

# Economic and mathematical modeling of industrial enterprise business model financial efficiency estimation

Mykola Havrylenko<sup>1</sup>, Vira Shiyko<sup>2</sup>, Liliana Horal<sup>2</sup>, Inesa Khvostina<sup>3,\*</sup>, and Natalia Yashcheritsyna<sup>3</sup>

<sup>1</sup>PJSC “Ukrtransnafta”, Kiyv, Ukraine

<sup>2</sup>Ivano-Frankivsk National Technical University of Oil and Gas, Department of Finance, Ivano-Frankivsk, Ukraine

<sup>3</sup>Ivano-Frankivsk National Technical University of Oil and Gas, Department of Economic, Ivano-Frankivsk, Ukraine

**Abstract.** The article proposes two methods for evaluating the financial efficiency of a business model of industrial enterprises. In order to evaluate the financial efficiency of the business model of an industrial enterprise, a system of single indicators for assessing the financial condition of the enterprise by such components as financial stability, liquidity and solvency, business activity and profitability was formed. Fishburne’s rule weights the major components of an integral measure of an enterprise’s business model financial performance. In addition, an integral measure of the financial performance of the business model is modeled using the fuzzy set method and taxonomic analysis, which will help to evaluate the financial performance level of the business model more objectively. The comparative analysis of the obtained results by different methods of calculation of integral indicators is carried out.

## 1 Introduction

An important issue in shaping the business model of an enterprise is the evaluation of its effectiveness, and especially of financial efficiency, which is a matter of principle for businesses focused on obtaining an economic effect.

Studying various scientific sources which cover problems of estimation of business models of enterprises [1, 2, 3, 4, 5] we have concluded that in modern works there are many approaches to formation of modern business models of enterprises, but we are offered two approaches for evaluating the financial performance of an industrial enterprise business model, according to which it is proposed to use an integral measure of the economic efficiency of an enterprise business model using the Harrington desirability function and the taxon method endemy, in addition to a comparative analysis of the results of calculations for integrated parameter with both methods.

## 2 Background

Kayaoglu Nuri in dissertation [1] proposed hierarchical business model evaluation approach, on the one hand, acts as a skeleton for the businesses by providing a structured way of thinking; it provides a strong foundation for abstract level analysis of relations, gains, and faults that form the core of the businesses. On the other hand, the contributed concepts, evaluation model approach, and the evaluation tool, give us enough confidence to place this work as a contribution under strategic management in the management context. Deviating from the commonly used

static methods, in this work, they propose a dynamic solution. The authors [2] elaborate a categorization of tools and methodologies concerning two major logics of evaluation: analytical/effectual and quantitative/qualitative. This sheds light upon the dominant mode of evaluation within different stages of digital BMI processes. A. Batocchio, A. Ghezzi and A. Rangone in their article [3] proposed method (roadmap for implementation of business models – RIBM) is composed of nine steps, and seven initial conditions (limitations). Such conditions reduce its complexity (e.g. performance management system is defined in the company). In the paper [4] author present the results of a review analysis on business model evaluation methods and their utility for entrepreneurs in developing and evaluating their business models. In addition, author indicate, there is a certain gap between the academic perspective to business models and the entrepreneur’s perspective, there being an ever-growing need for practical and operational instruments.

Although there has been an important amount of research on business models, defining the business model concept, taxonomy of business models, decomposing business models and identifying their components, ontology and design tools; the research on business model is still an area that has not been sufficiently investigated.

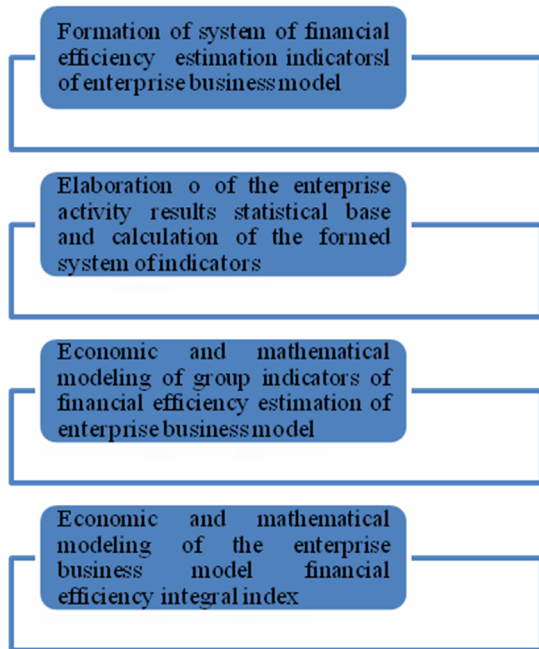
## 3 Methodology

The financial performance of an industrial enterprise is evaluated by a comprehensive system of indicators of financial stability, liquidity and solvency, business activity and profitability. All these indicators are well

\* Corresponding author: [inesa.hvostina@gmail.com](mailto:inesa.hvostina@gmail.com)

known. However, in order to determine the overall assessment of financial performance, we propose to form an integral indicator of evaluating the financial performance of an enterprise business model.

Thus, the process of evaluating the financial performance of a business model of an industrial enterprise (fig. 1.)



**Fig. 1.** The stages of economy and mathematical modelling of the enterprise business model financial efficiency integral index.

The financial performance of a business model of an industrial enterprise can be estimated on the basis of values of indicators values generalized groups:

$$I_f = f(Y_1; Y_2; Y_3; Y_4) \quad (1)$$

where  $Y_i$  is the corresponding  $i$ -th group of indicators. Given that each value of  $Y_i$  in model (1) is also an integral indicator of the evaluation of each of the evaluation directions, the given model is slightly modified.

$$Y_i = f(f_1(x_{1.1}; x_{1.2}; \dots x_{1.n}); f_2(x_{2.1}; x_{2.2}; \dots x_{2.m}); f_3(x_{3.1}; x_{3.2}; \dots x_{3.l}); f_4(x_{4.1}; x_{4.2}; \dots x_{4.k})) \quad (2)$$

where  $x_{1.1}; x_{1.2}; \dots x_{1.n}$  – single indicators of financial sustainability assessment;

$x_{2.1}; x_{2.2}; \dots x_{2.m}$  – single liquidity and solvency indicators;

$x_{3.1}; x_{3.2}; \dots x_{3.l}$  – single indicators of business activity evaluation;

$x_{4.1}; x_{4.2}; \dots x_{4.k}$  – single profitability metrics;

$f_1, f_2, f_3, f_4$  – integral indicators of each of an industrial enterprise business model identified component financial efficiency.

Table 1 summarizes the individual indicators for assessing the financial performance of a business model of an industrial enterprise.

**Table 1.** Indicators of selected components for economic and mathematical modeling of the integral indicator of the enterprise business model financial efficiency evaluation.

The name of the component	The name of a single metric	The designation used in the model
Component of financial stability ( $f_1$ )	Financial independence ratio	$x_{1.1}$
	Financial dependency ratio	$x_{1.2}$
	Financial Risk Ratio	$x_{1.3}$
	Coefficient of financial stability	$x_{1.4}$
	Ratio of mobile and immobilized assets	$x_{1.5}$
	Long-term commitment ratio	$x_{1.6}$
	Ratio of current liabilities	$x_{1.7}$
	Financial leverage ratio	$x_{1.8}$
	Maneuverability factor of own	$x_{1.9}$
	Coefficient of supply of inventories with own funds	$x_{1.10}$
	Working capital maneuverability factor	$x_{1.11}$
	Fixed Assets Index	$x_{1.12}$
	The coefficient of the real value of fixed assets	$x_{1.13}$
Solvency and liquidity component ( $f_2$ )	Solvency ratio	$x_{2.1}$
	Absolute liquidity ratio	$x_{2.2}$
	Quick liquidity ratio	$x_{2.3}$
	Critical liquidity ratio	$x_{2.4}$
	Coefficient of coverage	$x_{2.5}$
	Ratio of current and total assets	$x_{2.6}$
Business activity component ( $f_3$ )	Ratio of total capital turnover	$x_{3.1}$
	Mobile turnover rate	$x_{3.2}$
	The turnover ratio of tangible working capital	$x_{3.3}$
	Receivables turnover ratio	$x_{3.4}$
	The average term of receivables turnover	$x_{3.5}$
	Ratio of accounts payable	$x_{3.6}$
	The average term of turnover of accounts payable	$x_{3.7}$
	Fund return on fixed assets and other fixed assets	$x_{3.8}$
	Equity turnover ratio	$x_{3.9}$
The profitability component ( $f_4$ )	The rate of return on assets	$x_{4.1}$
	Return on equity ratio	$x_{4.2}$
	Return on Equity Ratio	$x_{4.3}$
	Profitability ratio	$x_{4.4}$
	The profitability ratio of products	$x_{4.5}$

Next, it is necessary to calculate the significance of the factors. To do this, we use the Fishburn rule, which allows us to determine the level of significance of indicators

based on their ranking. If you order the system of indicators according to the degree of their decrease, the significance of the  $f_i$ -th component should be determined by the formula (3):

$$r_i = \frac{2(N-i+1)}{(N+1)N} \quad (3)$$

where  $r_i$  is the weighting factor of the  $i$ -th component;  
 $N$  – the number of indicators of the population;  
 $i$  – sequence number (rank) of the population index.

Investigating scientific works that raised the issues of ranking components of the financial performance of enterprises, it was found that the priority indicators that characterize the financial condition of the company are indicators of profitability and business activity beyond solvency and liquidity and recent financial stability. Table 2 shows the results of calculating the degree of significance of each of the components.

**Table 2.** Calculation of component constituents significance degrees and single indicators.

The name of the component	The specific weight of the component
The profitability component ( $f_4$ )	0,4
Business activity component ( $f_3$ )	0,3
Solvency and liquidity component ( $f_2$ )	0,2
Component of financial stability ( $f_1$ )	0,1

Table 3 shows the estimated values of financial ratios for the company JSC Ukrtransnafta for 2014-2018 years.

It should be noted that when analyzing even some of the indices that characterize the financial efficiency of an industrial enterprise's business model, ambiguous situations are possible when, by these certain indicators, financial efficiency can acquire both positive and negative trends. Therefore, to solve this problem, we propose the use of methodology and mathematical apparatus of the theory of fuzzy sets.

The basis of the notion of fuzzy sets is the idea that the constituent elements of a given set, which have a common property, can possess this property to varying degrees (and to a different extent), and therefore belong to this set with different degrees [5]. Therefore, it is necessary to use a single universal generalized indicator.

However, if a business model's financial performance is assessed on the basis of several financial indicators, then it would be advisable to carry it out using some integral metric to construct a generalized Harrington function:

$$D = \sqrt[n]{\prod_{i=1}^n d_i} \quad (4)$$

$$d_i = \exp(-\exp(-y_i)) \quad (5)$$

where  $n$  is the number of indicators used to evaluate the financial performance of a business model of an industrial enterprise;

$d_i$  – is a partial function that is defined according to the Harrington scale;

$y_i$  – a single measure of the financial performance of a business model of a business enterprise in dimensionless form.

**Table 3.** Estimated values of financial ratios for the company JSC Ukrtransnafta for 2014-2018 years [8].

The name of a single metric	2014	2015	2016	2017	2018
Financial independence ratio	0,83	0,83	0,85	0,80	0,84
Financial dependency ratio	0,17	0,17	0,15	0,20	0,16
Financial Risk Ratio	0,20	0,20	0,17	0,25	0,19
Coefficient of financial stability	5,06	4,96	5,75	4,06	5,34
Ratio of mobile and immobilized assets	0,09	0,17	0,39	0,36	0,44
Long-term commitment ratio	14,26	6,83	4,54	6,93	15,78
Ratio of current liabilities	0,12	0,21	0,22	0,45	0,37
Financial leverage ratio	2,82	1,38	0,79	1,70	2,96
Maneuverability factor of own	0,10	0,17	0,33	0,33	0,36
Coefficient of supply of inventories with own funds	18,53	33,42	2,82	2,58	2,19
Working capital maneuverability factor	0,05	0,03	0,35	0,39	0,46
Fixed Assets Index	1,10	1,03	0,84	0,91	0,83
The coefficient of the real value of fixed assets	0,91	0,84	0,69	0,71	0,63
Solvency ratio	0,87	1,31	4,63	1,69	0,96
Absolute liquidity ratio	0,87	1,31	4,63	1,69	0,97
Quick liquidity ratio	3,92	4,01	5,55	1,83	2,81
Critical liquidity ratio	3,92	4,01	5,58	1,84	2,84
Coefficient of coverage	4,15	4,14	8,65	3,01	5,22
Ratio of current and total assets	0,08	0,14	0,28	0,27	0,31
Ratio of total capital turnover	0,10	0,13	0,16	0,18	0,27
Mobile turnover rate	1,13	0,94	0,58	0,69	0,89
The turnover ratio of tangible working capital	20,92	31,30	1,62	1,77	1,95
Receivables turnover ratio	8,00	20,77	20,73	15,47	53,11
The average term of receivables turnover	45,65	17,57	17,61	23,60	6,87
Ratio of accounts payable	4,68	3,87	4,97	2,07	4,66
The average term of turnover of accounts payable	77,96	94,20	73,39	176,49	78,38
Fund return on fixed assets and other fixed assets	0,10	0,16	0,22	0,25	0,39
Equity turnover ratio	0,11	0,16	0,19	0,23	0,32
The rate of return on assets	0,03	0,06	0,07	0,10	0,10
Return on equity ratio	0,03	0,07	0,08	0,13	0,12
Return on Equity Ratio	1,50	2,96	3,30	4,65	3,18
Profitability ratio	0,29	0,69	0,66	0,64	0,43
The profitability ratio of products	0,21	0,59	0,43	0,55	0,39

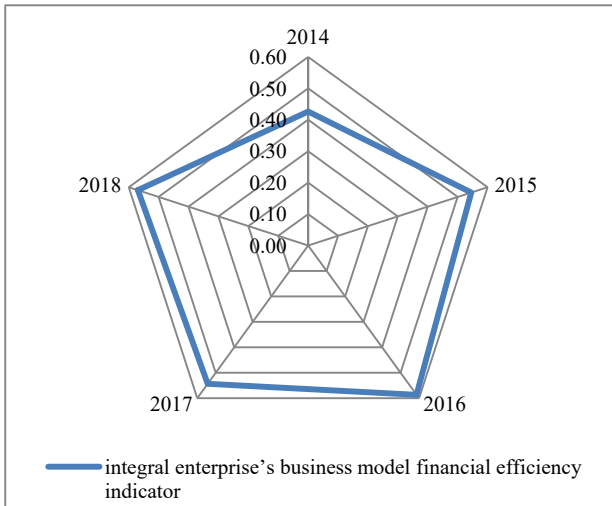
Harrington's generalized function is a quantitative, unambiguous, single, and universal measure of the quality of an object under study, and if you add such qualities as adequacy, efficiency, and statistical sensitivity, it becomes clear that it can be used as an optimization criterion.

The Harrington scale is conventionally divided into five sections, which characterize the dimensionless dimensions of the indicators under consideration. To apply the Harrington scale, all the studied parameters must be dimensionless in accordance with the abscissa and calculate the values of the partial functions of Harrington by equation (4). The number of partial functions obtained equals the number of indicators of evaluating the financial efficiency of an industrial









**Fig. 2.** The dynamics of the integrated financial performance indicator of a business model of an industrial enterprise calculated using the Harrington function for 2014-2017.

when

$$\bar{x}_k = \frac{1}{w} \sum_{i=1}^w x_{ik} \quad (11)$$

$$S_k = \sqrt{\frac{1}{w} \sum_{i=1}^w (x_{ik} - \bar{x}_k)^2} \quad (12)$$

where:  $z_{ik}$  – standardized value of indicator  $k$  for the  $i$ -th study period;  $x_{ik}$  – standardized value of indicator  $k$  for the  $i$ -th study period;  $\bar{x}_k$  – arithmetic mean of  $k$  indicator;  $S_k$  – standard deviation of  $k$  indicator;  $w$  – a number of periods.

By multiplying values of each standardized attributes by the hierarchy coefficient, corrected values of the corresponding attribute are used for taxonomic analysis.

The next step is the problem analysis of observation matrix differentiation. All variables are divided into stimulants and disincentives. The indicators of each component are divided into two groups based on the impact character of each of them on recreational forest management potential. Indicators, having a positive effect on recreational forest management potential, are considered stimulants, in contrast to the negative indicators, having a negative effect – the stimulants and, thus, reducing the level of recreational forest management potential [11].

Distribution of indicators into stimulants and disincentives serves as the basis to develop the so-called standard, represented by point  $P_0$  with coordinates:  $z_{01}, z_{02}, \dots, z_{0n}$ :

$$\begin{aligned} z_{0s} &= \max z_{rs}, \text{if } s \in I \\ z_{0s} &= \min z_{rs}, \text{if } s \notin I \quad (s = 1, 2, \dots, n) \end{aligned} \quad (13)$$

where:  $I$  is a set of stimulants,  $z_{rs}$  is a standardized value of the exponent  $s$  of a specific block of costs for period  $r$ . The distance between individual unit points and point  $P_0$ , representing the standard of cost level, is expressed as  $C_{i0}$  and calculate as follows:

$$C_{i0} = \left[ \sum_{s=1}^n (z_{is} - z_{0s})^2 \right]^{\frac{1}{2}} \quad (i = 1, \dots, w) \quad (14)$$

The obtained distances are considered as initial values used to calculate the indicator of recreational forest management potential:

$$d_i = 1 - \frac{C_{i0}}{c_0} \quad (15)$$

$$\bar{c}_0 = \frac{1}{w} \sum_{i=1}^w C_{i0} \quad (16)$$

$$S_0 = \left[ \frac{1}{w} \sum_{i=1}^w (C_{i0} - \bar{c}_0)^2 \right]^{\frac{1}{2}} \quad (17)$$

This indicator is interpreted as follows: it assumes a high value at high stimulus values and a low value at low stimulus values. The closer the figure is to one, the higher the level of recreational forest management potential. The indicator can serve for statistical characterises of elements infinity. It is possible to estimate the “average” level of the indicators, achieved within a certain period of time characterizing the analysed problem [12].

The results of the taxonomic analysis are summarized in table 7.

**Table 7.** Integral indicators of the financial performance components of an industrial enterprise business model are calculated using the taxonomy method.

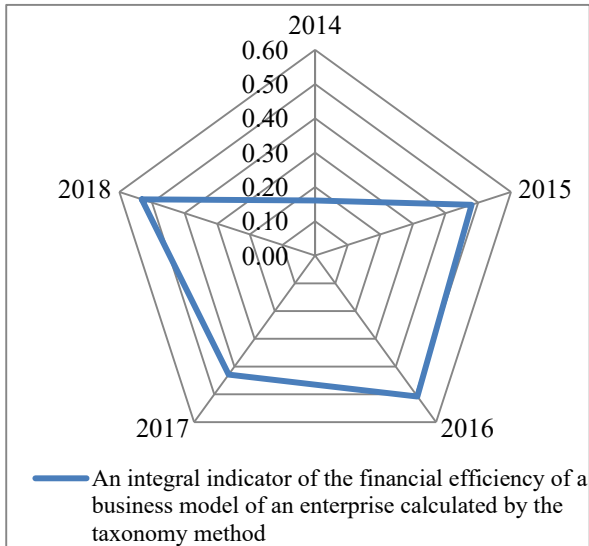
Components of financial efficiency of an industrial business model	Specific gravity components	2014	2015	2016	2017	2018
Component of financial stability ( $f_1$ )	0,1	0,22	0,41	0,59	0,10	0,32
Solvency and liquidity component ( $f_2$ )	0,2	0,17	0,34	0,48	0,08	0,36
Business activity component ( $f_3$ )	0,3	0,26	0,46	0,35	0,10	0,63
The profitability component ( $f_4$ )	0,4	0,06	0,58	0,62	0,93	0,60
Integral indicator of financial efficiency of business model of industrial enterprise		0,43	0,16	0,48	0,51	0,43

Figure 3 shows the dynamics of the integral indicator of financial efficiency of a business model of an industrial enterprise calculated using the taxonomy method for 2014-2017.

## 4 Results

Thus, from the obtained results of the calculations, we can conclude unequivocally that during the analyzed period the financial efficiency of the business model of the studied enterprise is at an average level, and it should be noted a positive trend of growth of these indicators at the end of the period relative to the base period of the study. The increase in the financial performance indicator of Ukrtransnafta’s business model has gone from 0,43 (43%) in 2014 to 0,57 (57%) in 2018 by an indicator calculated using the Harrington function and from 0,16 (16%) in 2014 to 0,53 (53%) in 2018 according to the taxonomic method. The growth of the integral indicator was largely due to the increase in the level of profitability of the

enterprise, which show us the integral indicators of the profitability components in Tables 6 and 7. Such results were obtained as a result of the increase of profit of the enterprise from 688,689 thousand UAH in 2014 to 1463,239 thousand UAH. at the end of the analyzed period, which led to an increase in the level of individual profitability indicators.



**Fig. 3.** The dynamics of the integral indicator of financial efficiency of a business model of an industrial enterprise calculated using the taxonomy method for 2014-2017.

Therefore, the interpretation of the calculated integral indicators of the financial performance of an industrial enterprise business model is as follows: it assumes high value at high values of stimulants and low value – at small values of stimulants (which clearly show us the results of calculations in Tables 6 and 7). The closer the index is to one, the higher the level of financial efficiency of the business model of the enterprise. An indicator of the financial performance level of an industrial enterprise’s business model can serve as a statistical characteristic of many elements. It is possible to estimate the “average” level of the indicators that characterize the problem, achieved in some period of time.

The results of the study indicate that both methods of calculation indicate the same tendency of change of integral index of financial efficiency of business model of industrial enterprise and confirm the possibility of application of Harrington function and taxonomic analysis in construction of integral index of financial efficiency of business model of industrial enterprise that fully reflects the adequacy of the operation of an industrial enterprise under the influence of various factors.

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