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## APPLICATION OF DISCRIMINANT MODELS IN ASSESSING THE PROBABILITY OF BANKRUPTCY IN THE REAL ESTATE DEVELOPMENT INDUSTRY

**Abstract:** Bankruptcy prediction constitutes a key area of research in finance, particularly in the context of young, high-risk companies or entities that remain outside the stock exchange market. A crucial element, therefore, is the development of tools that can classify the analyzed enterprises as “healthy” entities — not at risk of bankruptcy, “distressed” entities — classified as potential bankrupts, and “infected” entities — those facing a significant threat of bankruptcy. Consequently, an essential criterion is the accurate assessment of a company’s ability to continue as a going concern. The identification of causes and symptoms associated with the threat to business continuity is carried out using a range of analytical tools.

An assessment of the current financial condition can be an effective evaluation tool used by a company’s stakeholders, including lenders, business partners, investors, and auditors. The methods and models of financial analysis are extensively discussed in both Polish and international literature. The purpose of this article is to present the possibilities of applying discriminant models for bankruptcy prediction, to assess the financial condition of enterprises based on ratio analysis, and, ultimately, to compare the obtained results using the example of the real estate development industry.

**Keywords:** bankruptcy, bankruptcy models, bankruptcy risk, corporate finance, discriminant analysis.

### 1. Introduction

Enterprises, in the course of their operations, encounter various crisis situations, some of which, if left unresolved, may threaten their ability to function and ultimately lead to the cessation of business activities. Practically all market stakeholders (owners, creditors, suppliers, customers, employees, competitors, the state, etc.) monitor not only the company’s past development and its position among competitors but also focus primarily on the future, namely its probable development over the next few years. Each of these groups (creditors, competitors, key suppliers, etc.) employs different tools and techniques, but their objective is similar: to predict the future performance of business entities. The question is whether the analyzed enterprise will, in the future, avoid generating losses or whether poor financial performance might result in the discontinuation of its operations. This leads to the fundamental question: Can the future of an enterprise — both in terms of potential bankruptcy (liquidation) and prospects for survival — be reliably predicted? If so, what is the measure of such reliability?

This issue has been the subject of research by economists worldwide. Economists strive to develop models capable of predicting the future development of enterprises with sufficient probability. Methods for assessing a company’s future condition can be divided into two groups:

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**1. Credit rating models:** Their purpose is to assign a company a score reflecting its credibility, essentially answering the question of whether the company is stable, has growth potential, and can be expected to continue developing. Examples include Tamari's model and the Kralicek quick test. These models classify enterprises into groups that define their projected condition.

**2. Bankruptcy (insolvency) models:** Unlike credit rating models, their goal is to forecast impending bankruptcy. These models take the form of equations based on financial ratios with assigned weights. The most well-known examples include the Altman Z-score (developed by Edward I. Altman in the USA, available in several versions).

Many economists believe that assessing a company solely on the basis of financial data (balance sheet, income statement, cash flow) is insufficient. Critics point out that key factors such as quality of management, relationships with suppliers, loyal customers, or skilled employees are not reflected in financial statements. However, even if such so-called "soft factors" are not directly measured, their effects can be observed in financial results (e.g., increased sales due to effective marketing or reduced costs through more efficient production). For this reason, financial statements remain a useful source of data for quickly assessing a company's situation.

Most companies are founded with the assumption of perpetual existence and stable profits. Yet, as in life, not everything goes according to plan — unforeseen events may lead to the loss of customers, a decline in revenues, and ultimately liquidation. Can such risks be detected in time and the company restored to prosperity? This is precisely the question that bankruptcy prediction models seek to answer, and the analysis and evaluation of their effectiveness is the aim of this study.

This article focuses exclusively on selected bankruptcy prediction models based on financial ratios, omitting those that take into account non-financial factors.

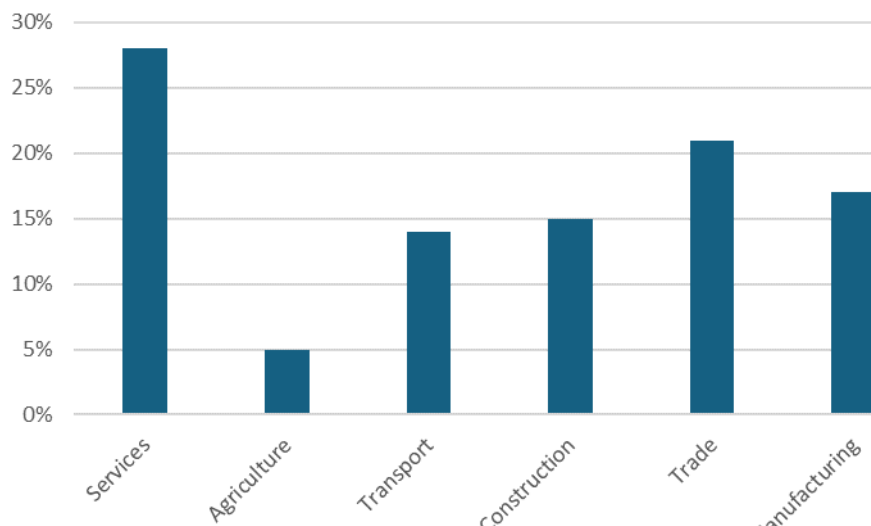
## **2. Current Bankruptcy Situation in Poland in the First Quarter of 2025**

In the first quarter of 2025, a significant increase in the number of corporate insolvencies was recorded in Poland, reaching 1,969 cases, which represents a 20% rise compared to the same period of the previous year. Data analysis revealed that 35% of all insolvencies reported in 2024 had already been registered within the first three months of 2025, indicating a persistently high growth rate of this phenomenon. In terms of industry structure, the highest increase was observed in the industrial sector, where the number of insolvencies rose by 32% year-on-year, with the metal processing, food production, and wood products industries being particularly affected.

The main factors contributing to the rise in insolvencies were cost pressures linked to high wages and energy prices, which in Poland are among the highest in the European Union, as well as a decline in corporate profitability, with the average level dropping to 3.4% in 2024. In addition, weakening external demand, caused by a recession in the German economy, and constraints on domestic consumption, despite the growth in real wages, contributed to the deterioration of the financial situation of many entities. Another significant factor influencing the statistics was legal changes, including simplified restructuring proceedings, which accounted for 95% of all procedures, marking a 21% increase compared to the previous year.

Forecasts for 2025 indicate a possible slowdown in the growth rate of insolvencies, driven by anticipated interest rate cuts and increased investment financed from EU funds such as the National Recovery Plan and the Cohesion Fund. Nevertheless, there are significant macroeconomic risks, including the introduction of new tariffs by the United States, which could negatively affect the global economic climate, as well as the appreciation of the Polish zloty, creating an additional burden for exporters.

In sectoral terms, the highest number of corporate insolvencies was recorded among service companies. The remaining industry structure is presented in Figure 1.



**Figure 1.** Share of Individual Industries in the Total Number of Insolvencies  
Source: Coface (2025), Corporate Insolvencies in Poland in the First Quarter of 2025

According to Statistics Poland (GUS), the construction market contracted by 7.7% in 2024. Consequently, the number of insolvencies in the sector rose by approximately 40% year-on-year, roughly twice as fast as the average for the economy. Across all construction segments, the main issue remains the same: low demand, which inevitably leads to increased competition under continued margin pressure, driven mainly by rising energy and labor costs. A moderately stabilizing factor was the relatively stable prices of construction materials, which on average decreased slightly by 1.7% year-on-year over the past year.

Coface research shows that in 2024 construction companies were forced to extend payment terms to their debtors by an average of four days, while at the same time shortening the period of overdue receivables by about one week. Debt levels recorded in the National Court Register (KRS) for entities in the sector have been increasing by over 10% annually for the past two years.

So far, in 2025, the situation in the sector remains difficult but stable. The market size after the first two months has not changed significantly (up by 0.4% year-on-year). The number of recorded insolvencies in the first quarter of the year continues to rise: 304 registered entities in 2025 compared to 245 cases in 2024. Notably, the negative trend has slowed—the increase in construction company insolvencies was comparable to the overall economy’s average. The majority of these cases continue to involve sole proprietorships (73% of cases this year).

In the coming months, a gradual market expansion is expected, not only due to the low base effect but also thanks to the inflow of funds, primarily from the National Recovery Plan (KPO). This ongoing process will, in the coming quarters, increase the volume of works related to the energy transition and infrastructure investments. For example, on March 30 this year, Polska Grupa Energetyczna signed two loan agreements with Bank Gospodarstwa Krajowego under the KPO, totaling over PLN 12 billion. These funds will be allocated to “increasing the capacity to integrate renewable energy sources and improving energy supply security through the construction and modernization of the power grid.”

### 3. General Form of the Model

Discriminant analysis is a statistical method that enables the division and classification of objects according to a specific criterion. This method allows for the classification of objects based on multiple explanatory variables simultaneously. The dependent variable is qualitative. To study the risk of corporate bankruptcy, a linear discriminant function is applied, expressed as follows:<sup>1</sup>

<sup>1</sup> **Melon P.** Predykcja upadłości przedsiębiorstw – przykład Monnari Trade S. A. *Ekonomia Międzynarodowa* 33 (January), 2022, pp. 45–54. <https://doi.org/10.18778/2082-4440.33.02>

$$Z = a_0 + a_1X_1 + a_2X_2 + \dots + a_kX_k$$

**where:**

$Z$  – dependent variable

$a_i$  – discriminant coefficient

$a_0$  – constant term

$X_i$  – explanatory variable

#### 4. Bankruptcy Prediction Models

The earliest studies on forecasting corporate bankruptcy using discriminant analysis include the work of E. Altman, published in 1968, in which he used five financial ratios to construct a model assessing the financial condition of 66 enterprises. The research on corporate bankruptcy initiated by E. Altman was subsequently continued and adapted to more local contexts. For the purposes of this article, the work of Polish researchers was applied, including that of D. Hadasik, A. Hołda, E. Mączyńska and M. Zawadzki, J. Gajdka and D. Stos, as well as D. Wierzba.

##### 4.1. Hadasik Model

D. Hadasik presented a discriminant analysis model for assessing bankruptcy risk. The research sample was dominated by state-owned enterprises, limited liability companies, independent entities, and joint-stock companies. As “bankrupt” enterprises, she classified those that filed for bankruptcy between 1991 and 1997. The formula presented below shows the D. Hadasik model most frequently used in analyses:<sup>2</sup>

$$Z_{HD} = 2,36261 + 0,365425W_A - 0,765526W_B - 2,40435W_C + 1,59079W_D + 0,00230258W_E - 0,0127826W_F$$

**where:**

$W_A$  – current assets / current liabilities

$W_B$  – (current assets – inventory) / current liabilities

$W_C$  – total liabilities / total assets

$W_D$  – (current assets – short-term liabilities) / total liabilities

$W_E$  – receivables / sales revenue

$W_F$  – inventory / sales revenue

##### 4.2. Hołda Model

Hołda’s study covered 40 enterprises in poor financial condition and 40 in good financial condition. This group was homogeneous and consisted of enterprises classified under numbers 45–74 in the European Classification of Economic Activities. A. Hołda’s research covered the years 1993–1996. Work on the final form of the model involved three stages, during which the number of 28 financial ratios initially considered by Hołda was reduced to 5. The final form of the discriminant function is given by the following formula:<sup>3</sup>

$$Z_H = 0,605 + 0,681W_A - 0,0196W_B + 0,157W_C + 0,00969W_D + 0,000672W_E$$

**where:**

$W_A$  – current assets / short-term liabilities

<sup>2</sup> Piróg A. Aplikacja modeli dyskryminacyjnych w ocenie kontynuacji działalności przedsiębiorstw. *Studia Ekonomiczne*, 284, 2016, pp. 187–199. [https://www.ue.katowice.pl/fileadmin/user\\_upload/wydawnictwo/SE\\_Artyku%C5%82y\\_271\\_290/SE\\_284/17.pdf](https://www.ue.katowice.pl/fileadmin/user_upload/wydawnictwo/SE_Artyku%C5%82y_271_290/SE_284/17.pdf)

<sup>3</sup> Antczak J. Application of discriminatory models in forecasting the liquidation of the enterprise. *Modern Management Systems*, 10(1), 2015, pp. 275–290. <https://doi.org/10.37055/nsz/129365>

$W_B$  – (total liabilities / total assets)  $\times$  100

$W_C$  – (net profit / average annual total assets)  $\times$  100

$W_D$  – (average annual short-term liabilities / cost of goods sold, products, and materials)  $\times$  365

$W_E$  – revenues from total activities / average annual total assets

#### 4.3. Mączyńska's Model

In 2006, Mączyńska together with Zawadzki published the results of their research. They developed seven early warning models and conducted their study on a sample of 80 companies listed on the Warsaw Stock Exchange, using financial statements from the years 1997–2001 and financial ratios calculated on their basis. In the initial research, they used 45 indicators describing profitability, liquidity, debt level, operational efficiency, and the growth dynamics of enterprises. The final version of the model is presented by the following formula:<sup>4</sup>

$$Z_M = 1,5W_A + 0,08W_B + 10,0W_C + 5,0W_D + 0,3W_E + 0,1W_F$$

where:

$W_A$  – (gross profit + depreciation) / liabilities

$W_B$  – total assets / liabilities

$W_C$  – profit before tax / total assets

$W_D$  – net profit / annual revenues

$W_E$  – inventories / annual revenues

$W_F$  – annual revenues / total assets

#### 4.4. Gajdka and Stos Model

This model was developed by its authors (similarly to the Mączyńska and Zawadzki model) for the purpose of assessing the financial condition of companies listed on the Warsaw Stock Exchange. The authors created the model based on a 34-company sample, of which 17 declared bankruptcy and 17 were classified as being in good financial condition. In the Gajdka and Stos model, the discriminant function takes the form described by the formula:<sup>5</sup>

$$Z_G = 0,7732059 - 0,0856425W_A + 0,0007747W_B + 0,9220985W_C + 0,6535995W_D - 0,594687W_E$$

where:

$W_A$  – sales revenue / total assets (average annual value),

$W_B$  – (current liabilities / cost of goods manufactured)  $\times$  365,

$W_C$  – net profit / total assets (average annual value),

$W_D$  – gross profit / net sales revenue,

$W_E$  – total liabilities / total assets (average annual value).

#### 4.5. Wierzba Model

This model was developed based on a 48-element sample of enterprises, of which 24 were classified as those in poor financial condition and 24 in good financial condition. For enterprises in poor financial condition, Wierzba used data from financial statements from the year preceding the year in which the company declared bankruptcy. He conducted his research in such a way that he matched pairs of enterprises in poor and good financial condition based on similarities.

<sup>4</sup> **Bombiak E.** Modele dyskryminacyjne jako metoda oceny sytuacji finansowej przedsiębiorstw. *Zeszyty Naukowe Uniwersytetu Przyrodniczo-Humanistycznego w Siedlcach. Seria Administracja i Zarządzanie*, Artykuł 13. 2010, pp. 141–152. <https://bazawiedzy.uws.edu.pl/info/article/UPH59ccefacd1834050918c4906b5b1bf60/>

<sup>5</sup> **Gajdka J., Stos D.** Wykorzystanie analizy dyskryminacyjnej w ocenie kondycji finansowej przedsiębiorstw, w: R. Borowiecki (red.) *Restrukturyzacja w procesie przekształceń i rozwoju przedsiębiorstw*, AE, Kraków. 1996, pp. 354 – 363.

In D. Wierzba's model, the discriminant function takes the form described by the formula:<sup>6</sup>

$$Z_W = 3,26W_A + 2,16W_B + 0,3W_C + 0,69W_D$$

where:

$W_A$  – (operating profit – depreciation) / total assets

$W_B$  – (operating profit – depreciation) / product sales

$W_C$  – current assets / total liabilities

$W_D$  – working capital / total assets

#### 4.6. Poznański Model

The Poznański model was developed by M. Hamrol, B. Czajka, and M. Piechocki based on a study of the financial statements of 100 Polish commercial law companies. The Poznański model is defined by the following formula:<sup>7</sup>

$$Z_P = 3,562W_A + 1,588W_B + 4,288W_C + 6,719W_D - 2,368$$

where:

$W_A$  – net profit / total assets

$W_B$  – current assets – inventories / short-term liabilities

$W_C$  – permanent capital / total assets

$W_D$  – operating profit on sales / sales revenue

Each presented model has its so-called cut-off point, on the basis of which a decision is made regarding the financial condition of the enterprise (Table 1).

**Table 1.** Cut-Off Points of Selected Discriminant Models

Highlight	Interpretation of the model
Hołda model	ZH < -0.3 – the company is at risk of bankruptcy -0.3 < ZH < 0.1 – the probability of bankruptcy is undefined ZH > 0.1 – good financial condition of the entity
Mączyńska model	ZM < 0 – the company is at risk of bankruptcy 0 < ZM < 1 – the company has a rather weak performance but is not at risk of bankruptcy 1 < ZM < 2 – the company is fairly good ZM > 2 – the company is very good
Wierzba model	ZW < 0 – difficult financial situation of the entity ZW > 0 – good financial situation of the entity
Hadasik model	ZHD < 0 – difficult financial situation of the entity ZHD > 0 – good financial situation of the entity
Poznański model	ZP < 0 – difficult financial situation of the entity ZP > 0 – good financial situation of the entity
Gajdka and Stos model	ZGS < 0.45 – enterprise at risk of bankruptcy ZGS > 0.45 – enterprise in good financial condition

Source: Own elaboration based on Pawłowski M. (2018). Discriminant Models in Assessing the Bankruptcy Risk of Corporate Bond Issuers. *Polityki Europejskie, Finanse i Marketing* 19 (68) 2018. <https://doi.org/10.22630/PE-FIM.2018.19.68.18>

<sup>6</sup> Gołębiowski G., Płasek A. Skuteczność wybranych modeli dyskryminacyjnych na przykładzie branży turystycznej. *Studia I Prace Kolegium Zarządzania I Finansów*, (164), 2019, pp. 9–24. <https://doi.org/10.33119/SIP.2018.164.1>

<sup>7</sup> Hamrol M., Czajka B., Piechocki M. Upadłość przedsiębiorstwa – model analizy dyskryminacyjnej. *Przegląd Organizacji*, vol. 6 (773). 2004, pp. 35 – 39. <https://doi.org/10.33141/po.2004.06.09>

## 5. Research Results and Discussion

The selection of the above-mentioned enterprises for the research sample was purposeful. These enterprises conduct business activity in one specific area. According to the data disclosed in the National Court Register (KRS), their main business activity is:

- 41.10.Z – execution of construction projects related to the erection of buildings.

Moreover, all enterprises have been conducting business activity continuously for at least 5 years, which also makes it possible to standardize the time frame of the study. The research covered the period from 2020 to 2024.

The following entities were included in the research sample:

- Semeko Grupa Inwestycyjna S.A., based in Gdańsk, KRS: 0000511385, date of registration: 28.05.2014

- Derby Investment sp. z o.o., based in Gdynia, KRS: 0000682465, date of registration: 12.06.2017

- Morska Vita S.A., based in Warsaw, KRS: 0000660604, date of registration: 26.01.2017

- Nowa Przyszłość sp. z o.o., based in Warsaw, KRS: 0000409297, date of registration: 25.07.2012.

The estimation of the discriminant function model is presented below.

**Table 2.** Estimation of the Discriminant Function Value for the Examined Entities in 2024

Specification	Nowa Przyszłość sp. z o.o.		Derby Investments sp. z o.o.*		Morska Vita S.A.		Semeko GI S.A.*	
	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment
M. Hadasik	23,14	Good	-	-	2,68	Good	-	-
M. Hołdy	447,88	Good	-	-	99,18	Good	-	-
M. Mączyńskiej	12,08	Good	-	-	-20,59	Bad	-	-
M. Gajdki	37,02	Good	-	-	2,60	Good	-	-
M. Wierzby	-12,40	Bad	-	-	2,50	Good	-	-
M. Poznański	2,05	Good	-	-	1,61	Good	-	-

\*The companies have not published financial statements for 2024.

Source: Own elaboration

**Table 3.** Estimation of the Discriminant Function Value for the Examined Entities in 2023

Specification	Nowa Przyszłość sp. z o.o.		Derby Investments sp. z o.o.		Morska Vita S.A.		Semeko GI S.A.	
	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment
M. Hadasik	43,27	Good	3,65	Good	2,07	Good	2,34	Good
M. Hołdy	244,72	Good	8,95	Good	322,14	Good	-0,41	Bad
M. Mączyńskiej	164,07	Good	0,82	Bad	-3 407,87	Bad	-7,76	Bad
M. Gajdki	40,30	Good	-0,18	Bad	-390,73	Bad	-1,25	Bad
M. Wierzby	-10,62	Bad	0,46	Good	-322,55	Bad	0,16	Good
M. Poznański	3,17	Good	5,98	Good	7,63	Good	-1,03	Bad

Source: Own elaboration

**Table 4.** Estimation of the Discriminant Function Value for the Examined Entities in 2022

Wyszczególnienie	Nowa Przyszłość sp. z o.o.		Derby Investments sp. z o.o.		Morska Vita S.A.		Semeko GI S.A.	
	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment
M. Hadasik	1,43	Good	1,23	Good	1,33	Good	3,34	Good
M. Hołdy	125,91	Good	14,64	Good	10,12	Good	6,66	Good
M. Mączyńskiej	8,80	Good	-0,44	Bad	-86,76	Bad	1,97	Good
M. Gajdki	10,80	Good	0,29	Bad	-43,62	Bad	-0,05	Bad
M. Wierzby	1,81	Good	-0,44	Bad	-42,46	Bad	0,56	Good
M. Poznański	6,96	Good	1,81	Good	-128,58	Bad	0,35	Good

Source: Own elaboration

**Table 5.** Estimation of the Discriminant Function Value for the Examined Entities in 2021

Wyszczególnienie	Nowa Przyszłość sp. z o.o.		Derby Investments sp. z o.o.		Morska Vita S.A.		Semeko GI S.A.	
	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment
M. Hadasik	6,46	Good	6,97	Good	1,31	Good	3,07	Good
M. Hołdy	152,01	Good	13,82	Good	696,63	Good	4,83	Good
M. Mączyńskiej	1,41	Good	3,55	Good	-253,89	Bad	1,09	Good
M. Gajdki	12,08	Good	-0,21	Bad	2,67	Good	-0,19	Bad
M. Wierzby	-2,20	Bad	0,00	Bad	-54,89	Bad	0,62	Good
M. Poznański	4,95	Good	6,50	Good	-16,65	Bad	0,55	Good

Source: Own elaboration

**Table 6.** Estimation of the Discriminant Function Value for the Examined Entities in 2020

Wyszczególnienie	Nowa Przyszłość sp. z o.o.		Derby Investments sp. z o.o.		Morska Vita S.A.		Semeko GI S.A.	
	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment	Estimated model value	Assessment
M. Hadasik	1,91	Good	6,97	Good	1,86	Good	3,53	Good
M. Hołdy	117,55	Good	13,82	Good	39,08	Good	5,46	Good
M. Mączyńskiej	6,45	Good	3,55	Good	-88,94	Bad	1,08	Good
M. Gajdki	9,25	Good	-0,21	Bad	-17,30	Bad	-0,21	Bad
M. Wierzby	0,19	Good	0,00	Bad	-2,46	Bad	0,51	Good
M. Poznański	3,44	Good	6,50	Good	-6,24	Bad	0,54	Good

Source: Own elaboration

## Conclusion

The article entitled “The Application of Discriminant Models in Assessing the Probability of Bankruptcy of Enterprises in the Development Industry” addresses an important research problem, namely the identification of bankruptcy risk in the real estate sector using statistical tools in the field of discriminant analysis. In view of the growing number of corporate insolvencies in Poland, particularly in the construction and development sectors, the author justifies the need for early detection of symptoms threatening the continuity of business operations. The study aims to provide an empirical assessment of the effectiveness of selected bankruptcy prediction models in the analysis of development companies operating on the Polish market.

The theoretical basis of the study consists of classical discriminant models used in the economic and financial literature, both international (e.g., the Altman model) and Polish (the models of Hadasik, Hołda, Mączyńska and Zawadzki, Gajdka and Stos, Wierzba, and the Poznań model). These models are based on the analysis of financial ratios such as liquidity, profitability, indebtedness, receivables turnover, and operational efficiency, which are aggregated into a single discriminant function enabling the classification of companies as healthy, at risk, or bankrupt.

In the empirical part of the study, the author applied six selected models to assess the financial condition of four development companies that had been operating for at least five years. For each analyzed year (2020 – 2024), the value of the discriminant function was calculated for each model, and the financial condition assessment was assigned according to the adopted classification thresholds. The results indicate significant discrepancies in the assessment of the financial situation of the same entities, depending on the model used. The Hadasik, Hołda, and Poznań models most often classified companies as “healthy,” while the Mączyńska, Gajdka and Stos, and Wierzba models were more restrictive, identifying a greater number of cases of companies in poor condition.

The analysis indicates that there is no single universal model that can unambiguously and effectively predict bankruptcy in the development sector, although each has its diagnostic value. Differences in assessment result both from the financial ratios applied and from the methodology used in the construction of the model. The author also emphasizes the importance of macroeconomic factors, such as rising energy costs, wages, and the decline in domestic and foreign demand, which in recent years have strongly influenced insolvency risk in the construction industry.

The key conclusion of the article is that discriminant models can serve as a useful tool to support bankruptcy risk assessment; however, their effectiveness depends on the proper selection of the model to the specifics of the industry and the market context. The author recommends using more than one model and supplementing quantitative analysis with qualitative assessment, taking into account factors that cannot be directly measured in financial statements but are important for a realistic evaluation of a company’s ability to continue operating.

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