# An Analysis of Selected Benchmarks and Evaluation Methods to Test the Replacebility of Mathematical-Statistical Methods in Benchmarking by Solvency and Bankruptcy Models: A Case Study in Assessing Gravel-Sand Mining Companies in the Czech Republic

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## Abstract

*Benchmarking is a useful managerial tool to identify opportunities in order to improve the efficiency and effectiveness of a company via the application of benchmarks to assess and compare the company efficiency with the leader in the field or other selected companies. For this reason, it is vital to conveniently select the different benchmarks and adequate methods for the evaluation. Having benchmarked five selected mining companies exploiting gravel-sand in the Czech Republic, CEMEX Sand, k.s., Českomoravský štěrk, a. s., LB MINERALS, s.r.o., CEMEX Cement, s.r.o., and ZEPIKO, spol. s r.o., the article aims to consider mutual replacebility of mathematical-statistical methods used for evaluation in benchmarking. Next, it verifies the agreement in results rendered by the solvency and bankruptcy models and those rendered by mathematical-statistical methods. We used eleven benchmarks (EBITDA, ROA, ROS, WACC, Quick ratio, Total assets turnover, Net working capital turnover ratio, Interest coverage, Altman's model, Index IN05, and Taffler's model), and seven evaluation methods. The research study shows that the majority of the examined benchmarking methods may be mutually replaced. Based on the results, we determined two groups of methods, out of which one method may be chosen and mutually combined with a method from the other group, and vice versa. The first group contains the Rank ordering weighting method, Point allocation method, Standardised variable method, Method of the distance from a fictitious object, Weighted sum method and TOPSIS method. The second group contains Weighted average method. The research also proves that selected benchmarks, such as Altman's model and Taffler's model, may be used on their own.*

*Keywords: benchmarking, mathematical-statistical methods, solvency and bankruptcy models, mining companies*

**Introduction**

One of the key challenges company management must face is the attainment and maintenance of the competitive advantage. Considering the variety of businesses and managers' creativity, there are an endless number of ways how to fulfil the challenge, and this usually constitutes a chain of decisions taken by managers. The quality of the decisions is conditioned, inter alia, by the quantity and quality of information that managers have available during the decision-making process.

Managers or decision makers may apply benchmarking to gain the crucial knowledge. Benchmarking has its roots in the 1970s in the company XEROX (Camp, 1995). In the 21st century, according to Stapenhurst (2009), organisations benchmark because of performance improvement, budgeting, testing ideas, technical problem solving and resolving disputes. The popularity of benchmarking in business and the industry may be explained by its usefulness as well as by the fact that comparison especially with others and with the best is natural to people. By analogy, we may approach comparison from the point of view of company management.

Moreover, benchmarking may contribute to the company's goodwill and its positive image on its surroundings, including the environmental impacts. The environmental aspects may be the benchmarks (e.g. the budget for environmental improvements, both absolute and relative). The fact that a company is the economic leader is not only a reflection of its commercial fitness, but also of its abilities to minimize the consumption of energies, materials, and production of waste during the production processes. If other companies aim to improve their results in the complex evaluation and approximate the leader, they cannot overlook positive attitudes to environmental aspects.

Company management is responsible for the decisions and choices. Apart from benchmarking, company managers may rely on other methods to help them decide. Still, the decisions

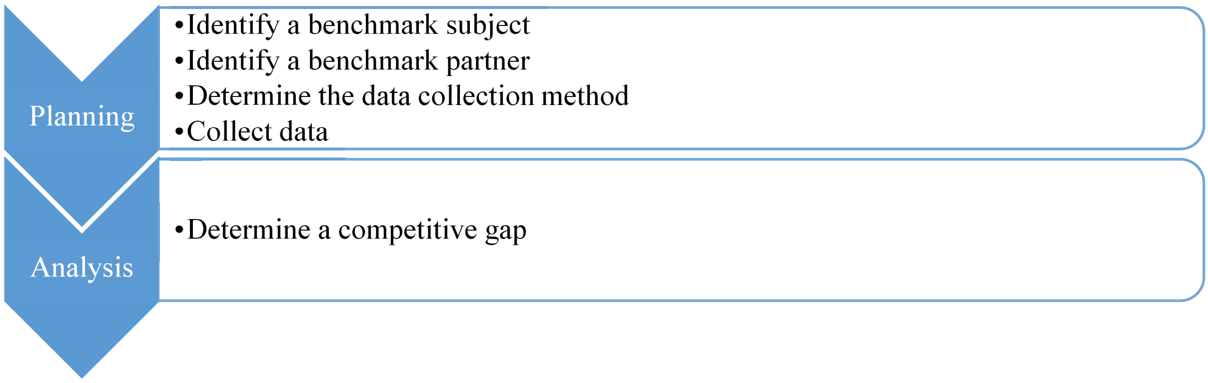


Fig. 1. Modified benchmarking process (modified according Camp, 1995)
Rys. 1. Zmodyfikowany proces benchmarkingu (zmodyfikowany według Camp, 1995)

Tab. 1. Brief characteristics of benchmarked mining companies. Source: Mining Yearbook, 2015 + company websites
Tab. 1. Krótka charakterystyka benchmarkingu spółek

| **Company name** | **Volume mined [m$^3$]** | **Brief characteristics** |
|---|---|---|
| CEMEX Sand, k.s. | 876 600 | The company was established under the name GZ - Sand, s.r.o. in 1993. The major business is extraction and processing of sand and gravel. In the Czech Republic the company offers high-quality sorted and unsorted stone and sand, both for customers and the needs of other members of CEMEX group. In the Czech Republic CEMEX Sand operates 11 gravel-pits and 7 stone quarries. |
| Českomoravský štěrk, a.s. | 954 539 | The company belongs to the multinational group Heidelberg Cement. The company belongs among the biggest producers of aggregate in the Czech Republic. They operate 14 stone quarries and 11 sand-pits. They sell a wide spectrum of fractions applicable in all branches of the building industry. |
| LB MINERALS, s.r.o. | 682 000 | The company is a member of the multinational concern LASSELSBERGER Group. The mines and processing plants are distributed around the Czech Republic, where gravel and sand are extracted as major or accompanying raw materials. |
| CEMEX Cement, s.r.o. | 361 671 | CEMEX Cement, k.s. has been a member of CEMEX group since 2015. The major business is the production of cement and special products to stabilise soils. |
| ZEPIKO, spol. s r.o. | 282 000 | The founding company of ZEPIKO GROUP is a purely Czech mining enterprise that started in Brno in 1992. The company deals with mining, mining of non-reserved minerals and waste management. They operate sandpits. Fro example, the sand-pit in Oblekovice u Znojma has reserves for next 20 years. |

should be made based on a number of criteria. Multicriteria decision making (MCDM) is also popular to screen, prioritise, rank or choose alternatives grounded in human judgment from a limited number of alternatives (Roszkowska, 2013), who dealt with MCDM and compared ranking methods of weight determination. Adding multicriteria decision making methods to benchmarking, managers have plentiful means to arrive at exact conclusions and may thus formulate measures for further development of their companies. However, we realise that benchmarking may be a challenge for many managers as the topic has been approached from many points of view and the efforts resulted in a number of publications.

Considering the high number of literature dealing with benchamarking, we may classify it into two groups. The first is constituted by books or textbooks, such as Camp, 1995; Rolstadas, 1995; Stapenhurst, 2009; Zairi, 2009, which acquaint readers with benchmarking, but naturally the books are characteristic of certain generalisation in the approaches. The second group comprises of benchmarking applications in specific disciplines and areas (Henriksson, 2017; Kołodziejczuk, 2016; Sweis, 2016; Talebi, 2014; Magd, 2011). Moreover, the study of multicriteria decision methods offers a wide range of specific methods that may be applied in benchmarking. Rozskowská (2013) refers to many such methods (ranking ordering method, DEA, AHP, DR, PA, LINPAC, SD, etc.) and authors in her comparative overview. It is clear that the stated methods vary in their intensity for data and processing. A question arises, though, whether simpler methods may render comparable results as many data-intense and time-consuming methods.

Tab. 2. Input data of the 5 selected mining companies – part I (calculated by authors based on company annual reports). Source: Calculated by authors based on company annual reports

Tab. 2. Dane wejściowe dla 5 spółek górniczych – część I (wyliczone przez Autorów na podstawie raportów rocznych)

| Year | Company | Benchmarks | | | | | |
|---|---|---|---|---|---|---|---|
| | | ROA | WACC | ROS | Quick ratio | Net working capital turnover ratio | Interest coverage |
| 2010 | **CEMEX Sand. k.s.** | 9.30% | 10.13% | 11.32% | 1.7327 | 3.7635 | 638.08 |
| | **Českomoravský štěrk. a.s.** | 8.79% | 8.69% | 10.34% | 3.5058 | 2.0945 | 198,771.00 |
| | **LB Minerals. s.r.o.** | 6.91% | 7.26% | 9.68% | 1.0518 | 13.4552 | 13.20 |
| | **CEMEX Cement. s.r.o.** | 8.33% | 11.00% | 7.60% | 0.2252 | -2.7560 | 4.932 |
| | **ZEPIKO. spol. s r.o.** | 5.69% | 7.60% | 7.40% | 0.6213 | -12.5636 | 31.69 |
| 2011 | **CEMEX Sand. k.s.** | 3.00% | 3.43% | 2.00% | 1.5808 | 4.3494 | 2.14 |
| | **Českomoravský štěrk. a.s.** | 5.88% | 6.52% | 6.49% | 1.6348 | 3.5514 | 118,132.00 |
| | **LB Minerals. s.r.o.** | 5.50% | 5.59% | 6.99% | 1.3402 | 7.5377 | 10.77 |
| | **CEMEX Cement. s.r.o.** | 7.63% | 6.68% | 7.44% | 1.5755 | -3.4261 | 4.76 |
| | **ZEPIKO. spol. s r.o.** | 5.18% | 6.96% | 6.62% | 0.7534 | -19.2722 | 49.52 |
| 2012 | **CEMEX Sand. k.s.** | 5.43% | 2.34% | 0.00% | 1.1225 | 7.7048 | 3.14 |
| | **Českomoravský štěrk. a.s.** | 3.58% | 3.65% | 3.87% | 1.5800 | 3.5976 | 171.42 |
| | **LB Minerals. s.r.o.** | 4.95% | 4.93% | 5.96% | 1.4464 | 6.3654 | 7.58 |
| | **CEMEX Cement. s.r.o.** | 5.78% | 5.41% | 5.10% | 1.1368 | 8.8981 | 2.38 |
| | **ZEPIKO. spol. s r.o.** | -11.41% | -19.69% | -14.75% | 1.0896 | 36.9906 | -58.39 |
| 2013 | **CEMEX Sand. k.s.** | 2.13% | 1.58% | 0.00% | 1.1310 | 6.1356 | 1.94 |
| | **Českomoravský štěrk. a.s.** | 3.76% | 4.02% | 5.06% | 2.0063 | 2.6230 | 819.94 |
| | **LB Minerals. s.r.o.** | 4.52% | 4.42% | 5.08% | 1.3980 | 5.9412 | 7.05 |
| | **CEMEX Cement. s.r.o.** | 0.89% | 1.19% | -2.92% | 0.2027 | -1.6283 | 0.33 |
| | **ZEPIKO. spol. s r.o.** | -4.15% | -9.98% | -5.35% | 0.7205 | -13.0973 | -15.81 |
| 2014 | **CEMEX Sand. k.s.** | 0.40% | 2.86% | 0.00% | 1.2193 | 5.8897 | 0.21 |
| | **Českomoravský štěrk. a.s.** | 6.34% | 6.91% | 7.58% | 2.1401 | 2.8471 | 125,759.00 |
| | **LB Minerals. s.r.o.** | 6.21% | 6.24% | 7.23% | 1.5313 | 5.7888 | 9.69 |
| | **CEMEX Cement. s.r.o.** | 6.55% | 5.61% | 4.52% | 0.9652 | 14.7030 | 2.67 |
| | **ZEPIKO. spol. s r.o.** | 5.74% | 14.22% | 6.47% | 0.7257 | -11.7739 | 27.71 |

Tab. 3. Input data of the 5 selected mining companies – part II (calculated by authors based on company annual reports). Source: Ccalculated by authors based on company annual reports

Tab. 2. Dane wejściowe dla 5 spółek górniczych – część II (wyliczone przez Autorów na podstawie raportów rocznych)

| Year | Company | Benchmarks | | | | |
|---|---|---|---|---|---|---|
| | | Total assets turnover | EBITDA | Altman's model | Index IN05 | Taffler's model |
| 2010 | CEMEX Sand. k.s. | 0.6571 | 79,598 | 1.2605 | 26.3770 | 0.4754 |
| | Českomoravský štěrk. a.s. | 0.6829 | 309,012 | 2.6742 | 7,952.3128 | 0.8542 |
| | LB Minerals. s.r.o. | 0.5301 | 381,561 | 1.4191 | 1.2393 | 0.3841 |
| | CEMEX Cement. s.r.o. | 0.6660 | 481,965 | 1.0559 | 0.8797 | 0.2974 |
| | ZEPIKO. spol. s r.o. | 0.6004 | 15,129 | 1.0951 | 1.8353 | 0.3516 |
| 2011 | CEMEX Sand. k.s. | 0.6849 | 45,183 | 1.1074 | 0.6781 | 0.2447 |
| | Českomoravský štěrk. a.s. | 0.7348 | 217,782 | 2.0233 | 4,726.2944 | 0.4946 |
| | LB Minerals. s.r.o. | 0.5727 | 316,486 | 1.5765 | 1.1251 | 0.3761 |
| | CEMEX Cement. s.r.o. | 0.6308 | 472,068 | 1.2293 | 0.8928 | 0.5282 |
| | ZEPIKO. spol. s r.o. | 0.6157 | 15,358 | 1.1370 | 2.5451 | 0.3231 |
| 2012 | CEMEX Sand. k.s. | 0.7054 | 65,594 | 1.1620 | 0.7702 | 0.2954 |
| | Českomoravský štěrk. a.s. | 0.6715 | 170,663 | 1.8573 | 7.7315 | 0.3942 |
| | LB Minerals. s.r.o. | 0.5733 | 288,103 | 1.4097 | 0.9601 | 0.3511 |
| | CEMEX Cement. s.r.o. | 0.5633 | 413,932 | 0.9228 | 0.6462 | 0.3507 |
| | ZEPIKO. spol. s r.o. | 0.6380 | -8,321 | 0.6094 | -2.2997 | -0.2298 |
| 2013 | CEMEX Sand. k.s. | 0.6792 | 48,310 | 1.0353 | 0.5860 | 0.2547 |
| | Českomoravský štěrk. a.s. | 0.6000 | 174,590 | 2.0340 | 33.7780 | 0.4362 |
| | LB Minerals. s.r.o. | 0.5822 | 290,647 | 1.4707 | 0.9425 | 0.3309 |
| | CEMEX Cement. s.r.o. | 0.5611 | 250,275 | 0.4995 | 0.3454 | 0.1860 |
| | ZEPIKO. spol. s r.o. | 0.6736 | 3,234 | 0.7470 | -0.3903 | 0.0493 |
| 2014 | CEMEX Sand. k.s. | 0.7744 | 48,310 | 1.0516 | 0.4642 | 0.2362 |
| | Českomoravský štěrk. a.s. | 0.6840 | 174,590 | 2.1384 | 7,952.3128 | 0.5472 |
| | LB Minerals. s.r.o. | 0.6123 | 290,647 | 1.5142 | 1.1319 | 0.4190 |
| | CEMEX Cement. s.r.o. | 0.6374 | 250,275 | 2.3317 | 1.1310 | 0.4083 |
| | ZEPIKO. spol. s r.o. | 0.6839 | 3,234 | 1.0424 | 1.6738 | 0.3087 |

Tab. 4. Benchmarking results of the examined companies between 2010 and 2014 using the benchmarking evaluation methods and selected benchmarks. Source: own

Tab. 4. Wyniki benchmarkingu badanych spółek w latach 2010-2014 z wykorzystaniem metod oceny i benchmarkingu

| **1.** | **Rank ordering weighting method** | **2010** | **2011** | **2012** | **2013** | **2014** | **Rank based on the sum of ranks throughout the period** | **Rank based on the coefficient of variation** |
|---|---|---|---|---|---|---|---|---|
| CEMEX Sand, k.s. | | 2 | 4 | 3 | 3 | 4 | 3 | 4 |
| Českomoravský štěrk, a.s. | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | | 3 | 3 | 2 | 2 | 2 | 2 | 3 |
| CEMEX Cement, s.r.o. | | 4 | 2 | 4 | 4 | 2 | 3 | 5 |
| ZEPIKO, spol. s r.o. | | 4 | 5 | 5 | 5 | 5 | 5 | 2 |
| **2.** | **Weighted average method** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | | 3 | 5 | 4 | 5 | 4 | 5 | 1 |
| Českomoravský štěrk, a.s. | | 2 | 2 | 3 | 3 | 1 | 1 | 3 |
| LB Minerals, s.r.o. | | 1 | 4 | 1 | 4 | 3 | 2 | 4 |
| CEMEX Cement, s.r.o. | | 4 | 3 | 2 | 2 | 2 | 2 | 2 |
| ZEPIKO, spol. s r.o. | | 5 | 1 | 5 | 1 | 5 | 4 | 5 |
| **3.** | **Point allocation method** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | | 3 | 4 | 4 | 4 | 4 | 4 | 2 |
| Českomoravský štěrk, a.s. | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | | 2 | 2 | 2 | 2 | 3 | 2 | 4 |
| CEMEX Cement, s.r.o. | | 4 | 3 | 3 | 5 | 2 | 3 | 5 |
| ZEPIKO, spol. s r.o. | | 5 | 5 | 5 | 3 | 5 | 5 | 3 |
| **4.** | **Standardised variable method** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | | 2 | 4 | 3 | 3 | 4 | 3 | 4 |
| Českomoravský štěrk, a.s. | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | | 3 | 3 | 2 | 2 | 3 | 2 | 3 |
| CEMEX Cement, s.r.o. | | 4 | 2 | 4 | 4 | 2 | 3 | 5 |
| ZEPIKO, spol. s r.o. | | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| **5.** | **Method of the distance from a fictitious object** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | | 2 | 4 | 3 | 3 | 4 | 3 | 4 |
| Českomoravský štěrk, a.s. | | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | | 3 | 3 | 2 | 2 | 3 | 2 | 3 |
| CEMEX Cement, s.r.o. | | 4 | 2 | 4 | 4 | 2 | 3 | 5 |
| ZEPIKO, spol. s r.o. | | 5 | 5 | 5 | 5 | 5 | 5 | 1 |

| 6. Weighted sum method | 2010 | 2011 | 2012 | 2013 | 2014 | | |
|---|---|---|---|---|---|---|---|
| CEMEX Sand, k.s. | 2 | 4 | 3 | 3 | 4 | 3 | 4 |
| Českomoravský štěrk, a.s. | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | 3 | 3 | 2 | 2 | 3 | 2 | 3 |
| CEMEX Cement, s.r.o. | 4 | 2 | 4 | 4 | 2 | 3 | 5 |
| ZEPIKO, spol. s r.o. | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| **7. TOPSIS method** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | 3 | 3 | 4 | 3 | 4 | 4 | 3 |
| Českomoravský štěrk, a.s. | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | 2 | 2 | 3 | 2 | 3 | 2 | 4 |
| CEMEX Cement, s.r.o. | 4 | 4 | 2 | 4 | 2 | 3 | 5 |
| ZEPIKO, spol. s r.o. | 5 | 5 | 5 | 5 | 5 | 5 | 1 |
| **Altman's model** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | 3 | 5 | 3 | 3 | 4 | 3 | 3 |
| Českomoravský štěrk, a.s. | 1 | 1 | 1 | 1 | 2 | 1 | 4 |
| LB Minerals, s.r.o. | 2 | 2 | 2 | 2 | 3 | 2 | 2 |
| CEMEX Cement, s.r.o. | 5 | 3 | 4 | 5 | 1 | 3 | 5 |
| ZEPIKO, spol. s r.o. | 4 | 4 | 5 | 4 | 5 | 5 | 1 |
| **Index IN05** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | 2 | 5 | 3 | 3 | 5 | 4 | 4 |
| Českomoravský štěrk, a.s. | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LB Minerals, s.r.o. | 4 | 3 | 2 | 2 | 3 | 2 | 3 |
| CEMEX Cement, s.r.o. | 5 | 4 | 4 | 4 | 4 | 5 | 2 |
| ZEPIKO, spol. s r.o. | 3 | 2 | 5 | 5 | 2 | 3 | 5 |
| **Taffler's model** | **2010** | **2011** | **2012** | **2013** | **2014** | | |
| CEMEX Sand, k.s. | 2 | 5 | 4 | 3 | 5 | 4 | 3 |
| Českomoravský štěrk, a.s. | 1 | 2 | 1 | 1 | 1 | 1 | 4 |
| LB Minerals, s.r.o. | 3 | 3 | 2 | 2 | 2 | 2 | 2 |
| CEMEX Cement, s.r.o. | 5 | 1 | 3 | 4 | 3 | 3 | 5 |
| ZEPIKO, spol. s r.o. | 4 | 4 | 5 | 5 | 4 | 5 | 1 |

Tab. 5. Comparison of results and statistical testing of the benchmarking evaluation methods based on Spearman's coefficient of rank correlation
Tab. 5. Porównanie wyników i testów statystycznych metod oceny benchmarkingowej w oparciu o współczynnik korelacji rang Spearmana

| **Method No.** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
|---|---|---|---|---|---|---|---|
| **1** | 0 | .7 (IND) 0 | .95 (PR) 1 | (PR) | 1 (PR) 1 | (PR) | 0.95 (PR) |
| **2** | | 0 | .85 (IND) 0 | .7 (IND) 0 | .7 (IND) 0 | .7 (IND) | 0.85 (IND) |
| **3** | | | 0 | .95 (PR) 0 | .95 (PR) 0 | .95 (PR) | 1 (PR) |
| **4** | | | | 1 | (PR) | 1 (PR) | 0.95 (PR) |
| **5** | | | | | 1 | (PR) | 0.95 (PR) |
| **6** | | | | | | | 0.95 (PR) |
| **7** | | | | | | | |

where IND – insignificant coefficient of rank correlation (independent results of benchmarkingmethods); NR – significant coefficient (negative ordinal r elation); PR – s ignificant c oefficient ( positive o rdinal r elation) R_(S,0.,95) (5)=0.9
Source: own

Tab. 5. Comparison of results and statistical testing of the benchmarking evaluation methods based on Spearman's coefficient of rank correlation

Tab. 5. Porównanie wyników i testów statystycznych metod oceny benchmarkingowej w oparciu o współczynnik korelacji rang Spearmana

| Method No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0 | .7 (IND) 0 | .95 (PR) 1 | (PR) | 1 (PR) 1 | (PR) | 0.95 (PR) |
| 2 | | 0 | .85 (IND) 0 | .7 (IND) 0 | .7 (IND) 0 | .7 (IND) | 0.85 (IND) |
| 3 | | | 0 | .95 (PR) 0 | .95 (PR) 0 | .95 (PR) | 1 (PR) |
| 4 | | | | 1 | (PR) | 1 (PR) | 0.95 (PR) |
| 5 | | | | | 1 | (PR) | 0.95 (PR) |
| 6 | | | | | | | 0.95 (PR) |
| 7 | | | | | | | |

where IND – insignificant coefficient of rank correlation (independent results of benchmarkingmethods); NR – significant coefficient (negative ordinal r elation); PR – s ignificant c oefficient ( positive o rdinal r elation) R_(S,0.,95) (5)=0.9
Source: own

To obtain reliable results, it is crucial to choose the benchmarking criteria conveniently along with the different evaluation methods. It is the financial health of a company and its status among the competition that are valuable pieces of information for managers. Financial indicators are popular benchmarks, which is also supported by a relatively good availability of primary data. Financial health of a company may also be evaluated by means of the so-called solvency and bankruptcy models. Altman and Eisenbeis (1978) established the final Z-score model which considered, inter alia, new standards of financial reporting. This final model is called Zeta analysis. Before 1980 Multiple Discriminant Analysis (MDA) prevailed in use in the majority of studies dealing with bankruptcy models of companies, and MDA has become a recognised standard method (Vochozka, 2010). In the Czech Republic, the most commonly applied methods are Altman's model, Taffler's index, Grünwald Solvency Model, etc. (Vochozka, 2010). Another question is whether solvency and bankruptcy models may fully substitute benchmarking carried out on the backgrounds of financial analysis indicators.

As the available literature does not provide satisfactory answers to the questions stated above, we claim that it is desirable to continue in the attempts to specify benchmarks and related evaluation methods. Our efforts aim to make the evaluation process easier for decision makers and accelerate the different phases of benchmarking evaluation. Referring back to the financial indicators, we may quote Benjamin Franklin and his famous quote that time is money.

In order to answer the questions above, we need to benchmark. As we specialise in economics in the mining industry, we selected mining companies for the benchmarking, namely five selected mining companies exploiting gravel-sand in the Czech Republic, CEMEX Sand, k.s., Českomoravský štěrk, a.s., LB MINERALS, s.r.o., CEMEX Cement, s.r.o., and ZEPIKO, spol. s r.o.

To direct the research, we formulated two hypotheses: H1- There are evaluation methods applied in benchmarking that are mutually replaceable. H2 - Some solvency and bankruptcy models render comparable results to the mathematical-statistical methods examined herein in benchmarking evaluation.

The research was carried out by means of a case study of five selected mining companies exploiting gravel-sand in the Czech Republic using mathematical-statistical methods and solvency and bankruptcy models for the evaluation. The major objective was to determine whether the different evaluation methods are mutually interchangeable and whether the selected methods and solvency and bankruptcy models render identical results and conclusions. Because of the high number of different approaches and methodologies applied, this may be useful for the managers in the roles of decision-makers to make the process simpler and more straightforward.

**Methods and materials**

Bechmarking is not a standardised method, which leads to a variety of definitions, concepts and methodological approaches (Nenadál, 2011). The starting point to answer the hypotheses was the benchmarking process comprising of five stages (planning, analysis, integration, action, and maturity) (Camp, 1995). The first two stages were key for the research and thus the benchmarking process was modified as below – see Figure 1.

We assumed that benchmarking of performance parameters (Nenadál, 2011) would be most suitable for the purpose as it focuses on the comparison of different performance parameters. We selected mining companies with volume mined of over 280,000 m3 of gravel-sand and sand for the benchmarking. Another criterion was the availability of accounting books during the period under observation. As the volumes mined vary in the different years, the reference year was the year 2015. The data on mining are available in the Mining Yearbook 2015 (Hornická ročenka, 2015). Table 1 displays the five mining companies that met the conditions stated above.

We compared the performance of the selected mining companies using benchmarks based on the financial analysis indicators and the so-called solvency and bankruptcy models. We used the following 11 benchmarks: (1) Earnings before Interest, Taxes, Depreciations and Amortization Charges – EBITDA; (2) Return on assets – ROA; (3) Return on sales – ROS; (4) Weight avarage cost of capital – WACC; (5) Quick ratio; (6) Total assets turnover; (7) Net working capital turnover ratio; (8) Interest coverage; (9) Altman's model (Paolone et al., 2015); (10) Index IN05; (11) Taffler's model (Bordeianu et al., 2011).

We realize that it is very difficult to determine the weights of the different benchmarks unambiguously. Therefore, we decided to attribute an identical weight to each used benchmark. The data for the analyses were obtained from the Annual Reports of the selected mining companies between 2010 and 2014 (the Annual Reports are publically available at www.justice.cz).

Tables 2 and 3 below provides the matrix of the input data for the benchmarking process.

***Evaluation methods of benchmarking***

Despite each benchmarking phase being important for its successful implementation, we may claim that the core of the benchmarking process lies in the analytical phase. This is because via the application of specific methods we obtain the final information not only on the ranking of the compared companies, but also on the differences among the companies in question.

According to Nenadál (2011), for the analysis to render relevant outputs, before own data processing it is vital to structure and classify the obtained data, to quantitatively verify the data, to clean the data from deformations, and finally to normalise the data (Nenadál, 2011).

The analytical phase is characteristic of many methods and tools applied (Nenadál, 2011), (Camp, 1995). With regard to the limits of an academic article, we tested the following five mathematical-statistical methods with the aim to determine whether they are interchangeable: (1) Rank ordering weighting method; (2) Weighted average method; (3) Point allocation method; (4) Standardised variable method; (5) Method of the distance from a fictitious object.

Apart from the mathematical-statistical methods, we also used two multi-criteria decision analysis methods: (1) Weighted sum method; (2) Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Kobryń, 2016).

A unifying feature of the first five methods above is the fact that the methods transform and synthesise various indicators into one, the so-called integration indicator. This subsequently expresses the level of the selected set of different companies in a complex manner (Sedláček, 2011; Triantaphyllou, 2000).

With regard to the application of various methods to benchmark companies, the methods may have different informative values when determining the final ranking order. At the same time, different methods work with different benchmarks. Some of these, the so-called "solvency and bankruptcy models" (Altman's model, Index IN05, Taffler's model) are more complex in their structure (they contain more indicators) than the remaining 9 benchmarks. There is a question whether Altman's model, Index IN05, or Taffler's model have an analogous informative value as the examined benchmarking evaluation methods. In case the different examined benchmarking methods have analogous informative capacities based on statistical testing, they may be mutually interchangeable. At the same time, if selected benchmarks (solvency and bankruptcy models) have a similar informative value as the examined benchmarking methods, the selected benchmarks may be applied as evaluation methods on their own.

The final evaluation of the selected mining companies is carried out using the ranking order method (1st rank – the best evaluated company, 5th rank – the worst evaluated company). As the majority of companies achieve different ranks in the course of the evaluated period, the final evaluation of the selected mining companies is made via adding the ranks during the period under observation and by means of ranking according to the coefficient of variation. The ranking indicator based on adding the ranks during the period under observation is arranged in the ascending order (the minimum sum represents the best value – 1st rank; the maximum sum represents the worst value – 5th rank). The indicator of the order according to the coefficient of variation is arranged in the same manner as mentioned previously.

To verify the hypotheses, it is advisable to examine the so-called level of rank correlation, for example, using the Spearman's coefficient of rank correlation coefficient defined as below (Sedláček, 2011; Wilcox et al., 1979):

$$R_s = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n \cdot \left(n^2 - 1\right)} \qquad (1)$$

where: $d_i$ is the difference obtained between the rank gained via the first method, and rank obtained via the second method out of the two methods; n is the extent of the selected set (number of benchmarked companies).

The coefficient gains the values from the interval <-1; +1> and the interpretation of results is the same as in case of the well-known Pearson's coefficients of pairwise correlation (Sedláček, 2011). The level of rank correlation (results) obtained using a benchmarking evaluation method and using selected benchmarks (solvency and bankruptcy models) must be statistically tested. The testing statistics to verify the order independencies of the ordinal quantities may be the above mentioned Spearman's coefficient of rank correlation RS (Budíková et al., 2010). The testing is carried out as below:

On the significance level α we test H0: The results of methods X and Y are order independent random quantities as opposed to:

- bilateral alternative HA: The results of methods X and Y are order-dependent random quantities. The critical region fro the bilateral alternative is $W=[-1\dashv, \vdash R_{S,1-\alpha/2}(n)] \cup [R_{S,1-\alpha/2}\dashv (n), \vdash 1]$,
- left-handed alternative HA: Between the results of methods X and Y there is an indirect order dependency. The critical region for the left-handed alternative is $W=[-1\dashv, \vdash R_{S,1-\alpha}(n)], \vdash 1]$ ,
- right-handed alternative HA: Between the results of methods X and Y there is a direct order dependency. The critical region for the right-handed alternative is $=[R_{S,1-\alpha}\dashv (n), \vdash 1]$ .
- $R_{S,1-\alpha/2}(n)$ or $R_{S,1-\alpha}(n)$ are critical values that we find in the statistical tables for α=0.05 or 0.01 and n≤30. The hypothesis on the order independency of the results of methods X and Y is thus rejected on the level of significance α, when $R_S \in W$(Budíková at al., 2010).

**Results and discussion**

The research results are summed up in Tables 4 – 6 that evaluate the different examined companies using the herein defined benchmarking evaluation methods and selected benchmarks (solvency and bankruptcy models) during the period under observation (2010-2014).

Using all the evaluation methods and selected benchmarks, the benchmarking results clearly imply that adding up the ranks for the given period the leader is Českomoravský štěrk, a.s., followed by LB Minerals, s.r.o. The third and forth came CEMEX Cement, s.r.o. and CEMEX Sand, k.s. The fifth was ZEPIKO, spol. s r.o. According to the indicator "Rank based on the sum of ranks throughout the period" we may find 2 groups of benchmarking evaluation methods and selected benchmarks that provide identical results. The first group of methods include Rank ordering weighting method, Standardised variable method, Method of the distance from a fictitious object, Weighted sum method and Altman's model. The second group contains Point allocation method, TOPSIS method and Taffler's model.

As for the "Rank based on the coefficient of variation" we may rank the companies based on the majority of evaluation methods and selected benchmarks as follows: Českomoravský štěrk, a.s., ZEPIKO, spol. s r.o., LB Minerals, s.r.o., CEMEX Sand, k.s. and CEMEX Cement, s.r.o. On the grounds of this indicator there is a group of benchmarking evaluation methods that render identical results. These are Standardised variable method, Method of the distance from a fictitious object, and Weighted sum method.

Nevertheless, the best method to determine the so-called level of rank correlation is Spearman's coefficient of rank correlation. This coefficient was calculated for n=5 observations (5 benchmarked companies). For pairwise correlation of all benchmarking evaluation methods (Table 5) the coefficient value did not fall below 0.7, which shows a high value of rank correlation. In the pairwise comparison of the methods with selected benchmarks (Table 6), the situation is different. When compared with all the benchmarking evaluation methods, Altman's model and Taffler's model reach high values of this coefficient (at least 0.7). When compared with all the benchmarking evaluation methods, Index IN05 reaches only mean values of the Spearman's coefficient of rank correlation (at least 0.45). In pairwise comparison we identified 2 groups of methods that render identical results. The first group includes 4 methods: Rank ordering weighting method, Standardised variable method, Method of the distance from a fictitious object, and Weighted sum method (Table 5). The second group comnprises Point allocation method, and TOPSIS method. In the case of pairwise comparison of selected benchmarks and evaluation methods, we found identical results in Altman's model and the first group of benchmarking evaluation methods as well as between the Taffler's model and the second group of benchmarking evaluation methods (Table 6). This way, both Altman's model and Taffler's model may be considered separate benchmarking evaluation methods.

Based on the carried out test of rank independence of ordinal quantities that was on the significance level $\alpha$=0.05 (being a common value in the economic and technical practice), we clearly proved a strong ordinal relation among the majority of the benchmarking evaluation methods (Table 4) as well as among the majority of the methods and majority of the selected benchmarks (Table 5).

Considering the obtained results of the first and last mining company, a possible conclusion may be that the company rank corresponds to its extraction volumes. The company Českomoravský štěrk, a. s. had the best results between 2010 and 2014, and it extracted the highest volumes of materials. The last company ZEPIKO, spol. s r.o., based on the benchmarking results, extracted the smallest volumes of gravel-sands among the benchmarked companies. However, this construct does not hold true for LB Minerals, s. r. o., who came second, but would be third as for the extraction volumes. The volumes of extracted materials are an important factor affecting the overall results, but effective and economical utilisation of input factors of production is undoubtedly decisive in success.

Going back to the hypotheses formulated at the beginning, let us first look at the mutual interchangeability of the benchmarking evaluation methods. Our research results prove that 6 out of 7 mathematical-statistical methods show a high level of agreement, which is represented by Spearman's coefficient of rank correlation (Rs □ 0.9). The only exception was the Weighted average method, in which Spearman's coefficient of rank correlation was 0.7.

As we benchmarked only five mining companies we may speak about a positive correlation only in case of a high coefficient value. In the case of a higher set of compared companies, the cricitical region of the tested criterion would expand. If we benchmarked X companies, the coefficient of 0.7 would be acceptable and we could speak of an agreement of the Weighted average method with the remaining tested mathematical-statistical methods used in benchmarking evaluation. The expansion of the set of the benchmarked companies is questionable, though, because of choosing suitable companies. On one hand, if we benchmark more companies, we may accept all the evaluation methods; on the other hand, it may not be sensible to include companies with low volumes of extraction and are thus incomparable as for the observed parameters.

The second hypothesis asked about the applicability of solvency and bankruptcy models. The results imply that 2 out of 3 models, namely Alman's model and Taffler's model, may be used for benchmarking evaluation. However, based on the statistical testing results herein, Index IN05 cannot be applied in benchmarking evaluation on its own. We may, therefore, claim that both the hypotheses were confirmed.

The next piece of knowledge arising from our research is the fact that by pairwise statistical comparison of results when studying the mathematical-statistical methods and solvency and bankruptcy models based on Spearman's coefficient of rank correlation (Table 4 and 5), there is no negative rank relation (NR). It means that it is possible to mutually combine the results of the mathematical-statistical methods and solvency and bankruptcy models.

All the tested models have different internal architectures, and thus we cannot herein identify the causes for the results. It is though clear that it is vital to test other solvency and bankruptcy models, such as Tamari's Index, Kralicek Quick Test, Grünwald Solvency Model, Solvency Index, etc. in the benchmarking evaluation.

**Conclusion**

The case study studied five selected mining companies exploiting gravel-sand in the Czech Republic using mathematical-statistical methods and solvency and bankruptcy models for the evaluation. It aimed to determine whether selected evaluation methods are mutually interchangeable. Next, it compared these method with solvency and bankruptcy models.

Within the case study we determined two groups of methods, out of which one method may be chosen and mutually combined with a method from the other group, and vice versa. The first group contains the Rank ordering weighting method, Point allocation method, Standardised variable method, Method of the distance from a fictitious object, Weighted sum method and TOPSIS method. The Weighted average method belongs to the second group. The research results also prove that selected benchmarks, Altman's model and Taffler's model, may be used on their own.

There are many different approaches and methodologies company managements may use, and thus the research results are useful for the managers in the roles of decision-makers to make the process simpler and more straightforward. Considering the number of available methods, we plan to continue in the comparison and research in mutual replaceability of benchmarking methods, different benchmarks and models.

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## *Analiza wybranych metod oceny w celu przetestowania zastępowalności metod matematyczno-statystycznych w benchmarkingu za pomocą modeli wypłacalności i upadłości: studium przypadku dla kopalń piasku i żwiru w Republice Czeskiej*

*Benchmarking jest użytecznym narzędziem do zarządzania, umożliwiającym identyfikację możliwości poprawy wydajności i skuteczności firmy poprzez zastosowanie testów porównawczych do oceny i porównania wydajności firmy z liderem w tej dziedzinie lub innymi wybranymi firmami. Z tego powodu konieczne jest wybranie punktów odniesienia i metod oceny. Przeprowadzono analizę porównawczą pięciu wybranych przedsiębiorstw wydobywczych eksploatujących złoża żwiru w Republice Czeskiej, CEMEX Sand, k.s., Českomoravský štěrk, a. s., LB MINERALS, s.r.o., CEMEX Cement, s.r.o. i ZEPIKO, spol. s r.o. Artykuł ma na celu przedstawienie zastępowalności metod matematyczno-statystycznych stosowanych w benchmarkingu. Zeryfikowano zgodność wyników dla modeli wypłacalności i upadłości oraz modeli matematyczno-statystycznych. Wykorzystano jedenaście benchmarków (EBITDA, ROA, ROS, WACC, Quick ratio, łączny obrót aktywów, wskaźnik rotacji kapitału obrotowego netto, pokrycie odsetek, model Altmana, indeks IN05 i model Tafflera) oraz siedem metod oceny. Badanie pokazuje, że większość badanych metod benchmarkingu może być wzajemnie zastępowana. Na podstawie wyników określono dwie grupy metod, z których jedna może zostać wybrana i połączona z metodą z drugiej grupy i odwrotnie. Pierwsza grupa zawiera metodę rankowania, metodę alokacji punktów, metodę zmiennej standardowej, metodę odległości od umownego obiektu, metodę sumy ważonej i metodę TOPSIS. Druga grupa zawiera metodę średniej ważonej. Badania dowodzą również, że wybrane testy porównawcze, takie jak model Altmana i model Tafflera, mogą być stosowane samodzielnie.*

*Słowa kluczowe: benchmarking, metody matematyczno-statystyczne, modele wypłacalności i upadłości, spółki górnicze*