furniture industry and developed recommendations for their prevention. Akyüz *et al*. (2016) studied accident statistics in the forest products industry sector and made general evaluations regarding the issue. Gedik and İlhan (2014) analyzed OHS issues among furniture manufacturers in Sakarya province. Sevim Korkut and Gedik (2010) examined occupational safety in the Turkish forest products industry sector. Ulutaş (2016) evaluated provinces in Turkey in terms of OADs. Bilim and Bilim (2015) conducted a statistical study on OHS in Turkey and analyzed the issue. Lombardi *et al*. (2019) modeled a risk profile using the European Statistics on Accidents at Work (ESAW). Xu and Xu (2021) statistically revealed fatal accidents, accident numbers, accident locations, and accident areas in the construction sector in China. Nissi and Rapposelli (2012) evaluated occupational accidents in three economic sectors (manufacturing, construction and distribution trades) in Europe through VZA analysis. In this study, unlike the studies in the field, besides an activity evaluation, a model is also proposed that can be used in evaluating the activity.

This research is aimed to develop suggestions to minimize the work accidents (WA) or occupational diseases (OD) that occur in the provinces where the Turkish furniture industry is concentrated. The provinces determined for this purpose were evaluated in terms of the number of enterprises, employees, workplace physicians (WP) and other health personnel (OHP), and the number of occupational health and safety specialists (OHSS).

1.1 Data envelopment analysis (DEA)
1.1. Analiza omeđivanja podataka (DEA)

The data envelopment analysis (DEA) method has been chosen for the evaluation. It is one of the non-parametric evaluation methods. It allows efficiency evaluation with many inputs and outputs, and at the same time, it is easy to include undesirable outputs (UO) in efficiency evaluation with various models.

DEA was developed by Charnes *et al*. (1978) to measure and compare the technical efficiency of public institutions based on an article by Farrell (1957) on productivity measurement (Safak *et al*., 2014). DEA is a linear programming-based technique used to measure the performance efficiency of organizational units called Decision Making Units (DMUs). This technique measures how efficiently DMUs use available resources in producing a set of outputs (Charnes *et al*., 1978).

DEA gets its name from covering observations to set a cutoff value for evaluating investigations that represent the performance of all assets. It can be used to evaluate the performance not only of enterprises but also of public institutions and non-profit organizations such as schools, hospitals, and banks, and also of cities, regions, and countries in various fields (Cooper *et al*., 2006; Ulutaş, 2016; Depren, 2008). For this purpose, the definition of DMUs has been kept flexible to include any entity that uses similar inputs to produce similar outputs (Cooper *et al*., 2006).

1.2 Classic DEA models
1.2. Klasični DEA modeli

Charnes *et al*. (1978) designed a model 'that generalizes a single output rate efficiency measure for a single DMU in terms of a fractional linear programming formulation that converts multiple outputs into a single virtual output (Manzoni and Islam, 2012; Charnes *et al*., 1994). It is called the 'Charnes, Cooper and Rhodes (CCR) Model' in the literature. When this model is used to solve the problem for each DMU under investigation, it determines the best set of weights for each DMU (Pasupathy, 2002). Later, the model was developed by Banker *et al*. (1984) and the two models, BCC and CCR, have started to be used in the literature. Then, the DEA technique was used and improved by many people (Ulutaş, 2016; Depren, 2008; Charnes *et al*., 1978; Banker *et al*., 1984). While the CCR model used the assumption of constant returns to scale only in the measurement of technical efficiency, the BCC model developed the concept of efficient scale and rearranged the linear programming formula in the CCR model for the estimation of the return to scale (Depren, 2008; Besen, 1994).

DEA is used to determine the "most efficient" or effective decision-making units (DMUs) within a set of DMUs by using the least inputs to produce the most outputs. The accepted efficiency boundary is 1, and the efficiency levels of ineffective DMUs are measured using this boundary as a technical reference. DEA enables obtaining a single efficiency value for each DMU based on multiple input and output variables by using a linear programming model (Depren, 2008).

In a simple DEA model, the efficiency of a random DMU(i) can be defined as:

$$\textit{Effectiveness of DMU(i)} = \frac{\textit{Weighted sum of outputs for DMU(i)}}{\textit{Weighted sum of inputs for DMU(i)}}$$

The solution of the formula is iterated with linear programming for each DMU under a set of predefined constraints. One of the constraints is the weighting factor. When reaching the solution, the unit is not allowed to choose weights that would cause it to achieve an efficiency greater than 100 %. The weighted sum of the DMUs outputs must be less than or equal to the weighted sum of its inputs. In addition, the weighted sum of the inputs is assumed to be 1 to prevent limitless solutions (Manzoni and Islam, 2009). The principal aim of this equation is the assumption of obtaining the maximum output with the minimum input.

One of the points to be considered for DEA is the number of DMUs. The number of DMUs is crucial as it affects the decision-making ability of the model. For the optimal sample size, the number of DMUs should be greater than the sum of the inputs and outputs. In addition, the sample size is acceptable if the number of fully productive DMUs is not more than one-third of the total number of DMUs in the sample (Cooper *et al.*, 2006; Manzoni and Islam, 2009).

1.3 DEA models with undesirable outputs
1.3. DEA modeli s neželjenim izlazima

The DEA approach has a structure that aims to bring the DMU closer to the determined efficiency limit by reducing inputs or increasing outputs after an active limit value is determined in general. However, UO or inputs may also occur in this process (Zhou *et al.*, 2008). UO are the unexpected results of manufacturing processes aimed at maximizing outputs while minimizing inputs. For this reason, the perspective of DEA to approach the effective limit by increasing the output should be handled differently in terms of UO (Seiford and Zhu, 2002). Therefore, many different DEA models have been developed, including UO. Seiford and Zhu (2002) or Faere *et al.* (1989) can be shown as the most widely known and used DEA models. Whereas Seiford and Zhu's (2002) model focuses on data transformation, Faere *et al.* (1989) show an approach that ignores UO (Zhou *et al.*, 2008; Seiford and Zhu, 2002). Table 1 lists six specific models that are most frequently used and recommended in the literature.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

Sectoral data in the study were taken from SSI 2019 statistical annuals. First, the provinces where the furniture sector was intense were determined using these data. From the insurance and workplace statistics table in statistical annuals of SSI 2019, the data under the furniture manufacturing title with the code 31 in the NACE coding system have been compiled according to the provinces. In 2019, the number of workplaces with SSI registration in the furniture sector was 21.758, and the number of employees was 154.829. In the study, it was determined that approximately 92 % of the insured employees in the sector are concentrated in 30 provinces (Table 2). The number of enterprises in 30 cities constitutes about 88 % of the total number of enterprises (SSI, 2019). For this reason, the research was limited to 30 provinces, as the representativeness of the data is high.

Table 3 presents the number of WP, OHP in the provinces and the numbers of A, B and C class OHSS. These data were taken from the statistical table on the website of the Ministry of Labor and Social Security (MoLSS, 2021). The information on the Ministry webpage is irregular and does not include the distribution by year. That was assumed as a constraint of the research.

The data used in the study have been compiled from the tables in the SSI 2019 Occupational Accident and Occupational Disease Statistics. These data were the number of employees who have had WA and OD, the number of cases of WA and OD, Temporary Incapacity for Work Duration (TIWD), the number of right holders and the number of permanent incapacity income recipients. Table 4 shows the distribution of these data by province. These data include only data reported and officially registered cases. There was no information about the unreported and unregistered data. That is another limitation of the study.

In this study, the DEA Solver add-on included in the Excel program was used for the efficiency evaluation of the data compiled and tabulated for data envelopment analysis. DEA Solver is a very suitable program for the evaluation of data to a maximum of 30 DMUs and it does not need to be purchased separately as it is included in the Excel program. As a method in the analysis, six different model approaches shown in Table 1 were preferred.

Table 1 DEA models used with UO
Tablica 1. Primijenjeni DEA modeli s neželjenim izlazima

Item No	Method / *Metoda*	Source / *Izvor*
1	Ignoring undesirable factors / *ignoriranje nepoželjnih čimbenika*	Faere *et al.* (1989)
2	Treating unwanted outputs (inputs) as inputs (outputs) (U=-u) *tretiranje neželjenih izlaza (ulaza) kao ulaza (izlaza) (U=-u)*	Dyckhoff and Allen (2001)
3	Improvement of undesirable factors in nonlinear DEA model *poboljšanje nepoželjnih čimbenika u nelinearnom DEA modelu*	Faere *et al.* (1989)
4	Applying a nonlinear monotone decreasing transform (U=1/u) to undesirable factors *primjena nelinearne monotone padajuće transformacije (U=1/u) na nepoželjne čimbenike*	Dyckhoff and Allen (2001)
5	A linear monotone decreasing transform to deal with undesirable factors *linearna monotona padajuća transformacija za rješavanje nepoželjnih čimbenika*	Seiford and Zhu (2002)
6	Directional distance function approximation *aproksimacija funkcije usmjerene udaljenosti*	Hua and Bian (2007)

Table 2 Distribution by provinces with intense furniture industry, number of enterprises and employees by provinces
Tablica 2. Pregled pokrajina u kojima je industrija namještaja bila intenzivna te broj poduzeća i zaposlenika u njima

Item No	Provinces *Pokrajine*	Enterprise (General) *Poduzeća (općenito)*	Employee (General) *Zaposlenici (općenito)*	Enterprise (Furniture) *Poduzeća (namještaja)*	Employee (Furniture) *Zaposlenici (u proizvodnji namještaja)*
1	İstanbul	537,982	4,130,578	5,073	29,855
2	Bursa	78,554	682,103	2,388	25,918
3	Kayseri	32,423	220,267	1,206	23,511
4	Ankara	144,459	1,116,500	2,481	13,343
5	İzmir	131,243	889,856	1,668	10,867
6	Antalya	74,551	503,569	856	4,954
7	Kocaeli	46,580	500,326	360	2,981
8	Sakarya	23,059	179,564	314	2,472
9	Konya	46,424	306,968	455	2,336
10	Gaziantep	33,702	299,808	263	2,273
11	Adana	41,767	301,270	498	2,240
12	Samsun	26,118	166,688	426	1,981
13	Hatay	24,092	168,446	397	1,763
14	Düzce	8,127	70,727	126	1,578
15	Eskişehir	20,888	170,464	208	1,574
16	Mersin	37,791	248,307	374	1,546
17	Çanakkale	14,343	85,437	128	1,410
18	Manisa	27,748	238,198	185	1,333
19	Denizli	25,811	186,613	253	1,151
20	Sivas	10,015	72,591	133	1,102
21	Diyarbakır	17,017	151,506	118	1,087
22	Balıkesir	29,698	172,904	219	1,083
23	Ordu	13,494	83,907	182	1,077
24	Tekirdağ	24,019	268,967	126	1,073
25	Trabzon	19,753	116,044	227	1,061
26	Zonguldak	11,269	86,844	119	741
27	Kahramanmaraş	16,281	144,710	118	673
28	Aydın	27,380	149,941	145	612
29	Malatya	12,695	99,419	115	552
30	Muğla	36,301	182,747	170	523
Subtotal		1,593,584	11,995,269	19,331	142,670
Sum Total		1,891,512	14,314,313	21,758	154,829

Table 3 Distribution of workplace physicians, other healthcare personnel, occupational physicians and occupational safety centers and OHSSs by provinces
Tablica 3. Raspodjela liječnika medicine rada i drugoga medicinskog osoblja, liječnika medicine rada i centara za zaštitu na radu te OHSS-ova prema pokrajinama

Item No	Provinces / *Pokrajine*	WP	OHP	WPOSC	OHSS (A)	OHSS (B)	OHSS (C)
1	İstanbul	7,108	3,808	414	3,112	5,854	7,996
2	Bursa	1,290	659	85	688	846	1,739
3	Kayseri	430	203	29	221	278	629
4	Ankara	2,794	1,666	295	1,744	1,900	4,195
5	İzmir	2,138	1,304	164	1,146	1,319	2,743
6	Antalya	945	457	39	402	442	1,038
7	Kocaeli	766	873	53	483	1,017	1,785
8	Sakarya	350	208	34	148	249	437
9	Konya	722	354	38	285	400	816
10	Gaziantep	523	184	43	173	254	623
11	Adana	653	382	55	341	633	1,265
12	Samsun	398	312	16	183	232	600
13	Hatay	349	223	10	152	281	647
14	Düzce	142	70	5	50	83	143
15	Eskişehir	408	341	37	213	300	668
16	Mersin	513	303	28	202	391	926

Table 3 Continuation
Tablica 3. Nastavak

Item No	Provinces / *Pokrajine*	WP	OHP	WPOSC	OHSS (A)	OHSS (B)	OHSS (C)
17	Çanakkale	176	181	8	87	146	337
18	Manisa	354	322	18	185	258	628
19	Denizli	422	247	29	222	218	458
20	Sivas	177	129	8	78	140	284
21	Diyarbakır	443	217	39	108	265	595
22	Balıkesir	369	322	22	176	307	556
23	Ordu	134	130	9	56	90	272
24	Tekirdağ	426	264	10	253	364	608
25	Trabzon	274	224	26	129	209	513
26	Zonguldak	208	123	46	222	180	449
27	Kahramanmaraş	272	137	10	101	162	426
28	Aydın	364	218	31	171	189	395
29	Malatya	261	132	24	116	135	374
30	Muğla	388	250	14	182	214	425
TOTAL		28,822	17,267	1,639	13,289	20,453	40,092

*WP – Workplace physicians, OHP – Other health personnel, WPOSC – Workplace physician and occupational safety center
**WP – liječnici medicine rada, OHP – ostalo medicinsko osoblje, WPOSC – liječnici medicine rada i centri za zaštitu na radu*

Table 4 Distribution of data on work accidents and occupational diseases by provinces
Tablica 4. Pregled podataka o nezgodama na radu i profesionalnim bolestima prema pokrajinama

Item No	Provinces *Pokrajine*	Employee *Zaposlenici* (WA)*	Employee *Zaposlenici* (OD)*	Death *Smrt* (WA)	TIWD* (Total / *Ukupno*)	Number of right holders *Broj nositelja prava* (WA)	Number of permanent incapacity recipients *Broj osoba s trajnom nesposobnošću*
1	İstanbul	109,695	186	199	697,844	641	12,757
2	Bursa	23,075	29	48	227,941	175	3,715
3	Kayseri	10,274	9	25	87,551	83	1,850
4	Ankara	30,286	54	88	214,421	262	4,578
5	İzmir	34,618	115	55	338,322	213	5,026
6	Antalya	23,483	2	47	118,221	125	1,757
7	Kocaeli	25,944	133	41	292,383	176	3,570
8	Sakarya	7,555	30	6	64,564	50	1,087
9	Konya	7,413	6	36	72,975	162	1,662
10	Gaziantep	6,048	2	28	75,511	125	1,379
11	Adana	6,550	3	31	64,036	166	1,782
12	Samsun	3,082	0	5	25,265	67	1,490
13	Hatay	2,257	5	16	32,315	124	1,299
14	Düzce	2,567	11	4	28,355	34	467
15	Eskişehir	7,283	15	14	66,524	25	979
16	Mersin	4,073	0	31	49,179	111	1,316
17	Çanakkale	2,207	11	7	24,751	35	353
18	Manisa	14,128	25	13	153,599	59	1,393
19	Denizli	6,772	2	20	79,036	82	1,012
20	Sivas	1,606	2	12	11,853	41	580
21	Diyarbakır	1,880	0	20	18,201	180	1,022
22	Balıkesir	4,135	5	21	46,080	82	1,108
23	Ordu	1,401	0	7	10,810	68	1,075
24	Tekirdağ	12,188	19	14	128,777	86	1,324
25	Trabzon	1,640	1	15	16,047	63	663
26	Zonguldak	5,670	48	10	77,932	386	6,150
27	Kahramanmaraş	2,426	1	7	25,079	82	966
28	Aydın	4,500	4	18	50,040	67	1,005
29	Malatya	1,830	0	11	14,122	59	1,393
30	Muğla	7,322	6	23	55,606	35	616
TOTAL		371,908	724	872	3,167,340	3,864	63,374

*WA – Work accident, OD – Occupational diseases, TIWD – Temporary incapacity for work duration
**WA – nezgoda na radu, OD – profesionalne bolesti, TIWD – trajanje privremene nesposobnosti za rad*

Table 5 Models used in DEA analysis and their inputs and outputs
Tablica 5. Modeli primijenjeni u DEA analizi te ulazi i izlazi u tim modelima

Model No *Broj modela*	**Input** *Ulaz*	**Output** *Izlaz*	**Undesirable output** *Neželjeni izlaz*
Model 1	G1, G2	O1, O2, O3	Ignored / *zanemareno*
Model 2	G1, G2, U1, U2, U3, U4, U5, U6	O1, O2, O3	As an input / *kao ulaz*
Model 3	G1, G2	O1, O2, O3, U1, U2, U3, U4, U5, U6	As an improved output / *kao poboljšani izlaz*
Model 4	G1, G2	O1, O2, O3, U1, U2, U3, U4, U5, U6	As a transformed output (a nonlinear monotone decreasing) *kao transformirani izlaz (nelinearno monotono padanje)*
Model 5	G1, G2	O1, O2, O3, U1, U2, U3, U4, U5, U6	As a transformed output (a linear monotone decreasing) *kao transformirani izlaz (linearno monotono padanje)*
Model 6	G1, G2	O1, O2, O3, U1, U2, U3, U4, U5, U6	As a transformed output by (directional distance function approximation) *kao transformirani izlaz (aproksimacija funkcije usmjerene udaljenosti)*

The abbreviations in Table 5 can be listed as follows:

G1 (number of enterprises), G2 (number of employees insured), O1 (total number of WP and OHP), O2 (number of WPOSC), O3 (A, B, and C-class OHSSs), U1 (number of employees who experienced WA), U2 (number of employees who experienced OD), U3 (number of deaths resulting from WA and OD), U4 (total temporary incapacity for work duration), U5 (number of beneficiaries) and U6 (number of permanent incapacity income recipients).

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

Table 6 shows the distribution of the efficiency scores according to the provinces obtained as a result of DEA, in which UO are modeled with the six different models shown in Table 1.

First, the model of Faere *et al*. (1989) was used. In the model, UOs are ignored. In the classical DEA, the increase of the outcomes is assumed by keeping the inputs. As a result of the analysis, Aydın, Diyarbakır, Muğla and Zonguldak came to the fore as the most effective cities. Kayseri was the most ineffective province with an efficiency score of 0.1143. The average efficiency of the states is 0.6199.

In the second model, UOs were included in the analysis as inputs, as proposed by Dyckhoff and Allen (2001). In the DEA analysis, UOs were defined as inputs by inverting them according to the addition process (U=-u). As a result of the analysis, Aydın, Diyarbakır, Manisa, Muğla, Tekirdağ and Zonguldak were seen as the most effective provinces. With an efficiency score of 0.1443, Kayseri was again the most ineffective city. The average efficiency score is 0.6339.

Seiford and Zhu (2002) stated that including UO as input into DEA like in the second model does not reflect the actual production process. For this reason, in their research, they predicted that UO in Faere *et al*. (1989) nonlinear DEA model should be included in the analysis by improving them with data transformation. Therefore, in the third model, according to this approach, UOs were improved and included in DEA as output. According to the DEA result, Aydın, Diyarbakır, Kahramanmaraş, Malatya, Muğla and Zonguldak came to the fore as effective provinces. Kayseri was in the last place in the efficiency evaluation as the most ineffective city with an efficiency score of 0.1071. In this model, the average efficiency score is 0.69100.

In the fourth model, as suggested by Dyckhoff and Allen (2001), undesirable factors are transformed into desired outputs by applying a nonlinear monotonous decreasing conversion (U=1/u). Then, they are included in DEA as natural outputs. In Table 6, where the results of the analysis are shown, Aydın. Çanakkale, Diyarbakır, Kahramanmaraş, Malatya, Muğla, Tekirdağ and Zonguldak are seen as the most effective cities. With an efficiency score of 0.1443, Kayseri is in the last place as the most ineffective province. The average efficiency score was calculated as 0.7561.

A linear monotone decreasing transformed model was applied as the fifth model. This model is suggested by Seiford and Zhu (2002). The undesirable factors were improved and added in DEA with natural outputs. As seen in Table 6, Aydın, Çanakkale, Diyarbakır, Düzce, Eskişehir, Kahramanmaraş, Malatya, Muğla, Ordu, Sakarya, Samsun, Sivas, Trabzon and Zonguldak were the most efficient provinces. While the average efficiency score of the provinces was calculated as 0.7871, Kayseri was seen as the most inefficient city with an efficiency score of 0.1443.

According to Yang *et al*. (2008), UOs can be transformed into desired outcomes by curing them with the Shephard distance function. Hua and Bian (2007) stated in their study that undesired factors can be transformed into desired outputs by using the directional distance function and that DEA results can better

Table 6 Distribution of efficiency scores of six different models calculated with DEA by province
Tablica 6. Rezultati učinkovitosti šest različitih modela izračunanih uz pomoć DEA-e prema pokrajinama

Item No	**Province** *Pokrajina*	**Efficiency scores** / *Rezultati učinkovitosti*					
		Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
1	İstanbul	0.4569	0.4569	0.4799	0.4569	0.4569	0.4569
2	Bursa	0.1660	0.1660	0.1554	0.1660	0.1660	0.1660
3	Kayseri	0.1443	0.1443	0.1071	0.1443	0.1443	0.1447
4	Ankara	0.4685	0.4685	0.4875	0.4685	0.4685	0.5391
5	İzmir	0.4840	0.4846	0.4426	0.4840	0.4840	0.4878
6	Antalya	0.3405	0.3405	0.3566	0.4466	0.3483	0.3432
7	Kocaeli	0.8905	0.9034	0.9911	0.8905	0.8905	0.9030
8	Sakarya	0.3655	0.3687	0.4010	0.7491	1	0.2488
9	Konya	0.5228	0.5228	0.5411	0.5228	0.5228	0.1861
10	Gaziantep	0.5026	0.5026	0.5054	0.8097	0.5073	0.5026
11	Adana	0.7013	0.7013	0.7496	0.7316	0.8148	0.8365
12	Samsun	0.3895	0.3895	0.3926	0.6386	1	1
13	Hatay	0.4056	0.4057	0.4492	0.5077	0.5582	0.4766
14	Düzce	0.2636	0.2719	0.9648	0.8700	1	0.2643
15	Eskişehir	0.7346	0.7346	0.7302	0.9681	1	1
16	Mersin	0.6504	0.6504	0.7098	0.6782	0.8925	0.8797
17	Çanakkale	0.7793	0.7835	0.9560	1	1	1
18	Manisa	0.7056	1	0.7280	0.8148	0.7766	0.7056
19	Denizli	0.6313	0.6313	0.6367	0.7420	0.7216	0.6493
20	Sivas	0.5439	0.5439	0.9079	0.9311	1	0.6106
21	Diyarbakır	1	1	1	1	1	1
22	Balıkesir	0.8515	0.8519	0.7515	0.8549	0.9343	0.8762
23	Ordu	0.3862	0.3863	0.6442	0.9193	1	0.4213
24	Tekirdağ	0.9054	1	1	1	0.9275	0.9073
25	Trabzon	0.6692	0.6692	0.6416	0.8876	1	1
26	Zonguldak	1	1	1	1	1	1
27	Kahramanmaraş	0.6876	0.6876	1	1	1	0.9259
28	Aydın	1	1	1	1	1	1
29	Malatya	0.9510	0.9510	1	1	1	1
30	Muğla	1	1	1	1	1	1
Average scores *Srednje vrijednosti rezultata*		0.6199	0.6340	0.6910	0.7561	0.7871	0.6844

reflect the actual production process. This approach model of Hua and Bian (2007) was used as the sixth model. According to the DEA result in Table 6, Aydın, Çanakkale, Diyarbakır, Eskişehir, Malatya, Muğla, Samsun, Trabzon and Zonguldak were the most influential cities. Kayseri took the last place again as the most ineffective province with an efficiency score of 0.1447. The average efficiency score is 0.6844.

Coping with UO is very important in DEA. In this study, the data with UO were improved and transformed according to six different models in Table 1. Then, they were included in DEA and subjected to an efficacy evaluation. Table 6 shows that Model 2, Model 3 and Model 6 produce similar results in terms of DMUs. When Table 6, Table 2, Table 3 and Table 4 are evaluated together, it can be observed that optimal results in terms of efficiency are obtained with the Model 6. Hua and Bian (2007) state that in this model, since the direction vector is strongly affected by the weights determined by the users, optimum results for DMUs can be achieved more effectively.

According to the OHS Law, an OHSS must be assigned to every 1000 employees for the less hazardous class, every 500 employees for the dangerous group, and every 250 employees for the very precarious class. Likewise, there is a requirement to appoint a workplace physician for every 2000 employees in the less dangerous business class, every 1000 employees in the hazardous class, and every 750 employees in the very precarious enterprise. According to the current law, these numbers in the sector are sufficient.

The 30 provinces within the scope of the study are about 88 % of the total number of enterprises or employees in the furniture sector. Also, they cover approximately 84 % of the total number of enterprises or employees in Turkey (Table 2). Istanbul is the city with the highest number of enterprises and employees countrywide. One out of every 38 employees in Istanbul had a work accident. One out of every 20757 employees died in a work accident (Table 2 and 4). Besides, the number of employees per one WP or OHP in Istanbul is approximately 380. The number of enterprises per workplace physician and occupational safety center is 1300. The number of enterprises per OHSS is 32, and the number of employees is 244 (Table 2 and 3).

As a result of DEA, Aydın, Diyarbakır, Muğla, and Zonguldak emerge as the most effective provinces in all models. Zonguldak is a significant city in both the furniture and mining sector. One of every 16 employees in Zonguldak has a work accident. One of every 8685 employees died in a work accident (Table 2 and 4). The employees' number per WP or OHP in Zonguldak is about 263. The number of enterprises per workplace physician and occupational safety center is determined as 245 (Table 2 and 3).

The death rate due to work accidents or occupational diseases in Turkey is 8.01 per 100,000 employees. The average of 30 provinces is 7.27. In the European Union (EU), the average rate is 1.77. In Romania, where the highest number of deaths occurred, this rate is 4.33, or in Luxembourg 4.22. When examining the ratio of work accidents, while it is 2951 per 100,000 in Turkey, the EU average is 1650. This rate is around 3450 in France. The average of 30 provinces within the scope of the research is 3100 (Eurostat, 2021), (Table 2 and 4).

4 CONCLUSIONS
4. ZAKLJUČAK

Previous studies show that the work environments of enterprises in the furniture sector are not suitable enough in terms of OHS. For example, according to Koç *et al*. (1998), 59 % of the enterprises were not adequately ventilated. Likewise, Karademir and Koç (2020) found in their study that 30 % of the enterprises were completely without air, while 40 % were not properly ventilated. Although 20 years elapsed between the two studies, it seems that the work environments of the enterprises have not been brought to a good point in terms of OHS. At this point, it is known that the sector enterprises should be effectively supervised and kept under control, especially in terms of employees' safety and health.

In the study, according to Model 6, 9 of 30 provinces were found to be effective and 21 of them were found to be ineffective. The most ineffective is Kayseri with an efficiency value of 0.1447. At this point, Kayseri should reduce the number of its employees by 10 % compared to Diyarbakır, for example, and 14 % compared to Zonguldak. Likewise, it should increase the number of WPOSC by 40 % compared to Diyarbakır and by 52 % compared to Zonguldak.

OHSSs' field tours, risk analyses, environmental measurements, periodic inspections and workups, and feedback from employees are very important for accelerating the detection and improvement of malfunctions in the workplace (Ulutaş. 2016). Reports and records kept by the occupational physician, other health personnel, occupational physician and occupational safety centers and OHSSs increase the accuracy and reliability of statistical data on occupational accidents and diseases.

Although the number of OHSSs seems sufficient according to the current laws, the data in the field shows that these numbers are insufficient to prevent OADs. Despite being the most efficient province in all analyses, the number of employees per WP is high even in Zonguldak. Herein, according to the hazard classes, work accidents that have occurred from the past to the present should be examined. According to accident frequency, causes of accident and death statistics, a sectoral status evaluation should be made in the enterprises. Optimal numbers should be determined according to assessment, and workloads should be recalculated. The relevant articles of the OHS law should be updated.

Increasing numbers and reducing workloads will play a significant role in preventing occupational accidents and deaths. However, it is not enough by itself. At this point, training programs with the participation of all stakeholders such as business owners, white and blue-collar employees, WP, OHP and OHSSs should be planned and periodically implemented.

Up till today, full cooperation between industry and universities has not been established in practice. For having a good collaboration, a legal basis must be established between the parties, and this legal ground must be a forcing factor. Universities must be involved as a partner in projects preparation, training, auditing and consultancy services.

According to Lombardi *et al*. (2019), learning from accidents is one of the steps that can be taken to prevent possible future accidents. The most substantial step for the learning approach is to create a detailed accident database on a sectoral basis across the country. The variables of all work accidents that occur should be determined, and the variables interrelationships should be calculated. In this way, the most probable accident causality models for each accident should be revealed and the accident proximal and distant specific features should be defined. As a result, risk profiling for each accident will provide foremost and practical information for the safety precautions.

As to the European Agency for Occupational Safety and Health (OSHA), the key to sustainable economic recovery is the employees' well-being. Moreover, OSH is seen as a significant aspect of responsible and sustainable development of rapidly growing new technologies (nanotechnologies and green jobs). Therefore, there is a need to establish an OHS culture, namely a cultural evolution, to increase the value of occupational health among an extensive range of stakeholders, from decision-makers to OHS experts, employers, workers and their representatives, and ultimately the whole society (Gagliardi. 2012).

5 REFERENCES
5. LITERATURA

1. Akyüz, K. C.; Yıldırım, İ.; Tugay, T.; Akyüz, İ.; Gedik, T., 2012: Work accidents in forest products industry sector general overview of statistics. Journal of Forestry, 12 (2): 66-79.
2. Banker, R.; Charnes, A.; Cooper, W., 1984: Some models for estimating technical and scale inefficiencies in data envelopment analysis. Management Science, 30 (9): 1078-1092.
3. Besen, F., 1994: Performance management system and application of data envelopment analysis in health sector. Master's Thesis. İstanbul, Istanbul Technical University, Institute of Science and Technology, pp 117.
4. Bilim, N.; Bilim, A., 2015: Occupational health and safety outlook in Turkey. In: Proceedings of the 25th European Safety and Reliability Conference, ESREL 2015. Safety and Reliability of Complex Engineered Systems Proceeding Book, Zurich, Switzerland, CRC Press / Taylor & Francis Group eBooks, pp. 3201-3204, ISBN:9781138028791.
5. Charnes, A.; Cooper, W.; Lewin, A. Y.; Seiford, L. M., 1994: Data envelopment analysis: theory, methodology and application (1st ed.). Springer Science-Business Media, New York. https://doi.org/10.1007/978-94-011-0637-5
6. Charnes, A.; Cooper, W.; Rhodes, E., 1978: Measuring the efficiency of decision-making units. European Journal of Operations Research, 2 (6): 429-444. https://doi.org/10.1016/0377-2217(78)90138-8
7. Cooper, W. W.; Seiford, L. M.; Tone, K., 2006: Introduction to DEA and its uses with DEA-solver software and references. Springer, New York. https://doi.org/10.1007/0-387-29122-9
8. Depren, Ö., 2008: Data envelopment analysis and an application. Master's Thesis. İstanbul, YTU, Institute of Science and Technology, pp. 117.
9. Dyckhoff, H.; Allen, K., 2001: Measuring ecological efficiency with data envelopment analysis (DEA). European Journal of Operational Research, 132 (2): 312-325. https://doi.org/10.1016/S0377-2217(00)00154-5
10. Eurostat, 2021: Eurostat Statistic Explained, Accidents at work statistics (online). Luxembourg, European Statistical Office (Eurostat), General Directorate of European Commission. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Category:Accidents_at_work (Accessed May 14 2021).
11. Faere, R.; Grosskopf, S.; Lovell, C. A.; Pasurka, C., 1989: Multilateral productivity comparisons when some outputs are undesirable: a nonparametric approach. The Review of Economics and Statistics, 71 (1): 90-98. https://doi.org/10.2307/1928055
12. Farrell, M., 1957: The measurement of productive efficiency. Journal of the Royal Statistical Society, Series A, 120 (3): 253-290. https://doi.org/10.2307/2343100
13. Gagliardi, D.; Marinaccio, A.; Valenti, A.; Iavicoli, S., 2012: Occupational safety and health in Europe: lessons from the past, challenges and opportunities for the future. Industrial Health, 50 (1): 7-11. https://doi.org/10.2486/indhealth.MS1342
14. Gedik, T.; İlhan, A., 2014: A study on occupational health and safety in furniture manufacturers in Sakarya province. SDU Faculty of Forestry Journal, 15: 123-129.
15. Hua, Z.; Bian, Y., 2007: DEA with undesirable factors. In: Modelling data irregularities and structural complexities in data envelopment analysis. Springer Science-Business Media, New York, pp. 103-121. ISBN:978-0-387-71606-0
16. Karademir, D.; Koç, K. H., 2020: Evaluating the work environment in Turkish furniture industry from the point of occupational health and safety. Fresenius Environmental Bulletin, 29 (04-A): 2639-2645.
17. Koç, K. H.; Aksu, B.; Yıldırım, M., 1998: Suggestions on the course and prevention of work accidents and occupational diseases in the Turkey furniture industry. In: Proceedings of 6th Ergonomics Congress, Ankara, MPM Publication, 622: 417-430.
18. Kurttekin, A.; Taçgın, E., 2019: An evaluation on occupational accidents in health services and cutter-drilling instrument injury investigations. Journal of Performance and Quality in Health, 17 (2): 135-182.
19. Lombardi, M.; Fargnoli, M.; Parise, G., 2019: Risk profiling from the European statistics on accidents at work (ESAW) accidents′ databases: A case study in construction sites. International Journal of Environmental Research and Public Health, 16 (23): 4728. https://doi.org/10.3390/ijerph16234748
20. Magezi, H. E.; Okan, T., 2023: A gravity model analysis of forest products trade between Turkey and European Union countries. Drvna industrija, 74 (2): 233-241. https://doi.org/10.5552/drvind.2023.0057
21. Manzoni, A.; Islam, S., 2012: DEA – data envelopment analysis: models, methods and applications (chapter 4). In: Quantitative modelling in marketing and management (1st ed.). World Scientific Publishing, Singapore, pp. 79-89. https://doi.org/10.1142/8503
22. Manzoni, A.; Islam, S. M., 2009: Performance measurement in corporate governance (1st ed.). Physica-Verlag A Springer Company, Heidelberg. http://dx.doi.org/10.1007/978-3-7908-2170-3
23. Nissi, E.; Rapposelli, A., 2012: Analysing industrial accidents in European countries using data envelopment analysis. In: Social exclusion: short and long term causes and consequences (1st ed.). Physica – Verlag A Springer Company, Heidelberg, 93-101. https://doi.org/10.1007/978-3-7908-2772-9_5
24. Pasupathy, K. S., 2002: Modelling undesirable outputs in data envelopment analysis: various approaches. Master's Thesis, Virginia, State University, Industrial and Systems Engineering, Faculty of the Virginia Polytechnic Institute, pp. 119.
25. Safak, I.; Gül, A.; Akkaş, M.; Gediklili, M.; Kanat, Ş.; Portakal, S., 2014: Efficiency determination of the forest sub-districts by using fuzzy data envelopment analysis (case study: Denizli forest regional directorate). International Journal of Fuzzy Systems, 16 (3): 358-367.
26. Seiford, L. M.; Zhu, J., 2002: Modelling undesirable factors in efficiency evaluation. European Journal of Operational Research, 142 (1): 16-20. https://doi.org/10.1016/S0377-2217(01)00293-4
27. Serin, H.; Şahin, Y.; Durgun, M.; Şimşek, A., 2015: A research on work accidents at manufacturing sector with regard to physical environment conditions. SELTH 2015 – International Scientific Conference of the Romanian-German University of Sibiu, pp. 358-366.

28. Sevim Korkut, D.; Gedik, T., 2010: A research on occupational safety in forest products. African Journal of Business Management, 4 (7): 1423-1433.
29. Ulutaş, B., 2016: Assessing the cities in Turkey in terms of accidents at work and work-related health problems with data envelopment analysis. C.U. Journal of Economics and Administrative Sciences, 17 (2): 23-46.
30. Xu, Q.; Xu, K., 2021: Analysis of the characteristics of fatal accidents in the construction industry in China based on statistical data. International Journal of Environmental Research and Public Health, 18 (4): 2162. https://doi.org/10.3390/ijerph18042162
31. Yang, C. C.; Hsiao, C. K.; Yu, M. M., 2008: Technical efficiency and impact of environmental regulations in farrow-to-finish swine production in Taiwan. Agricultural Economics, 39 (1): 51-61. https://doi.org/10.1111/j.1574-0862.2008.00314.x
32. Zhou, P.; Ang, B. W.; Poh, K. L., 2008: A survey of data envelopment analysis in energy and environmental studies. European Journal of Operational Research, 189 (1): 1-18. https://doi.org/10.1016/j.ejor.2007.04.042
33. ***MoLSS, 2021: Occupational health and safety registration, tracking and monitoring program. Ankara, Ministry of Labour and Social Security (MoLSS) of Republic of Turkey, General Directorate of Occupational Health and Safety (online). https://isgkatip.ailevecalisma.gov.tr/Logout.aspx (Accessed Apr. 14, 2021).
34. ***SSI, 2019: Statistics annuals, Ankara, Social Security Institution (SSI) (online). http://www.sgk.gov.tr/wps/portal/sgk/tr/kurumsal/istatistik (Accessed Mar. 2, 2021).

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