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USING DEA AS THE BASIS FOR STRATEGY IN MAKING DECISIONS IN A COLLABORATIVE SITUATION

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Purpose: The aim of the article is the implementation of DEA in the building trade and the identification of effective and ineffective entities operating in this industry in the context for strategy of making decisions on cooperation.
Design/methodology/approach: The article presents the author's own research. The time horizon of the research is 2018 - 2022. Within this period, the following were specified: the period of boom and collapse in the building industry. Periods of boom and bust were determined on the basis of the indicator of the general economic climate in the construction industry. This indicator is calculated as the arithmetic average of simple indicators relating to the current and expected general economic situation of the company and takes values from -100 to 100. The research sample includes 25 organizations operating in the construction industry and the construction sector. These entities are listed on the Stock Exchange.
Findings: Identification of effective and ineffective entities operating in this industry can be a kind of signpost for orientation as to the strategy of making decisions on cooperation
Originality/value: In the Polish literature, there is a deficit of studies in the field of management and economics, the subjective scope of which is focused on construction companies. Most of the literature is focused on legal and technical issues. The management domain is relatively neglected.

Keywords: DEA, building industry, strategy.

Category of the paper: Research paper.

1. Introduction

The aim of the article is the implementation of DEA in the building trade and the identification of effective and ineffective entities operating in this industry in the context for strategy of making decisions on cooperation.

The choice of the organization of the construction industry was justified by the fact that according to Córdova and Alberto the construction industry is one of the main actors in the economy of developing countries. In those countries, a significant housing deficit is evidenced

and it is common that their countries create policies including direct budget appropriations or financing through financial institutions that tend to boost the construction industry, thus generating employment sources and an important movement of domestic raw materials (Còrdova, Alberto, 2018).

DEA calculates the efficiency of an organisation within a group relative to observed best practice within that group. The organisations can be whole agencies (for example, Departments of Health), separate entities within the agency (for example, hospitals) or disaggregated business units within the separate entities (for example, wards) (Steering Committee for the Review of Commonwealth/State Service Provision, 1997).

The DEA analysis in the construction industry has had many applications in different industrial sectors (Còrdova, Alberto, 2018). Specifically, in the construction sector, there are important contributions that have considered several variables for efficiency assessment and the creation of a business ranking.

Many studies have worked with data from the Asian region, where there is a close relationship between the domestic product and the growth of the construction sector (Chau et al., 2005; Chen, Tang, 2014; Dzeng, Wu, 2013; Devicenzi et al., 2015). Other important studies were developed in Italy, Greece, Portugal, and Jordan (Guerrini et al., 2013; Tsolas, 2011; Horta et al., 2010; El-Mashaleh et al., 2010).

Most aforementioned studies consider sales in their respective currency unit to be a production variable, and the work valued at money or number of employees according to the availability of information, equipment or technology, consumption of materials and certain intermediate resources are mainly considered to be factors or consumed resources. Some studies investigate in the following stage, the explanatory factors of the efficiency indices calculated, which are evaluated through correlations between the efficiency and technical and financial data. This is the case of (Moreno et al., 2014), who applied a three-stage model and established through a Tobit-type regression certain efficiency determinants; or the study of (De Araujo et al., 2012), who related the efficiency calculated with the volume of revenue. J. Lehtinen and T. Ahola noted that performance measures support the implementation of the organization's strategy (Lehtinen, Ahola, 2010).

In the Polish literature, there is a deficit of studies in the field of management and economics, the subjective scope of which is focused on construction companies.

2. Characteristics of empirical research

Empirical research was carried out in the period June 2022 - February 2023.

The aim of the research was to identify effective leadership from the perspective of external and internal clients in favorable and unfavorable conditions.

The aim of the research is to use DEA in the building industry and to identify effective and ineffective entities operating in this industry.

The time horizon of the research is 2018-2022. Within this period, the following were specified: the period of boom and collapse in the building industry. Periods of boom and bust were determined on the basis of the indicator of the general economic climate in the construction industry.

This indicator is calculated as the arithmetic average of simple indicators relating to the current and expected general economic situation of the company and takes values from -100 to 100. Simple indicators for most questions included in the surveys are calculated as the difference between the percentage of weighted positive and negative answers. A neutral answer is skipped (Bankier pl, 2023).

The indicator of the general economic climate in the construction industry in 2018-2022 is presented in Figure 1.

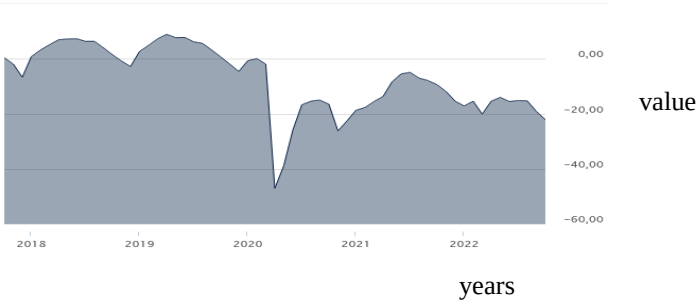

Figure 1. The indicator of the general economic climate in the building trade in 2018-2022.
Source: Bankier pl, 2023.

On the basis of Figure 1, it can be seen that the indicator of the general business climate is characterized by very large undulations in a relatively short period of time. The boom period in the construction industry is in the years 2018-2019. The downturn in this industry is in the years 2020-2022.

The research sample includes 25 organizations operating in the construction industry and the construction sector. These entities are listed on the Stock Exchange.

The characteristic of organizations is presented in Table 1.

Table 1.
The characteristics of organizations

Item	THE CHARACTERISTICS OF ORGANIZATIONS				
	year 2018 (pln thousand)	year 2019 (pln thousand)	year 2020 (pln thousand)	year 2021 (pln thousand)	year 2022 (pln thousand)
I.BUDIMEX S.A.:					
1. Sales revenue	7.387.137	7.569.663	8.382.240	7.911.192	8.619.054
2. Cost of manufacture of products sold	6.758.048	7.018. 111	7.445.207	7.077.395	7.746.611
3. Sales costs	30.650	30.478	31.273	11.733	13.530
4. Management cost general	229.593	198.992	276.966	269.011	317.153

Cont. table 1.

5. Other operating income	111.988	99.453	138.737	85.043	65.235
6. Other operating expenses	63.824	103.141	128.959	51.011	44.568
7. Financial income	28.291	60.127	34.708	13.583	131.961
8. Financial costs	40.118	50.949	51.385	46.239	45.589
9. Other income (costs)	-1.795	4.785	145	67	135
10. Net profit (loss) from discontinued activity	0	0	0	520.508	0
II.CNT S.A.:					
1. Sales revenue	1.393.910	1.108.463	324.915	386.669	797.124
2. Cost of manufacture of products sold	1.327.041	1.062.944	269.272	328.268	746.899
3. Sales costs	1.623	1.498	1.890	1.567	1.739
4. Management cost general	7.947	9.003	6.661	6.358	10.467
5. Other operating income	766	7.709	5.974	519	4.125
6. Other operating expenses	6.820	2.624	396	478	515
7. Financial income	786	862	413	67	6.010
8. Financial costs	24	39	180	108	132
9. Other income (costs)	0	0	0	0	0

Note: Technical manufacturing cost = direct materials + direct labor + variable departmental costs + fixed departmental costs**: (**Zielke, 2023).

Discontinued activity - Part of the company's activity, which in a given financial period was resold, successively liquidated or abandoned - most often due to one of the following reasons: the market for this type of activity was insufficient or uncertain, the share of the activity in the total profit of the enterprise turned out to be unsatisfactory (or - even worse - it brought losses), the activity was not in line with the strategic direction chosen by the enterprise, it was possible to sell it at a profit. Since the end-of-period balance sheet reflects the situation after disposal, the accounting for a discontinued operation is concentrated in the income statement, which shows the results achieved up to the point of disposal. In addition, all material details relating to the discontinuation of operations must be included in the notes to the financial statements. Accounting standards make a distinction between an "activity" (defined as a set of assets that have common physical, operational and reportable characteristics) and individual assets that do not require extensive disclosure (so gains or losses on the sale of individual assets may be just included in the item "other operating income": Monitor FX: https://monitorfx.pl/dzialalnosc-zaniechana/, 30.04.2023.

Source: Own study based on Biznesradar.pl

Due to editorial requirements related to the number of pages of the article, table 1 presents the characteristics of selected organizations. Detailed information can be found on the website: Biznesradar.pl.

3. The Results of Empirical Research

Using empirical amounts of outlays and effects, we search for weights that maximize efficiency for a given object, economic entity, organization (usually called a decision-making unit and usually abbreviated as DMU) scales that maximize efficiency.

As a result, it is about determining the effectivity of decision-making units in relation to their entire group. This is a new approach to evaluate the effectivity (Kozuń-Cieślak, 2011).

The definition of DMU is flexible and general. Decision-making units are understood as e.g. enterprises, public institutions, schools, libraries, hospitals, bank branches, non-profit organizations or construction organizations (Ćwiąkała-Małys, Nowak, 2009).

The measurement of effectivity in the years 2018-2022 according to the DEA method is shown in Tables 2, 3, 4, 5, 6.

Table 2.
The effectivity measure according to the method DEA in 2018

Item (DMU)	THE EFFEECTIVITY MEASURE ACCORDING TO THE METHOD DEA IN 2018			
	outlays (x)	Effects (y)	the efficiency index (y/x)	The relative effectivity index
1.Budimex S.A	7.124.028	7.527.416	1, 056	1,056/1,130 = 0,934 (93,4%)
2.CNT S.A.	1.343.455	1.395.462	1,038	0,918 (91,8%)
3.Dekpol S.A.	819.091	864.308	1,055	0,933 (93,3%)
4.Elektrotim S.A.	321.758	319.151	0,991	0,876 (87,6%)
5. Energoaparatura	43.474	45.291	1,041	0,921 (92,1%)
6. Erbur S.A.	2.362.562	2.340.945	0,990	0,876 (87,6%)
7.Herkules S.A.	138.815	147.742	1,064	0,941 (94,1%)
8.Instal Kraków S.A.	457.956	498.230	1,087	0,961 (96,1%)
9.MDI ENERGIA S.A.	134.451	138.264	1,028	0,909 (90,9%)
10.Mostostal Płock S.A.	107.194	101.973	0,951	0,841 (84,1%)
11.Mostostal Warszawa S.A.	1.066.483	1.029.736	0,965	0,853 (85,3%)
12.Mostostal Zabrze S.A.	614.262	629.826	1,025	0,907 (90,7%)
13.Mirbud S.A.	1.157.636	1.191.047	1,028	0,909 (90,9%)
14.Panova S.A.	170.844	193.130	1,130	1,00 (100,0%)
15.PGE S.A.	1.380.821	1.346.164	0,974	0,861 (86,1%)
16.Polimax-Mostostal S.A.	1.690.512	1.705.748	1,009	0,892 (89,2%)
17. PJP MAKRUM S.A.	254.704	269.648	1,058	0,936 (93,6%)
18.Prochem S.A.	158.369	160.568	1,013	0,896 (89,6%)
19.Tesgaz S.A	75.240	78.326	1,041	0,921 (92,1%)
20.Resbud S.A.	4.175	4.558	1,091	0,965 (96,5%)
21.Torpol S.A.	1.479.678	1.507.805	1,019	0,901 (90,1%)
22.Trakcja S.A.	1.726.077	1.598.673	0,926	0,819 (81,9%)
23.Unibep S.A.	1.632.078	1.669.447	1,022	0,904 (90,4%)
24.Zue S.A.	913.356	836.052	0,915	0,809 (80,9%)
25. Vistal Gdynia S.A.	135.227	85.476	0,632	0,559 (55,9%)

Source: Own study based on Biznesradar.pl.

Table 3.
The effectivity measure according to the method DEA in 2019

Item (DMU)	THE EFFEECTIVITY MEASURE ACCORDING TO THE METHOD DEA IN 2019			
	outlays (x)	Effects (y)	the efficiency index (y/x)	The relative effectivity index
1.Budimex S.A	7.401.671	7.734.028	1,044	1,044/3,191 = 0,327 (32,7%)
2.CNT S.A.	1.076.108	1.117.034	1,038	0,325 (32,5%)
3.Dekpol S.A.	747.297	810.025	1,083	0,339 (33,9%)
4.Elektrotim S.A.	280.289	262.217	0,935	0,293 (29,3%)
5. Energoaparatura	43.375	44.817	1,033	0,323 (32,3%)
6. Erbur S.A.	2.285.842	2.334.728	1,021	0,319 (31,9%)
7.Herkules S.A.	167.956	128.398	0,744	0,233 (23,3%)
8.Instal Kraków S.A.	414.375	447.923	1,080	0,338 (33,8%)
9.MDI ENERGIA S.A.	176.899	181.268	1,024	0,320 (32,0%)
10.Mostostal Płock S.A.	110.239	115.058	1,043	0,326 (32,6%)

Cont. table 3.

11.Mostostal Warszawa S.A.	1.304.245	1.312.301	1,006	0,315 (31,5%)
12.Mostostal Zabrze S.A.	598.203	614.557	1,027	0,321 (32,1%)
13.Mirbud S.A.	943.297	980.292	1,039	0,325 (32,5%)
14.Panova S.A.	258.111	306.396	1,187	0,371 (37,1%)
15.PGE S.A.	1.899.132	-2.974.200	-1,566	-0,490 (-49,0%)
16.Polimax-Mostostal S.A.	1.610.430	1.664.191	1,033	0,323 (32,3%)
17. PJP MAKRUM S.A.	266.164	2.536	0,009	0,002 (0,2%)
18.Prochem S.A.	320.735	330.436	1,030	0,322 (32,2%)
19.Tesgaz S.A	124.107	1.285.77	1,036	0,324 (32,4%)
20.Resbud S.A.	882	1.030	1,167	0,365 (36,5%)
21.Torpol S.A.	1.570.621	1.606.975	1,023	0,320 (32,0%)
22.Trakcja S.A.	1.758.084	1.444.715	0,821	0,257(25,7%)
23.Unibep S.A.	1.626.956	1.665.785	1,023	0,320 (32,0%)
24.Zue S.A.	992.627	999.380	1,006	0,315 (31,5%)
25. Vistal Gdynia S.A.	116.068	370.385	3,191	1 (100%)

Source: Own study based on Biznesradar.pl.

Table 4.

The effectivity measure according to the method DEA in 2020

Item (DMU)	**THE EFFEECTIVITY MEASURE ACCORDING TO THE METHOD DEA IN 2020**			
	outlays (x)	**Effects (y)**	**the efficiency index (y/x)**	**The relative effectivity index**
1.Budimex S.A	7.933.790	8.555.830	1,078	1,078/1,190 = 0,905 (90,5%)
2.CNT S.A.	278.399	331.302	1,190	1,0 (100,0%)
3.Dekpol S.A.	1.010.123	1.077.196	1,066	0,895 (89,5%)
4.Elektrotim S.A.	266.869	288.417	1,080	0,907 (90,7%)
5. Energoaparatura	30.089	28.130	0,934	0,784 (78,4%)
6. Erbur S.A.	2.182.988	2.247.241	1,029	0,864 (86,4%)
7.Herkules S.A.	154.428	160.110	1,036	0,941 (94,1%)
8.Instal Kraków S.A.	396.969	428.453	1,079	0,906 (90,6%)
9.MDI ENERGIA S.A.	256.065	262.247	1,024	0,860 (86,0%)
10.Mostostal Płock S.A.	91.874	97.621	1,062	0,892 (89,2%)
11.Mostostal Warszawa S.A.	1.367.627	1.379.620	1,008	0,847 (84,7%)
12.Mostostal Zabrze S.A.	606.866	623.617	1,027	0,863 (86,3%)
13.Mirbud S.A.	1.218.623	1.288.896	1,057	0,888 (88,8%)
14.Panova S.A.	145.412	165.232	1,136	0,954 (95,4%)
15.PGE S.A.	469129	-141.602	-0,301	-0,252 (-25,2%)
16.Polimex-Mostostal S.A.	1.565.774	1.644.755	1,050	0,882 (88,2%)
17. PJP MAKRUM S.A.	323.396	343.633	1,062	0,892 (89,2%)
18.Prochem S.A.	340.878	358.796	1,052	0,884 (88,4%)
19.Tesgaz S.A	96.813	103.801	1,072	0,900 (90,0%)
20.Resbud S.A.	1.624	23	0,014	0,011 (1,1%)
21.Torpol S.A.	1.337.822	1.396.647	1,043	0,876 (87,6%)
22.Trakcja S.A.	1.431.837	1.311.979	0,916	0,769 (76,9%)
23.Unibep S.A.	1.644.306	1.698.909	1,033	0,868 (86,8%)
24.Zue S.A.	897.354	907.365	1,011	0,849 (84,9%)
25. Vistal Gdynia S.A.	139.923	118.589	0,847	0,711 (71,1%)

Source: Own study based on Biznesradar.pl.

Table 5.
The effectivity measure according to the method DEA in 2021

Item (DMU)	THE EFFEECTIVITY MEASURE ACCORDING TO THE METHOD DEA IN 2021			
	outlays (x)	Effects (y)	the efficiency index (y/x)	The relative effectivity index
1.Budimex S.A	7.455.389	8.530.393	1,144	1,144/1,159 = 0,987 (98,7%)
2.CNT S.A.	336.779	387.255	1,149	0,991 (99,1%)
3.Dekpol S.A.	1.198.982	1.288.620	1,074	0,926 (92,6%)
4.Elektrotim S.A.	271.758	279.368	1,028	0,886 (88,6%)
5. Energoaparatura	524.68	55.335	1,054	0,909 (90,9%)
6. Erbur S.A.	3.024.566	3.109.961	1,028	0,886 (88,6%)
7.Herkules S.A.	168.653	170.575	1,011	0,872 (87,2%)
8.Instal Kraków S.A.	354.770	390.105	1,099	0,948 (94,8%)
9.MDI ENERGIA S.A.	253.353	253.377	1,000	0,862 (86,2%)
10.Mostostal Płock S.A.	157.583	178.866	1,135	0,979 (97,9%)
11.Mostostal Warszawa S.A.	1.279.641	1.315.059	1,027	0,886 (88,6%)
12.Mostostal Zabrze S.A.	755.301	778.361	1,030	0,888 (88,8%)
13.Mirbud S.A.	2.385.374	2.541.431	1,065	0,918 (91,8%)
14.Panova S.A.	175.823	203.822	1,159	1,000 (100,0%)
15.PGE S.A.	41.349	-150.845	-3,648	-3,147 (-314,7%)
16.Polimex-Mostostal S.A.	2.226.614	2.334.052	1,048	0,904 (90,4%)
17. PJP MAKRUM S.A.	312.619	316.165	1,011	0,872 (87,2%)
18.Prochem S.A.	230.174	257.378	1,118	0,964 (96,4%)
19.Tesgaz S.A	109.317	116.324	1,064	0,918 (91,8%)
20.Resbud S.A.	291.717	288.263	0,988	0,852 (85,2%)
21.Torpol S.A.	1.027.633	1.128.886	1,098	0,947 (94,7%)
22.Trakcja S.A.	1.468.765	1.467.140	0,998	0,861 (86,1%)
23.Unibep S.A.	1.683.226	1.747.506	1,038	0,895 (89,5%)
24.Zue S.A.	844.277	859.641	1,018	0,878 (87,8%)
25. Vistal Gdynia S.A.	79.574	62.333	0,783	0,675 (67,5%)
25. Vistal Gdynia S.A.	79.574	62.333	0,783	0,675 (67,5%)

Source: Own study based on Biznesradar.pl.

Table 6.
The effectivity measure according to the method DEA in 2022

Item (DMU)	THE EFFEECTIVITY MEASURE ACCORDING TO THE METHOD DEA IN 2022			
	outlays (x)	Effects (y)	the efficiency index (y/x)	The relative effectivity index
1.Budimex S.A	8.167.451	8.816.385	1,079	1,079/1,262 = 0, 854 (85,4%)
2.CNT S.A.	759.752	807.259	1,062	0,841 (84,1%)
3.Dekpol S.A.	1.322.174	1.420.061	1,074	0,851 (85,1%)
4.Elektrotim S.A.	478.037	508.451	1,063	0,842 (84,2%)
5. Energoaparatura	45.867	48.450	1,056	0,836 (83,6%)
6. Erbur S.A.	3.872.497	3.870.881	0,999	0,791 (79,1%)
7.Herkules S.A.	206.964	183.605	0,887	0,702 (70,2%)
8.Instal Kraków S.A.	375.086	413.845	1,103	0,874 (87,4%)
9.MDI ENERGIA S.A.	210.991	199.978	0,947	0,750 (75,0%)
10.Mostostal Płock S.A.	154.169	157.899	1,024	0,811 (81,1%)
11.Mostostal Warszawa S.A.	1.623.232	1.650.565	1,016	0,805 (80,5%)
12.Mostostal Zabrze S.A.	1.128.654	1.184.273	1,049	0,831 (83,1%)

Cont. table 6.

13.Mirbud S.A.	3.200.642	3.351.803	1,047	0,829 (82,9%)
14.Panova S.A.	182.759	210.544	1,152	0,912 (91,2%)
15.PGE S.A.	41.316	-265.083	-6,415	-5,083 (-508,3%)
16.Polimex-Mostostal S.A.	3.642.874	3.808.693	1,045	0,828 (82,8%)
17. PJP MAKRUM S.A.	504.008	540.193	1,071	0,848 (84,8%)
18.Prochem S.A.	241.650	236.722	0,979	0,775 (77,5%)
19.Tesgaz S.A.	127.075	130.276	1,025	0,812 (81,2%)
20.Resbud S.A.	1.350.283	1.394.673	1,032	0,817 (81,7%)
21.Torpol S.A.	881870	1113372	1,262	1,000 (100,0%)
22.Trakcja S.A.	1.444.344	1.770.776	1,226	0,971 (97,1%)
23.Unibep S.A.	2.237.109	2.279.012	1,018	0,806 (80,6%)
24.Zue S.A.	916.834	938.941	1,024	0,811 (81,1%)
25. Vistal Gdynia S.A.	551.086	76.105	0,138	0,109 (10,9%)

Source: Own study based on Biznesradar.pl.

From the information in Tables 2, 3, 4, 5, 6 you can see that the first column contains the name of the decision unit (DMU). The following columns, on the other hand, contain data on outlays and efects. The fourth column presents the calculation of the efficiency index for individual decision-making units (DMU). The relative effectivity index is presented in the fifth column.

The relative effectivity indicator was calculated as the quotient of the effectiveness of a given decision-making unit and the highest effectiveness achieved by the surveyed organizations. In this way, the share of the effectivity of a given organization in the effectivity of the best possible among the surveyed entities was determined. This share is presented as a percentage.

In such a case, the relative effectiveness indicator for an effective organization, the best in the studied group (the so-called benchmark, pattern) is respectively 100% or simply equal to one, that is:

- year 2018: Panova S.A. = 1.0 (100%),
- year 2019: Vistal Gdynia S.A. = 1.0 (100%),
- year 2020: CNT S.A. = 1.0 (100%),
- year 2021: Panova S.A. = 1.0 (100%),
- year 2022: Torpol S.A. = 1.0 (100%).

For ineffective units it is the reference limit against which theirs leaders can search for directions of changes in order to end up on the border of effectiveness, i.e. to become an effective unit.

4. Discussion

The article reviews the literature on the use of DEA in the literature. Then, the results of empirical research are presented. Empirical research results focus on the use of DEA in the building industry. Based on the conducted empirical research, effective organizations (Panova S.A., Vistal Gdynia S.A., CNT S.A., Torpol S.A.) and ineffective ones (Budimex S.A., Dekpol S.A., Elektrotim S.A., Energoaparatura, Erbur S.A., Herkules S.A., Instal Kraków S.A., MDI ENERGIA S.A., Mostostal Płock S.A., Mostostal Warszawa S.A., Mostostal Zabrze S.A., Mirbud S.A., PGE SA, Polimex-Mostostal S.A., PJP MAKRUM S.A., Prochem S.A., Tesgaz S.A., Resbud S.A., Trakcja S.A., Unibep S.A., Zue S.A.) was recognized. For ineffective leaders it is a reference limit against which they can seek directions of change in order to find themselves an effective unit.

The presented results of empirical research may constitute a kind of signpost to orientate in the direction of identifying the best partner or partners and developing adequate cooperation strategies, single-source sourcing, multi-source sourcing, dual-source sourcing and others in a collaborative stuation (Bozarth, Hanfield, 2007). The need to develop such strategies results not only from the basics of management, but also from the characteristics of the construction process, such as the presence of many participants (direct, indirect).

5. Summary

Over the last few decades, there has been an increase in interest in the DEA method on the world. The article begins with a literature review and shows that there is a deficit of studies focusing on construction companies in the Polish management and economics literature.

Then, the author's own research was presented. The purpose of the research was described and the scope of the research was characterized (subjective, objective, temporal). However, the DEA methodics and research conclusions, discussion were presented. It was emphasized that presented results of empirical research may constitute a kind of signpost to orientate in the direction of identifying the best partner or partners and developing adequate strategies.

In this way, the purpose of the article, which was the implementation of DEA in the building trade and the identification of effective and ineffective entities operating in this industry in the context for strategy of making decisions on cooperation, was achieved.

On the other hand, science is never a completed process. Excellent proposals usually appear long after less perfect proposals, which also contribute to the enrichment of science. Therefore, further research by the author in this domain of interest could be aimed at implementing other methods (e.g. AHP methods, statistical parametric methods).

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