Diagnostics of the structural risk level in the sphere of waste management at Ukrainian railways

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Abstract. The article focuses on the problem of the structural risk level diagnostics in the sphere of waste management at the railway transport objects. The specifics of the railway enterprises activity are the multi-vector business processes executed, which determines a significant nomenclature and volumes of formation, accumulation of wastes of different danger classes. A retrospective analysis of this problem on Ukrainian railways for 2007 – 2018 showed significant structural fluctuations both in terms of volume formation and in the costs and ecological payments for environmental protection in sphere of waste management. The method of sensitivity analysis, the peculiarity of which is to calculate the elasticity coefficients for determining the degree of environmental costs interaction in the field of waste management with the change of their components (capital investment, current costs, environmental tax and environmental services), is implemented. The corresponding elasticities for 2008 – 2018 showed a considerable variation of the most significant risk factors that were atypical for JSC "Ukrzaliznytsia" and 6 railways. The existing structure needs to be better diagnosed with a purpose of ensuring stability and predictability of environmental costs in order to reduce structural risk, rational environmental management and to ensure the ecology of rolling stock and objects of railway transport infrastructure.

Introduction

The problems of effective economic-ecological management of Ukrainian railways production activities and business operations received significant attention within the works of many scientists [1-14]. In particular, there have been investigated the key problems of railways management, mechanisms of environmental management (an organization-economical and economic-ecological one), of railway transport enterprises sustainable development; methodical approaches to assessing the environmental impact of railway transport enterprises activities; economic-ecological measures for upgrading environmental situation on the railways, etc.

JSC "Ukrzaliznytsia" and its 6 regional branches, when exercising their business operations, generate and accumulate vast quantities of wastes in different hazard categories. As a result, the company calculates and pays the environmental tax for waste disposal, allocates capital investments, provides for current expenditures and finances services at such direction of environmental protection as waste management. Retrospective study of the key financial and economic indicators in the area of waste management at Ukrainian railways and JSC "Ukrzaliznytsia" over the 12-years period, from 2007 to 2018, allows us to conclude about structural and dynamic fluctuations, both in natural and monetary equivalent. General costs for waste management consist of capital investments, current expenditures, environmental tax and environment-related services in the area of waste management. Regarding the structure of other waste management costs, they are characterized by the spasmodic oscillation: by an increase in some years (2008, 2011, 2012, 2016 and 2018) and decrease in the others (2009, 2010, 2013 – 2015, 2017). In particular, for 6 Ukrainian railways, these costs particularly halved in 2017 comparing with 2016, but increase in 2.25 times in 2018 in comparison with 2017.

In terms of the annual indicator "actually generated waste", a downward trend is observed in 2016 – 2018 (for reference: 2016 – 90.005 thousand tons, 2017 – 62.593 thousand tons, 2018 – 53.440 thousand tons). At the same time, in 2016, the share of the waste disposal was 33% in the structure of the environmental tax distribution; this share significantly increased and amounted to 58% in 2017, and 64.11% in 2018 [15] against the background of a general reduction in waste generation during these years.

Such a significant increase in the environmental tax for waste disposal is due, inter alia, to the ambiguity in the interpretation of the procedure for calculating and paying tax when placing scrap metal by some regional branches (by Ukrainian railways). This situation has developed because there is lack of a unified approach in JSC "Ukrzaliznytsia" on the issues of taxation for waste disposal. We should note that the conclusion of contracts for the provision of hazardous waste management services are subject to the Law of Ukraine "On Public Procurement" [16].

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However, when competitive tendering by regional branches for the purchase of these services was announced, the auction was often canceled. This situation was due to either an insufficient number of participants, or non-compliance with the conditions of the tender documentation. In such cases, a negotiation procedure is envisaged, but due to the disagreement of prices for the provision of services, such agreements were not concluded.

Also, during 2017, regional branches submitted applications for holding auctions for the sale of ferrous and non-ferrous metal scrap. However, many of them have not been implemented due to the high starting price recommended by the commission of JSC "Ukrzaliznytsia".

In accordance with Article 14 of the Tax Code [17], the waste disposal is the permanent (final) placement or landfilling of waste in specially designated areas or facilities (waste disposal sites, storage facilities, landfills, complexes, building structures, subsurface sites, etc.), and their utilization is exercised on the basis of permission from authorized bodies. Consequently, business entities that carry out the temporary placement (storage) of waste before its destruction through export / transfer for disposal, placement or landfilling to specialized enterprises, are not payers of the environmental tax for waste disposal.

The inefficiency of management in this area leads not only to the erroneous environmental tax assessment, but also an increase in the activity riskiness. And this, in turn, leads to unpredictable and unplanned expenses. Generally, such a trend does not contribute to mission declared on the official portal on sustainable development of JSC "Ukrzaliznytsia", which is to ensure the sustainable development of Ukraine by providing quality and affordable transport and logistics services based on the principles of social and environmental responsibility, as well as by an effective model of company management that corresponds to the challenges of today and tomorrow [18]. In view of the foregoing, it became necessary to diagnose the degree of structural risk in the field of waste management on the Ukrainian railways.

Research methods

In order to fulfill the research, a sample of statistical data is used in accordance with the state statistical reporting form No.1 – environmental costs "Expenditures on environmental protection and environmental payments for the year of 20__" [19] for 6 regional railways of Ukraine. A method of quantitative risk analysis (sensitivity method) was used as an instrument for diagnosing and identifying the riskiest factors of influence on total environmental costs in the field of waste management.

Based on this, elasticity indicators are calculated to determine the degree of interaction of environmental costs in the field of waste management with changes in their components (capital investment, current expenditures, environmental tax and environmental services) for the period of 2008 – 2018. The scientific publications on the subject, domestic legislation, reports of JSC "Ukrzaliznytsya" regional branches became the information base of the research.

Results and discussion

The problems of risk management in the activities of enterprises have been and still remain the subject of study of many Ukrainian and foreign theorists and practitioners. In particular, M. Dyba in his work [20] identified the concept of risk and structural risk, developed a classification of financial risks; basic methods of risk assessment in risk management and the use of quantitative methods of risk analysis (sensitivity analysis) are highlighted in the work of D. Kozenkova and P. Nikitin [21]; the use of sensitivity analysis in the context of risk testing is presented in [22].

Other scientists substantiated the need to use mathematical models for risk management [23], methods for quantitative analysis of vulnerability to develop effective strategies for companies [24]. Application of environmental vulnerability analysis in risk assessment from a methodological standpoint is presented in [25]; advantages and disadvantages of using elasticity index in [26].

The principles and methods of system analysis, economic-mathematical methods and models, economic risk management of business entities for making effective management decisions are considered in [27, 28].

Questions of the nature and classification of risks in railway transport are given considerable attention in the work of A. Rachinska [29]. Other scientists [30, 31], who investigated the activities of specific railways, indicated the influence of factors that lead to the occurrence of corresponding risks.

When diagnosing and quantifying risk using simulation methods, the fluctuation of the initial value is estimated with random changes in input values, taking into account the degree of interdependence of random changes in input values. Sensitivity analysis refers to quantitative risk analysis.

This is a method of considering the factors of uncertainty that are specific for the assessment of an economic indicator (total costs of waste management).

Such a process provides for the implementation of 2 stages: the formation of a model, which determines the mathematical relationships between variables and the sensitivity analysis itself. It is the latter that makes it possible to identify the riskiest variables in the model associated with the assessment of the overall indicator.

This analysis involves the measurement of the sensitivity (vulnerability) of the main indicators, the effectiveness of a certain economic indicator (total costs of waste management) depending on a random change of factors. As a sensitivity indicator related to the change of a certain factor, it is proposed to apply an elasticity coefficient.

It should be mentioned that elasticity is a measure of the response of one variable, or function, to the change

of the other one, that is, the argument. In turn, the elasticity indicator is a number that demonstrates the percentage change in a variable (function) as a result of a one-percent change in the argument. The total costs of waste management will be represented as a real-valued function of four factors (arguments):

$$y = f(x) = f(x_1, x_2, x_3, x_4), \quad (1)$$

where y – total expenditures on environment protection and providing environmental services in the area of waste management at regional branches (Ukrainian railways), UAH,

x_1 – capital investments in the area of waste management at regional branches (Ukrainian railways), UAH,

x_2 – current expenditures for waste management at regional branches (Ukrainian railways), UAH,

x_3 – an amount of environmental tax paid for waste disposal in specially designated places or facilities, except for the placement of certain types of waste as recyclable materials in regional branches (railways of Ukraine), UAH,

x_4 – payment for environment-related services in the area of waste management at regional branches (Ukrainian railways), UAH.

With the research purpose, we identify and systematize values of indicators x_1, x_2, x_3, x_4 – for each of the six regional branch (Ukrainian railways: Lvivska Railway, Donetska Railway, Odeska Railway, Prydniprovska Railway, Pivdenno-Zakhidna Railway, Pivdenna Railway) of JSC "Ukrzaliznytsia" and separately for JSC "Ukrzaliznytsia" on the basis of annual reports on the work of regional branches in the environmental protection area [15], as well as in aacordance with the state statistical reporting form No.1 – environmental costs "Expenditures on environmental protection and environmental payments for the year of 20__ " [19] for the period of 2007 – 2018. For JSC "Ukrzaliznytsia", it was taken the total value of each of the indicators of the six railways of Ukraine, other structural units that are part of this company was not taken into consideration.

According to the adopted system of hypotheses, the total costs of waste management (y) as a function of the main of the variables arguments (x_1, x_2, x_3, x_4) are proposed to be submitted using the following formula:

$$y = x_1 + x_2 + x_3 + x_4, \quad (2)$$

which will be considered an adequate model that is in compliance with the aim of the study and the adopted system of hypotheses. So, the I[st] stage of sensitivity analysis has been implemented. In the future, it is proposed to interpret the total costs of waste management (y) as a random variable, depending on random fluctuations of x_1, x_2, x_3, x_4 variables, which should be also treated as random quantities.

Stage II of the investigation is to calculate the elasticity indicators. Since the function is defined in a specific range of values of the 4 corresponding arguments, therefore, the elasticity index of this function is determined regarding the change of these 4 variables for each individual railway is defined as follows:

$$\varepsilon_{it} = \left(\frac{\Delta y_{it}}{\Delta x_{it}} \cdot \frac{x_{it}}{y_{it}} \right) \cdot 100, \quad (3)$$

where ε_{it} – the elasticity indicator of total expenditures related to environment protection in the area of waste management for the i-th railway at the t-th year, %,

i – the railways index ($i = \overline{1,6}$), 1 – "Lvivska Railway", 2 – "Donetska Railway", 3 – "Odeska Railway", 4 – "Prydniprovska Railway", 5 – "Pivdenno-Zakhidna Railway", 6 – "Pivdenna Railway",

t – the year index ($t = \overline{0,11}$), 0 – 2007, 1 – 2008, 2 – 2009, 3 – 2010, 4 – 2011, 5 – 2012, 6 – 2013, 7 – 2014, 8 – 2015, 9 – 2016, 10 – 2017, 11 – 2018.

The elasticity indicator for JSC "Ukrzaliznytsia" is determined by the following formula (4):

$$\varepsilon_{УЗ_t} = \left(\frac{\Delta y_{УЗ_t}}{\Delta x_{УЗ_t}} \cdot \frac{x_{УЗ_t}}{y_{УЗ_t}} \right) \cdot 100, \quad (4)$$

where $\varepsilon_{УЗ_t}$ – the elasticity indicator of total expenditures related to environment protection in the area of waste management for JSC "Ukrzaliznytsia" for the year t, %.

The main advantage of the elasticity indicator is that its value does not depend on the selection of units for measuring various factors. Consequently, the larger the absolute value of this economic indicator, the higher the degree of sensitivity will be. Therefore, the same is with a risk of changing a certain factor on which this indicator depends.

Note that the risks, which the overall costs of waste management are burdened with, are greater, the more the sensitivity (vulnerability), that is, the elasticity of this indicator before each factor changes, and the longer the range of possible variations of these factors (in the future) [27, 28].

This method gives an opportunity to carry out diagnostics based on the analysis of several possible options for the composition of the waste management total costs at individual regional branches.

As a result of the calculations, it is advisable to choose the option that is less susceptible to random changes in these 4 factors that affect the total amount of expenditure in the studied direction of environmental protection measures on the Ukrainian railways.

Only after it is confirmed that this indicator insignificantly depends on the main factors (the values of elasticity indicators are small in absolute value), you can refuse from further risk analysis.

On the basis of the calculation results for six Ukrainian railways and JSC "Ukrzaliznytsia" for the period of 2007-18, we have received the related values of 2008-2018 elasticity indicators represented in tables 1-7.

Table 1. Elasticity indicators, calculated for the regional branch "Lvivska Railway", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	53.18	-5.93	0.00	75.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ε_2	-199.91	-50.44	-15364.38	754.55	33.98	-24.19	-0.67	13.87	20.44	775.57	246.42
ε_3	-223.78	0.00	-123.12	83.75	-11.06	2.86	-0.55	4.44	33.57	-1257.15	565.81
ε_4	53.18	10.72	0.00	75.17	41.86	18.84	5.91	185.21	-794.00	0.00	86.80

Table 2. Elasticity indicators, calculated for the regional branch "Donetska Railway", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	-7.74	20.33	-6.15	78.35	-51.74	0.00	0.00	0.00	0.00	0.00	7.47
ε_2	-32.96	-152.84	0.34	0.00	37.24	72.80	46.04	45.36	1376.42	202.49	-0.49
ε_3	97.89	94.00	9.70	160.47	152.63	-27.09	24.39	15.27	851.57	0.00	0.00
ε_4	20.08	168.80	-9.78	93.44	90.72	98.14	129.80	147.80	51.40	71.43	18.48

Table 3. Elasticity indicators, calculated for the regional branch "Odeska Railway", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	97.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-11.12	129.06
ε_2	0.00	-1175.90	17.68	-13.00	12.95	157.83	-33.17	-0.04	25.27	3.10	67.70
ε_3	-16065.46	176.76	0.00	43.49	24.03	-3.47	0.00	0.00	0.00	-11.12	-114.80
ε_4	97.84	-1286.14	0.00	89.95	-468.51	61.17	72.17	0.51	113.31	5.05	78.46

Table 4. Elasticity indicators, calculated for the regional branch "Prydniprovska Railway", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	95.40	0.00	0.00	28.06	-66.89	49.14	0.22	27.34	17.54	-794.30	68.82
ε_2	226.23	396.79	-1222.10	-251.18	8.16	62.85	84.25	86.67	152.49	30.69	-796.16
ε_3	957.46	-1310.76	4068.17	32.23	25.41	-100.09	117.13	-2.26	-60.49	-34.74	-8.71
ε_4	82.34	20242.96	85.63	-329.76	-28.20	115.38	278.87	5794.28	257.52	35.90	228.23

Table 5. Elasticity indicators, calculated for the regional branch "Pivdenna Railway", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	88.25	89.98	13.86	0.00	92.01	3.41	0.00	0.00	0.00	-155.59	75.68
ε_2	274.20	5046.20	-462.98	35.69	-1831.75	-23309.54	66.32	53.41	12.60	72.57	2042.49
ε_3	190.23	-141.43	1353.72	8.83	-25.07	77.49	0.00	0.00	0.00	0.00	0.00
ε_4	78.88	1047.89	-1873.38	41.82	-1122.48	-7811.75	181.48	1829.44	-184.10	105.01	348.03

Table 6. Elasticity indicators, calculated for the regional branch "Pivdenno-Zakhidna Railway", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	97.16	51.48	0.87	455.41	60.88	0.00	0.00	9.92	42.69	0.00	0.00
ε_2	791.14	-516.04	-94.85	72.08	97.03	-124.51	128.48	61.45	-152.74	30.24	449.95
ε_3	171.64	3794.12	-60.27	76.50	46.36	0.00	0.00	0.00	42.63	-268.61	193.84
ε_4	97.16	-2167.15	-227.07	266.11	-201.51	-177.50	75.80	-854.84	214.53	137.08	51.64

Table 7. Elasticity indicators, calculated for JSC "Ukrzaliznytsia", %

Elasticity indicators	Years										
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
ε_1	89.01	62.88	9.04	118.84	74.81	3.15	0.13	12.20	-3.13	43.89	65.57
ε_2	1701.40	-5393.57	-425.64	129.78	232.45	-338.95	157.45	-278.43	5.00	43.53	-4265.48
ε_3	376.77	993.21	-244.70	50.65	332.88	39.09	54.52	-1.50	-2.61	-132.26	-365.99
ε_4	132.21	-283.22	-371.30	114.49	575.91	-375.20	91.13	68.33	11.35	79.37	102.13

The values of elasticity indicators for the period under review demonstrated dynamic fluctuations of risk factors both for individual railways of Ukraine, and for JSC "Ukrzaliznytsia" as a whole.

Thus, the Lvivska Railway in 2008 – 2018 was characterized by the various riskiest factors, as evidenced by the calculated elasticity indicators. In particular, in 2010 – 2011 the variable x_2 (current expenditures) was a significant risk factor, in 2008, 2017 and 2018 – the value of the environmental tax. And a factor "environmental protection services" was the most vulnerable in terms of risk in 2015-2016.

As for the Donetska Railway, the variable of the environmental tax x_3 was the highest in modulus during 2008, 2011 and 2012, in comparison with other variables. Consequently, this factor caused the greatest risk for the mentioned railway in the years indicated. This reflects a high degree of sensitivity, and, therefore, of risk. Such a factor as current expenditures acquired the largest absolute value of the elasticity index in 2016-2017, environmental protection services – in 2009, 2014, 2015.

It is worth noting that, based on the calculated values of elasticity indicators for variable x_1, we can conclude that for 11 years this risk factor was not sensitive, and it was not a risk factor at all.

The calculations for the regional branch "Odeska Railway" showed significant fluctuations of the main risk factors over the years. Thus, during the 4-year period (2011, 2012, 2014, 2016), the variable x_4 (environmental protection services) was a significant risk factor, as evidenced by the corresponding elasticity indicators. For 2009, 2010, 2013, the most sensitive in terms of the risk was the factor "current expenditures", in 2008 – the "environmental tax". The last two studied years were characterized by vulnerability to the "capital investments" factor.

The largest absolute values of the elasticity indicators of factor x_4 for the Prydniprovska Railway were demonstrated during 6 out of 11 years (in 2009, 2011, 2013-2016). The variable x_1 was a significant risk factor in 2012 and 2017, the variable x_2 – only in 2018, and variable x_3 – in 2010. Consequently, structural-dynamic risk fluctuations also occurred in the system of total waste management costs for this regional branch of JSC "Ukrzaliznytsia".

For the Pivdenno-Zakhidna Railway, structural and dynamic fluctuations in the risk of current expenditures and environmental protection services were most significant for 5 years for each of these factors (respectively: 2008, 2009, 2012, 2013, 2018; 2010, 2011, 2014 – 2016). Only in 2017, the "capital investment" factor caused the largest share of risk, while the environmental tax was not a risk factor during the researched period.

The environmental activities of the regional branch "Pivdenna Railway" were characterized by a high degree of risk due to the influence of all 4 factors. In particular, the factors "current expenses" and "environmental protection services" each caused the largest share of risk within 4 years, the variable x_3 – in 2009, x_1 – in 2011. It was concluded that environmental activity factors x_2 and x_4 for this railway also have a high degree of environmental sensitivity in the area of waste management.

Based on the systematization of the calculations, it was identified that in 2008 environmental tax was a risk factor both for each of the 6 regional branches and for JSC "Ukrzaliznytsya". This is due to the ambiguity of approaches to the collection of this tax on waste management.

The remaining 10 years demonstrated multi-vector sensitivity, that is, the sensitivity of the total waste management costs to changes in 4 factors (arguments), therefore, the risks were also unstable. When diagnosing JSC "Ukrzaliznytsia", which consists of 6 railways, as a whole, we arrive at the following findings. The magnitude of current waste management costs was the largest risk factor in 7 out of 11 years (2008 – 2010, 2014 – 2015, 2018).

The factor "environmental protection services" was sensitive or risky in 2012 – 2013, and the environmental tax only in 2017. Capital investments, according to calculations, were not a risk factor in any year, since the elasticity indicator was the lowest in absolute value. If we consider this factor for individual railways, it acquired the highest risk indicator values among others for the Odeska Railway in 2018, the Prydniprovska and Pivdenno-Zakhidna Railway in 2017 and for the Pivdenna Railway in 2011.

Summary

While summarizing the conducted research, we could conclude that under planning environmental protection expenditures in the field of waste management on Ukrainian railways, it is necessary to diagnose structural risk in order to identify possible vulnerable or most risky factors, primarily to determine, from many possible options, the optimal structure of waste management total costs that will provide minimal growth of the most significant risk factors. This approach further allows not only to plan efficiently the distribution of funds for environmental protection, but also to manage risks in the field of waste management.

The method of quantitative risk analysis applied in the work should be used for express diagnostics of risk factors, because it is somewhat limited. This method is based on the analysis of the impact of only certain factors on the total costs of waste management. But more significant for determining the riskiest factors is their integral influence.

Also, sensitivity analysis does not take into account interdependencies between certain factors. The lack of official data on the distribution of total costs in the field of waste management in the context of 4 hazard classes did not allow for the calculation of elasticity indicators

to determine the degree of interaction of waste management environmental costs for 4 hazard classes with changes in their components.

Although the implemented method has certain limitations, however, it can be used to make express diagnostics of the most important risk factors in the retrospective review, which later allows you to see how common they are for all railways, to define whether they describe a certain general trend between the cost components inherent in both for a separate railway, and for JSC "Ukrzaliznytsia" as a whole. It can be also used to determine the riskiest factors for other types of environmental protection, not only for the railways of Ukraine, but also for other enterprises of various economy sectors.

The completed studies allowed us to diagnose the percentage change in waste management costs as a result of the interaction of the most influential risk factors, which is actually a method for analyzing structural risk. Such diagnostics contribute to efficient cost management in the field of waste management at railway enterprises.

The study showed that for individual business entities it is necessary to differentiate between the priority factors that determine the largest share of the risk in the field of waste management. The corresponding 2007–2018 sensitivity analysis for JSC "Ukrzaliznytsia" and its 6 regional branches (Ukrainian railways) showed a significant variation of the most important risk factors that were not typical for all railways. It is concluded about the instability of the waste management expenditures structure during the study period.

Therefore, such a structure requires a better diagnosis with a view to ensure the stability and predictability of such environmental costs in order to reduce structural risk, to provide environmental management and rational environmental activities, and, in general, environmental friendliness of rolling stock and railway transport facilities.

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