

Application of the Harrington Function to Assess the Performance of Oil and Gas Companies

Iryna Perevozova

*Ivano-Frankivsk National Technical
University of Oil and Gas
Ivano-Frankivsk, Ukraine
orcid.org/0000-0002-3878-802X*

Nadiia Daliak

*Ivano-Frankivsk National Technical
University of Oil and Gas
Ivano-Frankivsk, Ukraine
orcid.org/0000-0002-1599-842X*

Oksana Lisova

*Ivano-Frankivsk National Technical
University of Oil and Gas
Ivano-Frankivsk, Ukraine
lisovaoksana2016@ukr.net*

Dmitriy Naumov

*Belarus State Economic University
Belarus
cedrus2014@mail.ru*

Abstract— Modern development and functioning of socio-economic systems requires the introduction of new management methods aimed at preventing, preventing and overcoming crisis phenomena. This is precisely what necessitates and intensifies scientific research aimed at improving the methodology for diagnosing the effectiveness of activities, which involves applying a systematic approach to enterprise management. Measurement can be considered as a process of interaction of the measured and measuring system at a certain point of their state in the flow of time. The measurement is subject to all processes that are included in the flow of creating an additional cost. These are not only financial but also logistical, material, energy, information, marketing and other flows that represent the first system of commercial structure. In this structure, marketing flows are key, integrating, as they provide an opportunity to explore the causes and identify ways to improve market efficiency. To determine the integral indicator of the efficiency of the oil and gas industry, Harrington's desirability function is used, which allows modeling the process of coordinated behavior of individual subsystems of a single whole, taking into account the relationship and the influence between them. Instead of a simple comparison, system parameters are converted to numeric values, and then processed to get the overall system efficiency. The basis for constructing and prioritizing this generalized function is the transformation of the natural values of partial parameters of different physical entities and dimensions into a single dimensionless scale of desirability (advantage).

Keywords— *performance, Harrington function, oil and gas company, integral indicator, optimization*

I. INTRODUCTION

The oil and gas market plays a significant role both in Ukraine's foreign economic activity and in raising living standards. At present, the current theoretical and practical problem is to reduce the level of monopoly power in the field of transportation, production and sale of oil, gas and products of their processing. Implementation of modern concepts of competition in the context of free market globalization (especially in the oil and gas markets) is practically impossible in the classical sense, since they are characterized by conditions of dominance of corporations, whose influence within a particular industry is extremely powerful. Particularly noteworthy is the struggle for the consumer of smaller participants, which is inferior to the place of struggle

for participation in the value chain. The right of choice of partners belongs to the principal - the owner of key resources, which forms the business model of network interaction, focusing on maximizing the resource and market synergy of joint activity, and at the same time, seeking to consolidate the basic positions in value creation (taking into account the uniqueness of their competencies).

The industry is dominated by vertically integrated oil companies, which include geophysical, drilling, exploration, oil and gas, and refining enterprises. The efficiency of each enterprise is interrelated and the economic and financial position of the entire economy is interconnected. It should be emphasized that the dynamics of the development of network interaction is not characteristic of oil and gas companies, because stable networks are the most promising "form of cooperation in the field of consumer value creation.

Interaction of the subjects of the marketing system, within the framework of which the formation of long-term relations, the exchange of resources and information is considered as a certain sequence of actions of this process. The effectiveness of the interaction process depends on the overall goal of each entity's behavior, the situation or the state of the managed system, resource availability, and the level of readiness for the joint actions of the system entities. The process of interaction can be considered as a cumulative type of activity that characterizes the degree, methods and forms of interaction of the subjects (partners) of the network in the process of achieving the goals of the business [1], [2].

In order for the interaction process to be carried out effectively, it is necessary to measure the characteristics of each stage of this process. Based on the results of the measurements and their analysis, it is necessary to prove new strategies of the behavior of the commercial structure in the market. In this object of purchase and sale, exchange of values become relations, as a result of balanced, on demand and supply, interaction. Relationships become a product in which integrated intellectual and informational resources are the main factors of the stability of market relations.

Creating value is closely linked to the rational search and use of material resources of energy and information. To manage the process of creating value, it must be measured. Measurement can be considered as a process of interaction of the measured and measuring system at a certain point of their

state in the flow of time. The measurement is subject to all processes that are included in the flow of creating an additional cost. These are not only financial but also logistical, material, energy, information, marketing and other flows that represent the first system of commercial structure. In this structure, marketing flows are key, integrating, as they provide an opportunity to explore the causes and identify ways to improve market efficiency.

In the process of interaction (Fig. 1) of the commercial structures F1 and F2 there is the integration of partners, the existence of mutual economic and social commitment to create value (V) in order to achieve the desired efficiency (E1; E2).

Measuring the results of marketing activities should be considered as a process of economic and statistical representation of the characteristics (metrics) of the management system during the regulation of supply and demand in the market.

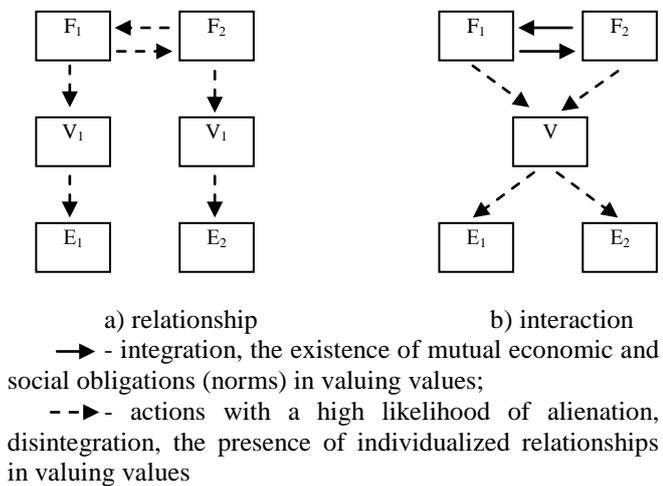


Fig. 1. Relationship system: relationship (a) and interaction (b) in the process of obtaining the effect

In today's conditions it is quite difficult in the economy to develop a system of indicators, which would fully reflect all the interaction of the company and its value created. The problem is not the number of interactions, because modern information technologies and database capabilities allow you to structure and manage a large amount of information, and in the difficulty of obtaining and evaluating quality information, measuring the experience of interaction, as each of its variants is unique. Therefore, the task of the study is to assess the impact of the state of the system of relations with contractors of the oil and gas company on the efficiency of its economic activities.

II. DETAILED PRESENTATION OF THE METHODOLOGY OF THE STUDY, CHARACTERISATION OF MATERIALS AND METHODS OF ANALYSIS, STATISTICAL PROCESSING OF RESULTS

A common goal of interacting with counterparties that integrates both subsystems: maximizing the benefits for all system members on a long-term basis. Important in management is the desire to translate all members of the system from consumer status, when it forms its requirements and seeks to meet them, in the status of a partner who aims at

achieving their goals on the basis of mutual benefit and focused on long-term relationships.

The effectiveness of the system of relations with counterparties is largely determined by external factors that form the basis of the interaction with respect to the system. We propose to divide performance factors into two groups: organizational and informational. Among the organizational factors are the following: quality of the product or service, which reflects the degree of conformity of the characteristics of the product and service to the requirements of consumers; satisfaction and loyalty of employees of the organization; the quality of the production, commercial and management system of an oil and gas company, characterized by the criteria of flexibility, level of cost, productivity, efficiency, capacity, etc. An important aspect of the effectiveness of the engagement process is its information support. Clearly, timely information is crucial to interacting in such a complex system.

Existing literary approaches do not foresee the possibility of evaluating the effectiveness of the management system as a holistic entity, consisting of separate subsystems. In addition, it is necessary to take into account the human factor that Gummesson called h-relations [3]. Quite a lot of research is devoted to satisfaction, loyalty, level of commitment and other parameters related to clients, while the relationship between these variables and profitability is absent.

An assessment of the effectiveness of governance has many controversial and unresolved issues, which are mostly related to the development of specific methodological solutions.

Today, there are several approaches in determining the efficiency of the enterprise [4]-[7]. The most common are: the calculation of synthetic indicators of management efficiency (efficiency, reliability, profitability, etc.); comparison of factual data with normative, planned or with indicators for past years (norms of the size of the control apparatus, productivity, management efficiency, etc.); application of qualitative estimation of efficiency with the help of experts and use of empirical formulas for calculation of indicators, characterizing efficiency of activity. Since an enterprise is an open system that interacts with the external environment, an enterprise's performance evaluation should be based on external and internal component evaluations. It is the efficiency of the external component and its correlation with the internal indicators characterizes the effectiveness of the system of relations with counterparts (Table 1). Based on the criterion of completeness, the most widely and comprehensively evaluate the performance of the enterprise group of profitability parameters, of which Table 2 was grouped by the criteria of efficiency and minimum most important indicators that will be used in the calculation of the efficiency of oil and gas enterprise: profitability of operating activities, profitability financial activity, profitability of investment activity.

A key trend in the relationship with the counterparties of oil and gas companies at the current stage of development of fuel and energy markets is to increase its importance, personal contacts with it, which marked the development of personalized communications and individual approach to each client.

TABLE I. COMPONENTS OF ESTIMATION OF THE EXTERNAL COMPONENT OF THE EFFECTIVENESS OF THE SYSTEM OF RELATIONS WITH COUNTERPARTIES (WRITTEN BY AUTHOR ON THE BASIS OF 1)

Assessment components	Indicators of evaluation
Balance of interests between investors and the enterprise	<ul style="list-style-type: none"> - the level of business reputation of the enterprise; - the level of the credit rating of the enterprise; - level of satisfaction with the database of existing and potential investors; - level of satisfaction with the availability of special means of communication; - level of satisfaction with the availability of the degree of rotation of investors; - level of satisfaction with the growth of invested capital; - level of satisfaction with payment of interest and dividends; - level of trust in the management of the enterprise; - level of satisfaction with availability of appropriate credit resources; - the level of long-term relationships with investors
Balance of interests between suppliers and the enterprise	<ul style="list-style-type: none"> - the level of business reputation of the enterprise; - level of trust to suppliers (to the enterprise); - level of satisfaction with the database of existing and potential suppliers; - level of satisfaction with the speed of receipt of information about / from suppliers; - level of satisfaction with special means of communication; - Satisfaction rate and quality of deliveries; - level of satisfaction with prices and timeliness of payment for deliveries; - level of satisfaction with the system of discounts and deferral of payment; - level of long-term relationships with suppliers; - level of satisfaction with the availability of basic information that facilitates the supply of material resources and the provision of services
Balance of interests between consumers and businesses	<ul style="list-style-type: none"> - the level of business reputation of the enterprise; - level of trust to consumers (to the enterprise); - level of satisfaction with the possibility of monitoring the requirements of consumers; - level of satisfaction with the database of the consumers of the enterprise; - level of satisfaction with the efficiency of receipt of information about / from consumers; - level of satisfaction with special means of communication; - level of satisfaction with the speed and quality of product delivery; - the level of satisfaction with the prices of products and the system of discounts; - level of satisfaction with timely payment for products; - level of long-term relations with consumers
Balance of interests between the bodies regulating activity and the enterprise	<ul style="list-style-type: none"> - level of satisfaction with compliance with the requirements of laws and legislative acts; - the level of reliability of reporting on the activities of enterprises and taxes; - level of satisfaction with timely payment of state taxes and fees; - the level of satisfaction with the stability and clarity of the regulatory framework that regulates the activities of the enterprise; - level of satisfaction with measures of public authorities

TABLE II. INDICATORS FOR CALCULATING THE EFFICIENCY OF THE OIL AND GAS BUSINESS (INTERNAL COMPONENT)

Indicator	Marking	Formula	Recommended value	Economic interpretation
Profitability of operating activity, %	<i>Poa</i>	$\frac{PO}{Co} \cdot 100$	>0, increase	Shows what proportion is the profit of operating activities in operating expenses
Profitability of financial activity, %	<i>Pfa</i>	$\frac{PF}{Cf} \cdot 100$	>0, increase	Shows what proportion is the profit of financial activity in the expense of financial activity
Profitability of investment activity, %	<i>Pia</i>	$\frac{PI}{Ci} \cdot 100$	>0, increase	Shows what proportion is the profit of investment activity in the cost of investment activity
Legend: PO - operating profit, Co – operating costs, PF – profit of financial activity, Cf – costs of financial activity, PI – profit of investment activity, Ci – costs of investment activity				

On the whole, we can conclude that it is advisable to apply marketing interaction approaches to elements of the consumer subsystem. In our opinion, the use of the partnership model in relation to consumer interaction is not excluded. Thus, in order to make an assessment of the efficiency of an oil and gas undertaking, there is a need to take into account the plurality of factors (parameters) that are the basis for further calculation of the evaluation (integral) efficiency indicator. To determine the integral indicator of the efficiency of the oil and gas industry, Harrington's desirability function [8] is used, which allows modeling the process of coordinated behavior of individual subsystems of a single whole, taking into account the relationship and the

influence between them. Instead of a simple comparison, system parameters are converted to numeric values, and then processed to get the overall system efficiency. The basis for constructing and prioritizing this generalized function is the transformation of the natural values of partial parameters of different physical entities and dimensions into a single dimensionless scale of desirability (advantage). The purpose of the scale is to establish a match between the physical and psychological parameters of optimization.

The desirability function can be used as a function of belonging, because $d \in [0,1]$. It arose as a result of observations of real decisions of respondents and possesses such useful properties as continuity, monotony and

smoothness. In addition, this curve is well transmitted by the fact that in the regions it is desirable, close to 0 and 1, its "sensitivity" is significantly lower than in the middle zone (Fig. 2). In essence, it is a logistic (S-like) system efficiency curve. The value of a partial variable, translated into a dimensionless scale of desirability, is denoted by d_i ($i = 1, 2, \dots, n$) and is called partial desirability. The scale of desirability has a range from zero to one. The value $d_i = 0$ corresponds to an absolutely inappropriate level of this property, and the value $d_i = 1$ is the best value of the property. From the mathematical point of view, the author of the approach recommends that the value of the desirability of d be set to 0.37 by the normative values of the indicators. The number 0.37 is the approximate result of dividing the unit by the number e , where e is the basis of the natural logarithm.

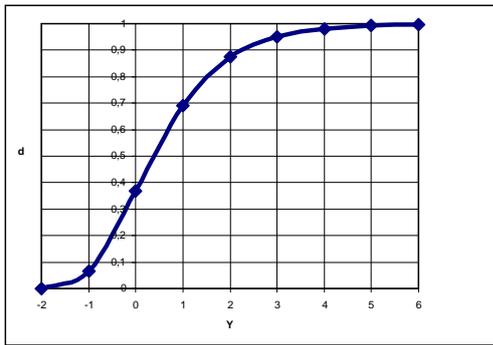


Fig. 2. Graph of Harrington's desirability function with unilateral constraints

The second such point is the value of the desirability of 0.63, which is the result of the difference $(1 - 1/e)$. In table 3 shows the numbers corresponding to some points of the curve.

TABLE III. HARRINGTON'S "SCALE OF DESIRE" [8, p. 495]

Desirability	Qualitative mark on the scale of desirability «d»	Qualitative characteristics of the scale «d»
Excellent	1,00	Displays the extreme level of excellent quality, the improvement of which makes no sense
Very kind	1,00-0,80	Acceptable at the "excellent" level. Displays unusually good quality or performance
Good	0,80-0,63	Acceptable at the "good" level. Displays a level that exceeds the best level to which the value of $d = 0.63$ corresponds
Satisfactory	0,63-0,37	Acceptable at the "satisfactory" level. The quality is acceptable to the margin of tolerance, but needs to be improved
Bad	0,37-0,20	Limit level. If there are standard requirements for characterization, some of the products will lie outside these characteristics. (If the characteristic corresponds exactly to the set minimum or maximum, then the value of "d" should be equal to $0,36788 = 1/e$)
Very bad	0,20-0,00	Unacceptable level

The generalized index of desirability is calculated by the formula:

$$\Delta = \sqrt[n]{d(1)d(2)\dots d(n)}, \quad (1)$$

where n is the number of used parameters of comparison parameters in this system. The number of these indicators may not be the same for different systems. This allows you to compare the generalized coefficients even when there is no part of the comparison parameters in different systems or data on them. The root of the n th degree "smoothes" the resulting deviations, and the resulting result allows us to evaluate the system (with a certain degree of accuracy), so to speak, "mathematically."

In turn, the desirability index d for each individual given characteristic Y' for a group of indicators with unilateral constraints is determined by the formula:

$$d = e^{-e^{-Y'}}, \quad (2)$$

where e is the logarithmic constant, which is approximately equal to 2.71828 ...; Y' is the result of the linear transformation of the characteristic variable Y .

This formula represents a special case of the Gompertz's growth function, which is depicted in Figure 2.

In order to further transform this group of indices into a dimensionless appearance, Harrington E. recommends initially introducing two pairs of variables ($Yd1, d1$) and ($Yd2, d2$). After that, the $Yd1, Yd2$ indicators are standardized using the following formula:

$$Y' = -[\ln(-\ln d)] \quad (3)$$

Using a pair of reduced values of Y' two constants b_0 and b_1 are calculated, which are needed for standardization of other indicators with unilateral constraints. These constants are from the linear equation:

$$Y' = b_0 + b_1 Y \quad (4)$$

After translating all the indicators into a dimensionless view, a generalized desirable index is calculated as the geometric mean of all partial descriptors. The logic posed by the use of the average geometric value is that if at least one of the parameters is zero, that is, it is undesirable, then the state of the entire object of evaluation is undesirable [9]-[10].

III. DISCUSSION OF RESULTS

As can be seen from the above calculation of a generalized indicator using the desirability function, standardization of the indicators requires the definition of their normative values, the determination of a pair of numbers (Yd_0, d_0) for calculating the parameter n , as well as two other pairs of quantities (Yd_1, d_1) and (Yd_2, d_2) for standardization of unilateral constraints. It is these stages that generate the greatest drawback of Harrington's approach - subjectivism. Therefore, in order to reduce the influence of subjective assessment from the oil and gas exploration enterprises, a group of experts was involved to identify these pairs of numbers [11]-[12].

Table 4 shows the values of the analyzed coefficients, their score on the Harrington scale in the dynamics for 2016-2018, and Table 5 - an integral indicator of the efficiency of the activity without taking into account the assessment of the management system for relations with counterparties and with its consideration.

TABLE IV. THE VALUES OF THE ANALYZED COEFFICIENTS, THEIR SCORE ON THE HARRINGTON SCALE

Enterprise	Indicator	Input value				Harrington Score			
		2016	2017	2018	2019 (forecast)	2016	2017	2018	2019 (forecast)
Stryynaftogaz Ltd.	Poa	0.13	0.15	0.18	0.21	1.3	1.5	1.8	2.1
	Pfa	0.37	0.4	0.44	0.48	1.85	2	2.2	2.4
	Pia	0.09	0.07	0.08	0.11	1.8	1.4	1.6	2.2
	Level of management system for relations with counterparties				0.773				2.74
Bogorodchanyaftogaz Ltd.	Poa	0.18	0.19	0.21	0.23	1.8	1.9	2.1	2.3
	Pfa	0.29	0.3	0.32	0.34	1.45	1.5	1.6	1.7
	Pia	0.14	0.17	0.18	0.2	2.8	3.4	3.6	4
	Level of management system for relations with counterparties				0.762				2.68
Ivano-Frankivskgas sales Ltd.	Poa	0.22	0.22	0.23	0.24	2.2	2.2	2.3	2.4
	Pfa	0.17	0.19	0.18	0.16	0.85	0.95	0.9	0.8
	Pia	0.11	0.09	0.08	0.1	2.2	1.8	1.6	2
	Level of management system for relations with counterparties				0.766				2.7
NGK BanGas Ltd.	Poa	0.12	0.11	0.09	0.08	1.2	1.1	0.9	0.8
	Pfa	0.15	0.15	0.14	0.13	0.75	0.75	0.7	0.65
	Pia	0.05	0.05	0.06	0.07	1	1	1.2	1.4
	Level of management system for relations with counterparties				0.777				2.77

TABLE V. INTEGRAL INDICATOR OF THE EFFICIENCY OF THE OIL AND GAS BUSINESS

Enterprise	2016	2017	2018	2019 (forecast) without incident. assessing the level of the relations system with counterparties	2019 (forecast) in view. assessing the level of the system of relations with counterparties
Stryynaftogaz Ltd.	0.82	0.81	0.85	0.90	0.91
Bogorodchanyaftogaz Ltd.	0.86	0.87	0.89	0.91	0.91
Ivano-Frankivskgas sales Ltd.	0.81	0.80	0.79	0.80	0.83
NGK BanGas Ltd.	0.68	0.68	0.67	0.67	0.73

It should be noted that the effectiveness of Stryynaftogaz Ltd. and Bogorodchanyaftogaz Ltd. is characterized as high, and Ivano-Frankivskgas sales Ltd. and NGK BanGas Ltd. are good if you use the Harrington scale. However, using the ECTS scale and interpreting the results for 2019 (forecast), we will have the efficiency of Stryynaftogaz Ltd. is good ("B"), for the Bogorodchanyaftogaz Ltd. is excellent ("A"), for Ivano-Frankivskgas sales Ltd. - good ("C"), for NGK BanGas Ltd. - satisfactory ("D"). It is clear from the calculations that taking into account the level of the system of management of relations with counterparts unambiguously raises the assessment of the efficiency of the oil and gas business, moreover, the lower the assessment, the more significant difference between the efficiency, taking into account the level of the system of interaction with counterparties and without its inclusion.

IV. CONCLUSIONS

Thus, an assessment was made of the impact of the state of the system of interaction with counterparties of the oil and gas company on the effectiveness of its activity on the basis of external (indicator of the level of organization of the system of management of relations with counterparties, reflecting the qualitative efficiency of the oil and gas companies) and internal (operating profitability, profitability of financial activity, profitability investment activity) components. To determine the integral indicator of the efficiency of the operation of the oil and gas company, the Harrington function is used, the basis of construction and the priority opportunity is the transformation of the natural values of partial parameters of different physical nature and dimension into a single dimensional scale of desirability (advantage). The simulation of the coordinated behavior of the individual subsystems of the studied enterprises as a single entity, taking into account the connection and the influence between them, has been evaluated by the subsystem of interaction of the investigated subjects in the process of formation of relations with counterparties both with regard to the level of interaction, so without. According to these results, Bogorodchanyaftogaz Ltd and Stryynaftogaz Ltd. are described as high, Ivano-Frankivskgas sales Ltd. and NGK BanGas Ltd. are good, and it was noted that taking into account the level of the relations management system with counterparties unequivocally raises the assessment of the efficiency of the oil and gas enterprises.

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