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MODELING OF A SET OF QUALITATIVE PARAMETERS FOR ASSESSING THE COMPETITIVENESS OF A TRANSPORT ENTERPRISE USING GRAPHICAL-ANALYTICAL AND SCORING METHODS

The purpose *of the article is to build a system of qualitative parameters of influence and to identify their cardinal and ordinal estimates to determine the level of competitiveness of a transport enterprise based on a graph-analytical approach and linear modeling. To achieve this goal the following tasks have to be solved: determining key qualitative factors that affect the level of competitiveness of the enterprise; decomposition of the complex task of evaluating a qualitative indicator into a system of interconnected sub-goals – primary parameters of influence; formation of a set of primary evaluation indicators; development of an approach to aggregating expert assessments for primary input parameters using a graph-analytical method or scoring method and obtaining cardinal or ordinal estimates (linguistic terms) for them.*

Methods. *The methodological basis of the study is the fundamentals of system analysis, economic and mathematical modeling and decision-making theory. The work uses a decomposition approach to structuring the task of assessing the competitiveness of an enterprise, the method of expert assessments, the graph-analytical method of formalizing relationships between indicators, as well as a scoring method to obtain cardinal (ordinal) assessments of qualitative parameters.*

Results and conclusions. *The article carries out the process of identifying and structuring a set of qualitative parameters for assessing the competitiveness of a transport enterprise using graph-analytical and scoring approaches. As a result of the study, a system of qualitative indicators characterizing key aspects of the functioning of a transport enterprise was substantiated, in particular the level of organizational culture, the effectiveness of the information system and internal communications, the culture of safety, the image of the enterprise, the influence of the external environment, as well as the qualification level of personnel and the competence of management. The process of formalizing qualitative parameters presented by the authors of the article is carried out on the basis of a decomposition approach using agreed expert assessments and their further aggregation using graph-analytical or scoring methods. This approach allows for the systematic identification, formalization and aggregation of qualitative parameters of the transport enterprise's activities for further assessment of its competitiveness. The formed system of parameters creates the basis for further integrated assessment of the competitiveness of the transport enterprise using, in particular, the fuzzy logic method which makes it possible to produce an effective resulting decision based on different qualitative parameters of influence and allows making informed management decisions without taking into account all combinations of the values of the evaluation parameters which significantly simplifies such a process and minimizes its costs.*

Key words: enterprise competitiveness, qualitative performance indicators, expert evaluation, linguistic variables, graph-analytical modeling, scoring method, decomposition of indicators, integral evaluation.

JEL Classification: L91, L10, C63.

Anzhelika AZAROVA,
Professor at the Department of Management and Security of Information Systems
Vinnytsia National Technical University
PhD in Technical Science, Professor
azarova.angelika@gmail.com
orcid.org/0000-0003-3340-5701

Vitalina BORTNYUK,
Higher Education Applicant
Vinnytsia National Technical University
vitalinapetrivna1@gmail.com
orcid.org/0009-0001-3764-2061

Introduction. Under the current conditions of the development of the transport market and increased competition between carriers the problem of objective assessment of the competitiveness of transport enterprises is particular relevance. Dynamic changes in the economic environment, the development of logistics technologies, the growth of consumer requirements for the quality of transport services and the need for rapid adaptation to market changes necessitate the improvement of approaches to the analysis of the activities of transport enterprises. Now traditional methods of assessing competitiveness based mainly on quantitative financial and economic indicators are unable to fully reflect the real state of the enterprise and its development potential. At the same time, a significant impact on the formation of competitive advantages of a transport enterprise make the qualitative characteristics of its activities, in particular, the level of organizational culture, the

effectiveness of the management system, personnel qualifications, the image of the enterprise in the market, as well as the influence of the external environment. Such factors have a complex nature which complicates their quantitative measurement and integration into the complex assessment models. Insufficient structuring of qualitative parameters and the absence of precise methods for their formalization lead to a decrease in the accuracy of integral assessment of the enterprise's competitiveness. Due to this there is a need to develop approaches that allow for the systematic identification, ordering and formalization of a set of qualitative parameters that characterize the activities of a transport enterprise. A perspective way for solving this problem is the use of a graph-analytical approach which provides the decomposition of a complex evaluation indicator into a sequence of simpler elements or the use of a scoring model for further aggregation of evaluation parameters. The use of such approaches allows for an increase in the validity of the assessment of the enterprise's competitiveness and creates the prerequisites for making more effective management decisions.

Literature review. Taking into account the permanent changes of the transport market the issue of increasing the accuracy of assessing the competitiveness of an enterprise is becoming particularly relevant. Traditional approaches of modeling this process are mostly based on quantitative indicators of financial and economic activity which are formed on the basis of reporting data. At the same time, the practice of operating transport enterprises shows that a significant impact on the level of their competitive positions is exerted by qualitative factors which formalization is difficult due to their intangible nature and the presence of a subjective component (Strzelczyk, 2024; Syzdykbayeva, 2025).

It should be noted that the issues of assessing the competitiveness of transport enterprises and the application of mathematical methods for analyzing transport and logistics systems are considered in the scientific works of A. Strzelczyk and S. Guze, B. Syzdykbayeva et al., P. Singhal and S. Gupta (Strzelczyk, 2024; Syzdykbayeva, 2025; Singhal, 2026). Multi-criteria evaluation methods, in particular weighted sum models and fuzzy analysis methods, are studied in the works of A. Williams (2024) and M. Chen, T. Wu, X. Mao (2025). A significant contribution to the study of increasing the competitiveness of transport enterprises was made by O. Arefieva (2023), V. Godun (2023), O. Zvyagintseva (2025), O. Bakulich (2022), V. Holodenko (2022), O. Golovchenko (2022), etc.

A special feature of the studies of the above authors is the lack of consideration of the component of qualitative parameters that have a significant impact on the level of competitiveness of the enterprise or their insufficient structuring or the absence of a clear decomposition of the primary evaluation indicators. It's necessary noting that the imperfections of the methods of their quantitative interpretation lead to the appearance of inaccuracies in complex evaluation models. As a result, the integral indicator of competitiveness can reflect not fully the real state of the enterprise and its development potential. That is why there is a need to apply an approach that allows for the systematic identification, structured presentation and formalization of a set of qualitative parameters with the possibility of their further mathematical aggregation (Singhal, 2026; Williams, 2024; Chen, 2025).

Thus, despite the significant scientific achievements in the field under study, the issue of formalization of qualitative parameters for assessing the competitiveness of transport enterprises requires further improvement.

Formation of a system of parameters for assessing the competitiveness of a transport enterprise. The process of mathematical modeling of assessing the competitiveness of a transport enterprise is a complex applied problem that requires simultaneous consideration of a large set of input and output parameters and the construction of adequate functional mappings between them. For practical implementation, it is advisable to apply a decomposition approach: the overall goal is divided into a sequence of subgoals and the solution of each lower-level subgoal forms indicators or fixes parameters for the next level. Such a sequence ensures complete solving of the initial problem and makes it manageable.

It is advisable to group all the influence parameters into several functional blocks – aggregating functions for assessing the competitiveness of a transport enterprise that allow taking into account such aspects as marketing activities, logistics component, driver composition, financial condition of the enterprise, level of organizational culture, influence of the external environment, efficiency of management of the transport enterprise etc.

The subject of the article is the process of evaluating a set of qualitative aggregating functions $f_1, \ldots, f_3$ which will enable, together with quantitative ones, the formation of a complex and structured process of identifying the level of competitiveness of a transport enterprise. Let us consider them in detail.

Function f_1 – the development of the organizational culture of the enterprise – will be determined by such qualitative indicators as the level of organizational structure – $x_{1.1}$, the presence of a system of

enterprise goals and strategies for achieving them – $x_{1.2}$, the effectiveness of the information system – $x_{1.3}$ and internal communication between departments – $x_{1.4}$, safety culture – $x_{1.5}$ (Arefieva, 2023).

The aggregating function f_2 examines the impact of the external environment of the enterprise and is characterized by such qualitative indicators as the image of the enterprise – $x_{2.1}$, the rivalry indicator in the industry – $x_{2.2}$, competition among alternative modes of transportation – $x_{2.3}$, the impact of the regulatory and infrastructure environment – $x_{2.4}$, the impact of consumers – $x_{2.5}$ (Zvyagintseva, 2025).

It's advisable to introduce to the aggregating function f_3 – management efficiency – both qualitative indicators, such as the qualification level of personnel – $x_{3.1}$, management competence – $x_{3.2}$ and quantitative indicators (Bakulich, 2022), in particular, the productivity of managerial work, the share of management costs, the share of managerial employees, management efficiency etc.

Application of graph-analytic and scoring methods to obtain ordinal estimates of qualitative parameters of aggregating functions f_1,…,f_3. Unlike quantitative parameters which cardinal estimates based on numerical values taken from primary reporting, the identifying of qualitative parameters will make with the 5 appropriate linguistic term $t = \overline{1,T}$, $T = 5$: t = L – low level of parameter, t = BM – before middle level, t = M – middle level, t = AM – above middle level, t = H – high level of parameter. Let's use agreed expert estimates that acquire their further formalization based on the graph-analytic or scoring method.

So, the level of organizational structure – $x_{1.1}$ is a qualitative parameter the definition of which is proposed to be carried out using the appropriate linguistic term according to the graph-scheme shown in figure 1. This approach allows us to formalize expert estimates for the set $\mathbf{X}'$ of primary evaluation indicators x_p' , represented by the following questions:

A: Introduction of primary information necessary for analysis.

B: Is there a clear hierarchy of management and centralized decision-making?

C : Is the organizational structure able to adapt quickly to changes in the market, technology or legislation?

D: Are there formalized internal regulations, job descriptions, work standards?

E: Is the interaction between departments (logistics, finance, dispatch, administration) effective?

The presence of a system of enterprise goals and strategies for achieving them is a qualitative parameter $x_{1.2}$ which definition is proposed to be carried out using appropriate linguistic terms by decomposing into a set $\mathbf{X}'$ the primary evaluation indicators x_p' , presented in table 1, using expert assessments and dependence (1).

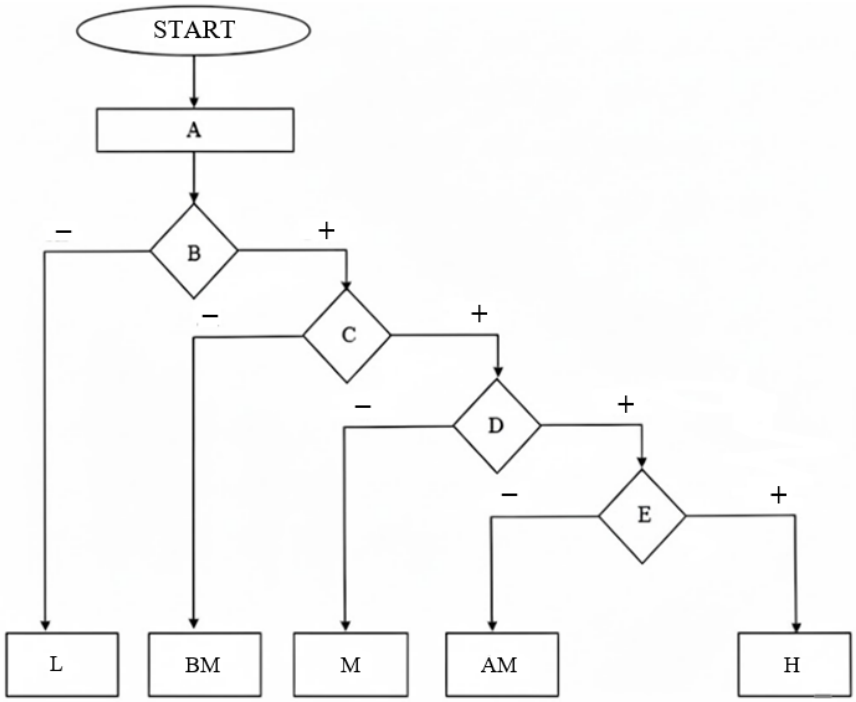

Fig. 1. Graph-scheme of evaluation of qualitative parameter of organizational structure level $x_{1.1}$ by corresponding linguistic term, $t = \overline{1, 5}$

Table 1

Assessment of the presence of a system of enterprise goals and strategies for achieving them – $x_{1.2}$

Parameter name	Parameter value change range
Clarity and specificity of goals	[0–3]
Compliance of the company's goals with its mission	[0–3]
Having strategies to achieve goals	[0–4]
Realistic and achievable goals	[0–3]
Effectiveness of the monitoring and adjustment system for goals	[0–3]

$$x_{1.2} = \begin{cases} L, if \sum_{p=1}^{5} x_p^{'} \in (0;3]; \\ BM, if \sum_{p=1}^{5} x_p^{'} \in (3;6]; \\ M, if \sum_{p=1}^{5} x_p^{'} \in (6;9]; \\ AM, if \sum_{p=1}^{5} x_p^{'} \in (9;12]; \\ H, if \sum_{p=1}^{5} x_p^{'} \in (12;16]. \end{cases} \quad (1)$$

The effectiveness of the information system – $x_{1.3}$ – is a qualitative parameter which definition will carry out using the appropriate linguistic terms by decomposition into a set **X′** of the primary evaluation indicators $x_p^{'}$ (presented in table 2) using expert assessments and formula (2).

Table 2

Indicators of evaluation of the parameter $x_{1.3}$ – the effectiveness of the information system

Parameter name	Parameter value change range
Data processing speed	[0–3]
Reliability and stability of work	[0–3]
Systems integration	[0–2]
User-friendly interface	[0–2]
Data security	[0–3]

$$x_{1.3} = \begin{cases} L, if \sum_{p=1}^{5} x_p^{'} \in (0;2]; \\ BM, if \sum_{p=1}^{5} x_p^{'} \in (2;5]; \\ M, if \sum_{p=1}^{5} x_p^{'} \in (5;8]; \\ AM, if \sum_{p=1}^{5} x_p^{'} \in (8;10]; \\ H, if \sum_{p=1}^{5} x_p^{'} \in (10;13]. \end{cases} \quad (2)$$

$x_{1.4}$ – The effectiveness of the internal communication system between departments (dispatchers, drivers, logisticians) is a qualitative parameter. We propose to estimate it using the appropriate linguistic terms by decomposition into a set $\mathbf{X}'$ of the primary evaluation indicators $x_p^{'}$ (presented in table 3) using expert assessments and formula (3).

Table 3

Indicators of evaluation of the parameter $x_{1.4}$ – the effectiveness of the internal communication system between departments

Parameter name	Parameter value change range
Information transfer speed	[0–3]
Quality of information transfer	[0–3]
Productiveness of communication channel	[0–2]
Degree of communication between dispatchers and drivers	[0–3]
Efficiency of the coordination logistics center	[0–3]

$$x_{1.4} = \begin{cases} L, if \sum_{p=1}^{5} x_p^{'} \in (0;2]; \\ BM, if \sum_{p=1}^{5} x_p^{'} \in (2;5]; \\ M, if \sum_{p=1}^{5} x_p^{'} \in (5;8]; \\ AM, if \sum_{p=1}^{5} x_p^{'} \in (8;11]; \\ H, if \sum_{p=1}^{5} x_p^{'} \in (11;14]. \end{cases} \quad (3)$$

Safety culture $x_{1.5}$ is qualitative parameter that will be assessed using appropriate linguistic terms by decomposing into a set $\mathbf{X}'$ the primary evaluation indicators $x_p^{'}$, presented in table 4, using expert assessments and formula (4).

Table 4

Parameters for assessing safety culture

Parameter name	Parameter value change range
Following the rules of traffic safety	[0–4]
Control of the technical condition of transport	[0–4]
Conducting accident prevention training and motivation for a safe driving culture	[0–2]

$$x_{1.5} = \begin{cases} L, if \sum_{p=1}^{3} x_p^{'} \in (0;2]; \\ BM, if \sum_{p=1}^{3} x_p^{'} \in (2;4]; \\ M, if \sum_{p=1}^{3} x_p^{'} \in (4;7]; \\ AM, if \sum_{p=1}^{3} x_p^{'} \in (7;9]; \\ H, if \sum_{p=1}^{3} x_p^{'} \in (9;10]. \end{cases} \quad (4)$$

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The image of a transport enterprise – $x_{2.1}$ is a qualitative parameter. To assess it, we will use the linguistic terms described above. Let's decompose this parameter into a set **X′** of the primary evaluation indicators $x_p^{'}$, presented in table 5, using expert assessments and formula (5).

Table 5

Parameters for evaluating the image of a transport enterprise

Parameter name	Parameter value change range
Cargo integrity	[0–3]
Adherence to transportation schedule	[0–3]
Term of operation of the enterprise	[0–3]
Market share occupied by the enterprise	[0–3]

$$x_{2.1} = \begin{cases} L, if \sum_{p=1}^{4} x_p^{'} \in (0;2]; \\ BM, if \sum_{p=1}^{4} x_p^{'} \in (2;4]; \\ M, if \sum_{p=1}^{4} x_p^{'} \in (4;8]; \\ AM, if \sum_{p=1}^{4} x_p^{'} \in (8;10]; \\ H, if \sum_{p=1}^{4} x_p^{'} \in (10;12]. \end{cases} \quad (5)$$

For qualitative parameters $x_{2.2} – x_{2.4}$ we will use the graph-scheme shown in figure 2–4 and table 6 which allows us to formalize expert assessments regarding a set of primary input indicators.

Table 6

Designation of blocks A, B, C, D, E, F of the graph-scheme for qualitative evaluation parameters $x_{2.2} – x_{2.4}$

Parameter	A	B	C	D	E	F
$xx_{2.2}$	Industry competi-tion analysis	Does the company capture a wide segment of market including international transportation?	Does the company have a modern material and technical base?	Does the company have highly qualified staff and an individual approach to customers?	Does the company make regular investments in development?	Does the company have a positive reputation?
$xx_{2.3}$	Analysis of alternative modes of transportation	Does the trucking company have alternative modes of transportation?	Are alternative modes of transportation available to your business?	Does motor transport provide faster delivery compared to alternatives?	Is the level of infrastructure support for road transport higher than for other modes?	Is there an increase in demand for road transport compared to other modes of transport?
$xx_{2.4}$	Analysis of the impact of regulatory and infrastructure environments	Is the regulatory environment stable for the operation of a transport company?	Does state policy promote the development of the transport industry?	Is the infrastructure sufficient for effective operation?	Is there an excessive administrative burden that complicates operations?	Is the development of digital infrastructure supported?

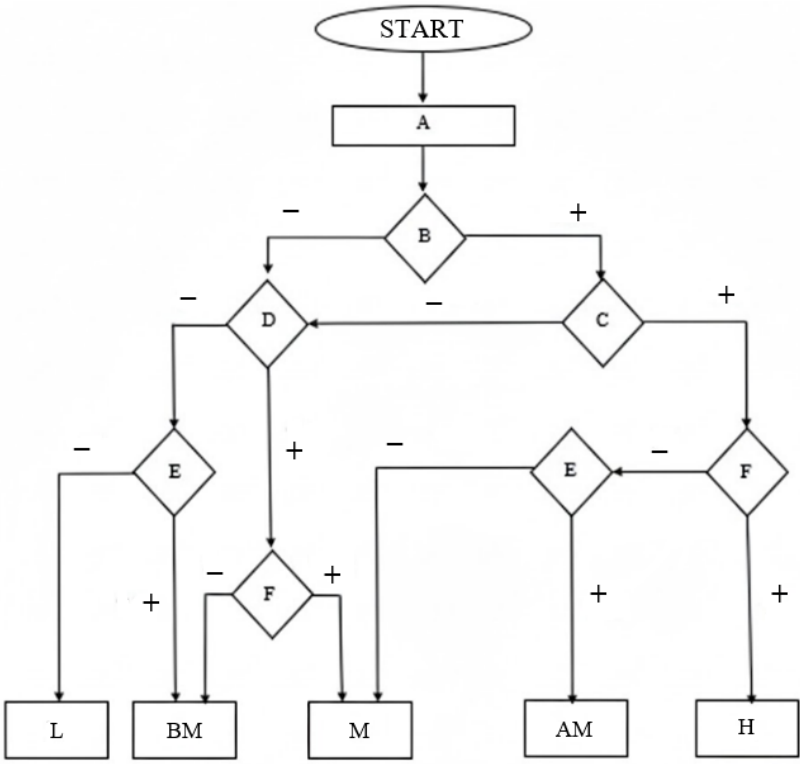

Fig. 2. Graph-scheme of the evaluation of the qualitative parameter $x_{2.2}$ – the level of competition in the industry – by the corresponding linguistic term, $t = \overline{1,5}$

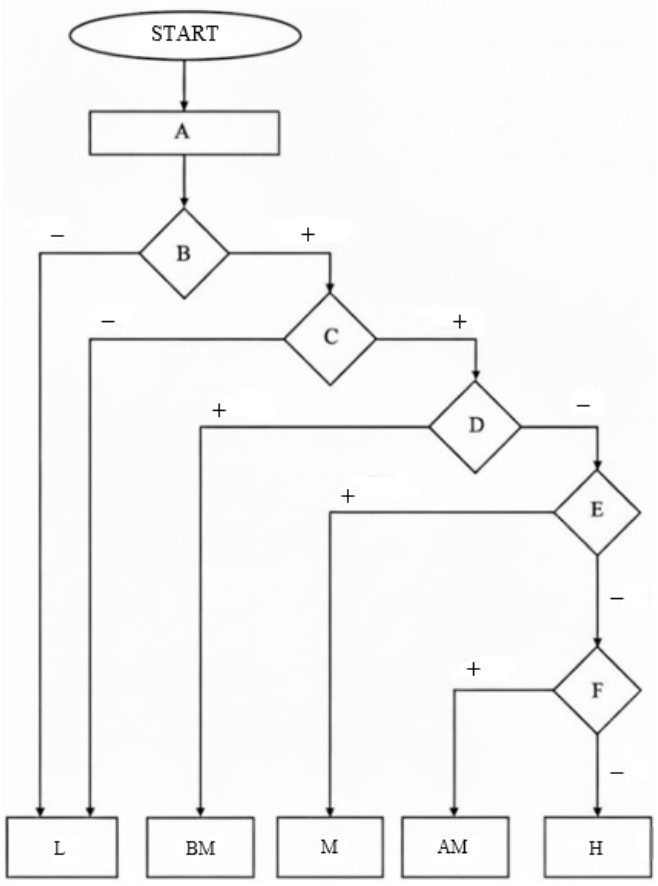

Fig. 3. Graph-scheme of evaluation of qualitative parameter $x_{2.3}$ – competition among alternative modes of transportation – by the linguistic term, $t = \overline{1,5}$

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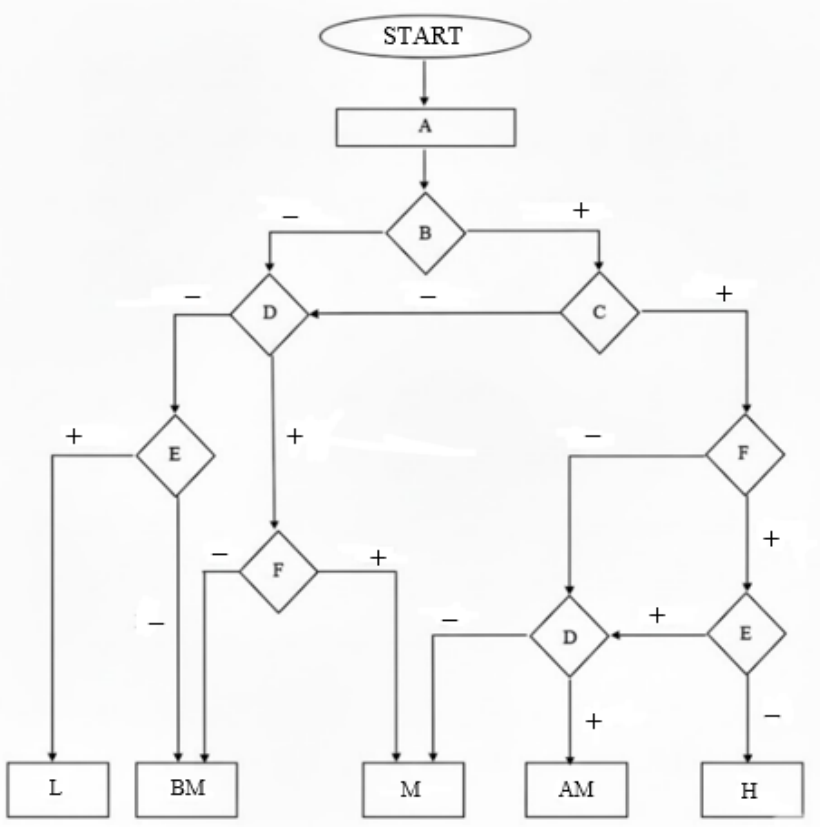

Fig. 4. Graph-scheme of the evaluation of the qualitative parameter $x_{2.4}$ – the impact of the regulatory and infrastructure environments – by the linguistic term

The consumer influence parameter $x_{2.5}$ will determine in the above-mentioned linguistic terms by decomposing the primary evaluation indicators $x_p^{'}$ (which are presented in table 7) into a set X′ using expert assessments and formula (6).

Table 7

Parameters for evaluating the consumer influence indicator – $x_{2.5}$

Parameter name	Parameter value change range
Dependence on large customers	[0–3]
Competition for customers	[0–3]
Ability of customers to influence prices	[0–2]
Customer loyalty	[0–2]

$$x_{2.5} = \begin{cases} L, if \sum_{p=1}^{4} x_p^{'} \in (0;2]; \\ BM, if \sum_{p=1}^{4} x_p^{'} \in (2;4]; \\ M, if \sum_{p=1}^{4} x_p^{'} \in (4;7]; \\ AM, if \sum_{p=1}^{4} x_p^{'} \in (7;9]; \\ H, if \sum_{p=1}^{4} x_p^{'} \in (9;10]; \end{cases} \quad (6)$$

We propose to define the qualification level of personnel $x_{3.1}$ in appropriate linguistic terms by decomposing the primary evaluation indicators $x_p^{'}$ (which are presented in table 8) into a set $\mathbf{X}'$ using expert assessments and formula (7).

Table 8

Parameters for assessing the qualification level of personnel

Parameter name	Parameter value change range
Level of professional education	[0–4]
Experience in the industry	[0–3]
Regularity of advanced training	[0–3]
Practical skills and competencies	[0–3]

$$x_{3.1} = \begin{cases} L, if \sum_{p=1}^{4} x_p^{'} \in (0;2]; \\ BM, if \sum_{p=1}^{4} x_p^{'} \in (2;5]; \\ M, if \sum_{p=1}^{4} x_p^{'} \in (5;8]; \\ AM, if \sum_{p=1}^{4} x_p^{'} \in (8;10]; \\ H, if \sum_{p=1}^{4} x_p^{'} \in (10;13]. \end{cases} \quad (7)$$

Management competence $x_{3.2}$ is a qualitative parameter which will be estimated with appropriate linguistic terms by decomposition into a set $\mathbf{X}'$ of primary evaluation indicators $x_p^{'}$, presented in table 9, using expert assessments and formula (8).

Table 9

Parameters for assessing the competence of a manager

Parameter name	Parameter value change range
Professional industry knowledge	[0–4]
Management skills	[0–3]
Strategic thinking	[0–3]
Communication skills	[0–3]
Ability to innovate	[0–3]

$$x_{3.2} = \begin{cases} L, if \sum_{p=1}^{5} x_p^{'} \in (0;3]; \\ BM, if \sum_{p=1}^{5} x_p^{'} \in (3;6]; \\ M, if \sum_{p=1}^{5} x_p^{'} \in (6;9]; \\ AM, if \sum_{p=1}^{5} x_p^{'} \in (9;12]; \\ H, if \sum_{p=1}^{5} x_p^{'} \in (12;16]. \end{cases} \quad (8)$$

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Thus, due to the research a set **X** of evaluation parameters $x_{i,j}$ was defined, structured and substantiated. The values of such indicators are established on the basis of a set **X′** of primary input indicators x'_p. The formed system of parameters reflects the key aspects of the functioning of a transport enterprise and provides the possibility of a comprehensive and formalized assessment of the level of its competitiveness.

Taking into account that experts and the decision-maker are able to simultaneously analyze 7 ± 2 factors while maintaining high accuracy of assessments, it is advisable to form a compact and informative set of initial decisions. Based on the principles of completeness, consistency and practical significance, such a set can be evaluated by the five linguistic terms considered above which describe the levels of competitiveness of a transport enterprise.

Conclusions. The article develops an approach to identifying a set of qualitative parameters for assessing the competitiveness of a transport enterprise. The necessity of comprehensive consideration of not only quantitative financial and economic indicators but also qualitative characteristics of the enterprise's activities, which significantly affect the level of its competitive positions, is substantiated. A decomposition approach is used to structure the evaluation process. It allows dividing the general evaluation task into a system of interconnected sub-goals and forming a logically ordered system of parameters.

A set of qualitative parameters characterizing the organizational culture of the enterprise, the influence of the external environment, and management effectiveness has been precisely defined. For their formalization the authors of the article propose to use graph-analytical and scoring methods which allow the decomposition of complex parameters of influence on a set of primary indicators and provide the possibility of aggregating their expert assessments. The author's approaches allow obtaining ordinal estimates for qualitative parameters. They make possible the objective consideration of intangible factors of a transport enterprise's activity and using them in the practice of managing transport enterprises to increase the efficiency of their activities and strengthen competitive positions in the transport services market.

The presence of strictly described sets of input and output parameters provides the possibility of further application of the fuzzy logic apparatus (Azarova, 2013) or neural network modeling for integral measurement of the competitiveness of a transport enterprise.

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МОДЕЛЮВАННЯ МНОЖИНИ ЯКІСНИХ ПАРАМЕТРІВ ОЦІНЮВАННЯ КОНКУРЕНТОСПРОМОЖНОСТІ ТРАНСПОРТНОГО ПІДПРИЄМСТВА ЗАСОБАМИ ГРАФО-АНАЛІТИЧНОГО ТА БАЛЬНОГО МЕТОДІВ

Анжеліка АЗАРОВА,
професор кафедри менеджменту та безпеки інформаційних систем
Вінницького національного технічного університету,
кандидат технічних наук, професор
azarova.angelika@gmail.com
orcid.org/0000-0003-3340-5701

Віталіна БОРТНЮК,
здобувач вищої освіти
Вінницького національного технічного університету
vitalinapetrivna1@gmail.com
orcid.org/0009-0001-3764-2061

Метою статті *є побудова системи якісних параметрів впливу та ідентифікація їх кардинальних та ординальних оцінок для визначення рівня конкурентоспроможності транспортного підприємства на основі графо-аналітичного підходу та лінійного моделювання. Для досягнення поставленої мети передбачено виконання таких завдань: визначення ключових якісних факторів, що впливають на рівень конкурентоспроможності підприємства; декомпозиція складної задачі оцінювання якісного показника на систему взаємопов'язаних підцілей – первинних параметрів впливу; формування множини первинних оцінювальних показників; розроблення підходу до агрегування експертних оцінок для первинних вхідних параметрів із використанням графо-аналітичного методу або бального підходу і отримання для них кардинальних або ординальних оцінок (лінгвістичних термів).*

Методи. *Методологічною основою дослідження є положення системного аналізу, економіко-математичного моделювання та теорії прийняття рішень. У роботі використано декомпозиційний підхід до структурування задачі оцінювання конкурентоспроможності підприємства, метод експертних оцінок, графо-аналітичний метод формалізації взаємозв'язків між показниками, а також бальний метод для отримання кардинальних (ординальних) оцінок якісних параметрів.*

Результати та висновки. *У статті здійснено процес ідентифікації та структуризації множини якісних параметрів оцінювання конкурентоспроможності транспортного підприємства із застосуванням графо-аналітичного та бального підходів. У результаті дослідження обґрунтовано систему якісних показників, що характеризують ключові аспекти функціонування транспортного підприємства, зокрема рівень організаційної культури, ефективність інформаційної системи та внутрішніх комунікацій, безпекову культуру, імідж підприємства, вплив зовнішнього середовища, а також кваліфікаційний рівень персоналу та компетентність керівництва. Представлений авторами статті процес формалізації якісних параметрів здійснюється на основі декомпозиційного підходу із застосуванням узгоджених експертних оцінок та подальшого їх агрегування із використанням графо-аналітичного або бального методів. Такий підхід дозволяє системно ідентифікувати, формалізувати та агрегувати якісні параметри діяльності транспортного підприємства для подальшого оцінювання рівня його конкурентоспроможності. Сформована система параметрів створює основу для подальшого інтегрального оцінювання конкурентоспроможності транспортного підприємства із застосуванням, зокрема, методу нечіткої логіки, яка уможливлює продукування ефективного результуючого рішення на основі різноякісних параметрів впливу та дозволяє приймати обґрунтовані управлінські рішення без врахування усіх комбінацій значень оцінювальних параметрів, що значно спрощує такий процес і мінімізує витрати на нього.*

Ключові слова: конкурентоспроможність підприємства, якісні показники діяльності, експертне оцінювання, лінгвістичні змінні, графо-аналітичне моделювання, бальний метод, декомпозиція показників, інтегральне оцінювання.

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