Measuring the performance of supply chain innovations

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Abstract. The issue of evaluating the performance of supply chain innovations in an organization in the current economic environment is studied in the paper. The proposed technique is used to compare several projected supply chain innovations and is based on a comprehensive evaluation using an integral coefficient and taking into account both financial and non-financial indicators, depending on the purpose and focus of suggested innovations. The presented approach was tested as part of the analysis of two supply chain innovations, using the example of the selected trading company. Based on the tasks that are planned to be solved with the use of corresponding supply chain innovations, the categories and indicators are identified for calculating the integral coefficient in order to measure the performance of supply chain innovation. The final analysis also takes into consideration the selected indicators for evaluating the efficiency of investments and functional subsystems of a supply chain to develop sound management decisions in the field of the company's logistic system transformation.

1 Introduction

Contemporary logistics systems, in particular those embodying such concepts as just in time, cross-docking, etc., should be based on appropriate technologies and management solutions in order to provide the required level of flexibility, process automation and optimization. The high level of competition in the market forces businesses to introduce innovative solutions and technologies in various subsystems, including logistics. The essence of innovation can be interpreted quite widely as a new process, new algorithm of actions, or as an end product, a result, a new solution. On the other hand, innovation can also be seen as a number of activities aimed at solving the set tasks and characterized by a certain degree of novelty. Supply chain innovation is associated with a company's efforts to develop new products, apply a new approach to solving logistics problems, and introduce new processes and technologies that require a corresponding level of investment (Sevhan et al., 2021; Tebaldi et al., 2018).

A supply chain can be described as a network of organizations involved in a sequence of various processes, flows, and activities in order to deliver finished products to end consumers. Thus, this category includes a coordinated network of logistics and operational

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links between companies involved in the processes of procurement, production, distribution, and delivery of products to the final consumer (Bouhannana, El Korchi, 2021; Savina et al. 2021). A supply chain involves the movement of flows of physical objects (including raw materials, semi-finished products, finished products), financial resources and information between businesses, transport companies, consumers, etc.

The key area of company's changes today is the system of information flows in logistics, since the performance and reliability of the processes of supply, production, and distribution of products largely depend on the speed and efficiency of information transfer and processing. Innovations in information systems and technologies, which represent the fundamental elements of the logistics infrastructure of a modern company, can increase the efficiency of information processing and, consequently, the performance of the supply chain as a whole (Barmuta et al., 2020; Dudukalov et al., 2021). However, innovations aimed at improving the supply chain performance are not limited to information management solutions. They may also include various organizational, technological, marketing, functional and other innovations.

Effective supply chain management involves a holistic and systematic approach to the supply chain analysis, taking into account all its components, coordinating and synchronizing the processes of product distribution. It should be noted that the problem of measuring supply chain performance and evaluating the performance of logistics innovations is a highly topical subject of contemporary studies. Despite the high degree of study of the research problem, it is important to emphasize the need for further studies due to the complex nature of innovation and supply chain concepts along with the difficulties of measuring innovation performance in the planning phase in view of the specifics of logistics innovations. In addition, there is an ongoing discussion in the literature regarding the most effective methods and indicators for innovation measurement. Pursuant to above said, the purpose of this study is to elaborate proposals for the use of a comprehensive technique that provides for the determination of an integral coefficient for measuring the performance of a company's supply chain innovations.

2 Materials and methods

The methodology of this study is based on the application of methods of comparative analysis, classification and categorization, induction, deduction, as well as scientific approaches to the synthesis of methods for evaluating the performance of innovations and supply chains. The method proposed in the article for comparing different supply chain innovative solutions was developed using the criteria for evaluating innovation performance, mathematical methods and expert judgement.

The supply chain performance includes the efficiency of the use of logistics resources (human, financial, technological, etc.), decisions made in the field of procurement, product distribution, information flow management and transportation in order to meet the needs of an end consumer (Jagan et al. 2019). The corresponding parameters and indicators are needed to determine the performance of a supply chain. When choosing these indicators, it is important to consider the goals of using specific solutions, which may include improving customer service, optimizing costs, increasing the efficiency of planning processes for manufacturing and selling products, minimizing the duration of turnover cycles of raw materials and finished products, optimizing warehouse stocks, etc. A number of indicators are often used to measure supply chain performance, based on criteria of the quality of logistics operations and their implementation costs (Putri et al., 2019).

It should be noted that both simple and complex models can be used to analyze the supply chain innovation performance, based on indicators of functional subsystems and

their dynamics and/or indicators for evaluating investment decisions (Lehyani et al., 2021; Jagan et al., 2019). However, simple models often do not allow for a full assessment of the profitability of improving a company's supply chain, presenting the evaluation results based on the ratio of several indicators (for example, payback period, return on investment, etc.). Complex evaluation models provide an opportunity for more in-depth analysis, but often do not consider the specifics and objectives of the innovation in question, which can lead to the calculation of redundant indicators that cannot reflect the performance of a particular innovation. The complexity of this task increases if it is required to carry out a comparative analysis of different innovation options in the supply chain in order to choose the optimal one. It is suggested in the study that applying an integral coefficient for evaluating the supply chain innovation performance based on selected categories and indicators could be a way to solve this problem. In our opinion, the selection of indicators to measure supply chain innovation performance depends on the specifics of innovation and the tasks it is intended to solve (Wong, Ngai, 2022; Barmuta, Grishchenko, 2020). In this regard, a dynamic evaluation policy is proposed, which involves selecting individual categories and indicators depending on specifics and goals of a particular innovation. The technique developed is tested in the next section of the article. For calculation and analysis purposes, the table with the selected categories and indicators along with their weighting values should be made (the template is presented in Table 1). There can be any number of categories, but it is not recommended to overload the model with indicators, the calculation of which, with high probability, will not contribute to solving the problem of evaluating the performance of the considered supply chain innovation. The number of indicators (coefficients) should be the same for each category.

Table 1. Data required to calculate the integral indicator of the supply chain innovation performance.

Category	Indicator	Indicator weighting
X category	Indicator X1	0.5
	Indicator X2	0.3
	Indicator X3	0.2
Y category	Indicator Y1	0.5
	Indicator Y2	0.3
	Indicator Y3	0.2
Z category	Indicator Z1	0.5
	Indicator Z2	0.3
	Indicator Z3	0.2

The following formula is applied to calculate the integral coefficient of the supply chain innovation performance:

$$E_{SC} = \frac{(X_1 \times 0{,}5 + X_2 \times 0{,}3 + X_3 \times 0{,}2) + (Y_1 \times 0{,}5 + Y_2 \times 0{,}3 + Y_3 \times 0{,}2) + (Z_1 \times 0{,}5 + Z_2 \times 0{,}3 + Z_3 \times 0{,}2)}{\mathrm{n}} \times 100 \qquad (1)$$

where n – number of indicators applied.

The higher the value of the integral performance index, the more the supply chain innovation under study meets the requirements established within the assessment category. The values of integral coefficients obtained as a result of calculations for different supply chain innovative solutions are compared in order to choose the optimal one. The proposed technique can be applied as a component of the integrated evaluation of the supply chain innovation project along with the analysis of selected functional parameters and investment performance measuring indicators.

The theoretical basis of the study includes scientific works of Russian and foreign researchers in the field of analyzing logistics systems and processes, as well as measuring the effects of introducing supply chain innovations. The method proposed in the study is tested by comparing two supply chain innovative solutions on the example of the selected trading company.

3 Results

Supply chain performance can be defined as the ability of an organization to provide value to all parties concerned, including the ability to overcome emerging barriers, adapt to change, develop competitive advantages, optimize resources, use environmentally friendly solutions, etc. (Lehyani et al., 2021; Muratova et al., 2021). To evaluate the supply chain performance, information is needed on various segments of its performance, reliability, and continuity of logistics processes, the ability to optimize delivery time, increase the elasticity and adaptability of the logistics system, transparency of costs, sustainability of inventory management, and the efficiency of information flows. An efficient supply chain requires not only an appropriate level of process coordination, focus on customer satisfaction and cost optimization in key subsystems, but also an evaluation system that allows to determine whether the supply chain is performing according to expectations (Jagan et al., 2019). In this regard, the analysis of the supply chain performance seems to be a complex and time-consuming process, that is based on the analysis of qualitative and quantitative data describing operating performance. In addition, the evaluation approach should consider the strategy and objectives of the organization. When choosing performance indicators, it seems appropriate to consider those that are of key importance for the functioning and development of the company (Karl et al., 2018; Putri et al., 2019). Furthermore, the supply chain performance largely depends on the internal processes of the company, including the management of information flows.

It should be emphasized that enterprises are currently striving to introduce various kinds of innovative transport, forwarding and logistics solutions, which can be grouped as follows:

- technological innovations (cross-docking, smart tracking, telematics),
- marketing innovations (last-mile delivery, predictive analytics systems),
- process innovations (new methods of loading/unloading goods, IT systems for modeling and optimizing traffic flows, electronic document management systems),
- organizational innovations (cluster solutions, implementation of organizational strategies and operations integration programs),
- financial innovations (currency risks neutralization, blockchain).

The technique proposed in this paper for evaluating the supply chain innovation performance was tested on the example of the selected Russian organization engaged in retail trade of cosmetic products purchased from domestic and foreign distributors. In the company under study, options are being considered for a radical transforming of the supply chain functioning in order to ensure compliance with current market conditions and competition. The projected version of the supply chain includes a number of changes, shown in Table 2.

Table 2. Comparison of the base and projected supply chain of the organization under consideration.

Characteristic	Base (currently used) supply chain	Projected (proposed for implementation) supply chain
Management system	Centralized	Decentralized
Management concept	Focus on assets and costs	Focus on customer needs and processes
Information flow and processing	Sequentially	In parallel
Response time to changes	Days	Hours
Planning	Interval	Continuous
Attitude to the environment	Optimal solutions based on cost criterion	Optimal solutions based on cost, safety, environmental friendliness and resource conservation, as well as environmental impact assessment at all stages of supply chain management
Logistics	Mass-approach	Mass and customized approach depending on customer needs
System of document flow	Traditional with elements of electronic system	Electronic
Cost management approach	Cost minimization	Cost optimization

Comparison of the base and projected supply chains of the selected organization (Table 2) shows the need to introduce new solutions to achieve the goals in the area of management, planning and implementation of logistics processes. In particular, it is planned to automate the processes of supply planning and management using relevant software and equipment. Two alternative supply chain innovative solutions were developed by the company's specialists, the key differences between which include the introduction of different software products and related solutions. The first project involves the introduction of special software (customized to meet the needs of the company under study) to automate the process of supply chain management, staff training, activating the environmental management policy (by introducing measures for the use of recycled materials, environmental-friendly packaging, waste reduction, route optimization). The second project is based on the introduction of a standard automated logistics system, recruiting additional qualified employees (to develop the logistics team) and activating the environmental management policy (including measures for the use of environmental-friendly packaging, recycled materials and route optimization). The options under consideration are aimed at providing automated transportation and risk management, data analysis, reporting, using key performance indicators for personnel management, ensuring electronic document management, information security, developing and making optimal decisions based on customer needs, and improving the environmental performance of the supply chain. The efficiency of solving these problems depends on the choice of one of the two projected solutions. The categories and indicators required for calculating the integral indicator of the supply chain innovation performance were determined in collaboration with experts of the company under consideration in order to evaluate these two options (Table 3).

Table 3. Categories and indicators defined for calculating the integral indicator of the two alternative supply chain innovations for company under study.

Category	Indicator	Indicator weighting	The value of the indicator (solution 1)	The value of the indicator (solution 2)
Reliability	share of on-time deliveries in the total number of completed deliveries	0.5	0.96	0.87
	order picking accuracy	0.3	0.92	0.86
	labor utilization rate	0.2	0.96	0.98
Customer focus	customer satisfaction index	0.5	0.81	0.74
	share of error-free orders fulfilled in the total number of completed orders	0.3	0.92	0.93
	share of loyal customers in the total number of company customers	0.2	0.38	0.44
Environmental friendliness	share of low-emission deliveries in the total number of deliveries	0.5	0.32	0.25
	recycled materials utilization rate	0.3	0.44	0.40
	share of rail transport in the company's total supply turnover	0.2	0.65	0.52

The analysis made it possible to reveal that the innovation projects in question are aimed, foremost, at improving the reliability, customer focus and environmental friendliness of the supply chain of the company considered. Corresponding indicators were selected within these categories. The experts assigned weighting values to the indicators (Table 3). It is important to emphasize that many authors of publications devoted to the analysis of a supply chain functioning discuss the need to shift from assessing individual logistics operations to evaluating processes as a whole, using integral and synthesized indicators (Lehyani et al., 2021; Putri et al., 2019). At the same time, this approach does not exclude the use of individual indicators for additional evaluation in order to select the optimal option among the alternatives. Based on the analysis conducted, the following main functional subsystems and indicators for supply chain evaluating can be identified:

- transport subsystem (time of loading/unloading of goods, timeliness of deliveries, transportation costs),
- inventory management (inventory management costs, inventory turnover),
- production subsystem (duration of the production cycle, capacity utilization rate),
- procurement management (supplier lead time),
- customer service subsystem (number of customer service outlets, number of claims, customer satisfaction index),
- marketing subsystem (demand forecasting accuracy, sales performance, number of loyal consumers),

- information subsystem (speed of transmission and processing of information, level of information security),
- planning (speed of altering plans, accuracy of planning and forecasting),
- innovation subsystem (level of technological development, the number of new technologies applied, the number of employees who have undertaken advanced training).

To evaluate the considered alternative supply chain innovative solutions for the selected organization, the indicators shown in Table 4 were chosen and analyzed. Changes in indicators are forecasted based on the proposed software application model for two considered options.

Table 4. Comparison of the selected performance indicators of the functional subsystems of the alternative supply chain innovative solutions.

Functional subsystem	**Selected indicators for the analyzed period (year)**	**Projected change compared to the base period (solution 1)**	**Projected change compared to the base period (solution 2)**
Transport	the number of kilometers traveled by trucks without load	reduction by 21-25%	reduction by 16-18%
	total kilometers traveled by trucks	reduction by 7-9%	reduction by 7-9%
	total logistics costs	reduction by 12-15%	reduction by 10-12%
	average lead time	reduction by 7-8%	reduction by 7-10%
Inventory and storage	inventory turnover ratio	12-16% increase	12-15% increase
	inventory management costs	reduction by 6-8%	reduction by 4-15%
	warehouse space utilization rate	8-11% increase	6-8% increase
	share of shipments of goods from current stocks	12-15% increase	12-16% increase
Customer relationship	response time to customers	reduction by 14-18%	reduction by 10-12%
	number of claims	reduction by 18-21%	reduction by 15-17%
	costs related to returns management	reduction by 6-9%	reduction by 6-8%
Information system	speed of transmission and processing of information	30-35% increase	24-28% increase
	time spent on data analysis and decision making	reduction by 22-25%	reduction by 18-20%

The data in Table 4 indicate that the first considered option, which involves the use of the customized automated system of logistics process management, is more promising for the implementation, since, in this case, the company can count on a much greater improvement in most indicators in the analyzed period compared to the second option that shows potentially better values only for the parameters of average lead time and share of shipments of goods from current stocks.

For a comprehensive analysis, indicators for measuring innovations and the integral performance indicator of the supply chain innovation were determined. The results for the two compared solutions are presented in Table 5.

Table 5. Indicators for evaluating the supply chain innovation performance for the company under study.

Indicator	The value of the indicator (solution 1)	The value of the indicator (solution 2)
Return on invested capital (ROIC)	42%	36.2%
Benefit-cost ratio (BCR, the discount rate of 16.5% is used, the analyzed period is 5 years)	21.6	16.9
Integral performance indicator of the innovative supply chain (ESC, calculated by formula (1) using data from Table 3)	23.63	21.94

The analysis conducted shows that the implementation of the first supply chain innovative solution in the organization under study is a more effective solution compared to the second proposed option. In case of introducing the first considered supply chain innovation, not only the integral performance indicator, but also other parameters, including the return on invested capital and benefit-cost ratio (Table 5), show greater values.

4 Discussion

According to the literature, there is no single, universally accepted mechanism for measuring the performance of a company's supply chain (Jagan et al., 2019; Putri et al., 2019). In addition, the use of existing methods and models for evaluating the supply chain performance is associated with various challenges, including attempts to analyze an excessive number of indicators, which are not related to the organization's strategy and the goals of introducing supply chain innovations. This approach implies increased complexity of processing large amounts of data, the analysis of which does not always help develop effective management decisions. In addition, many methods are based on the use of financial indicators as key criteria, which leads to ignoring equally important non-financial indicators of the supply chain performance. Analysis of the literature on the issues under study suggests that a promising area for overcoming the indicated barriers may be the synthesis of certain methods and performance indicators in order to select a limited number of categories and coefficients, which consider critical success factors and provide the opportunity to obtain the results needed using the integrated criteria approach instead of evaluation methods based on calculation and analysis of as many indicators as possible (Lehyani et al., 2021; Winkelhaus, Grosse, 2020). In certain cases, planned changes may be related to the development of a supply chain with the new focus, such as a green supply chain (optimization approach aimed at reducing the environmental impact throughout the product life cycle (Herrmann et al., 2021; Hijjawi, 2022)), a lean supply chain (an approach that ensures the delivery of products to the end consumer in the most efficient way, with minimal losses, costs, sufficient flexibility and adaptability (Bouhannana, El Korchi, 2021)), a sustainable supply chain (an approach based on using environmentally friendly resources, as well as their processing in order to improve their properties or reuse without harming the environment (Fu et al., 2022)). The company considered in this paper plans to

ensure a sustainable supply chain approach over time, and therefore the possibility of introducing corresponding innovative solutions is explored. As a result of the study, a technique was developed and tested, that allows considering this focus when choosing indicators for measuring the supply chain innovation performance. The suggested approach enables a balanced evaluation of alternative supply chain innovations using financial and non-financial indicators, taking into account the purpose and planned effects from the application of new solutions and technologies.

5 Conclusion

Under conditions of increased dynamics of the external environment and growing competition, the introduction of innovations is one of the most effective methods for the development of modern businesses. Global economic and technological trends set new requirements for doing business and form the need to transform business systems, including logistics. The problem of evaluating the supply chain innovation performance seems to be particularly relevant in such conditions. The article presents a comprehensive approach of measuring supply chain innovations based on the use of an integral indicator in combination with existing analysis methods, considering the goals and effects of supply chain innovations. A promising area for further research in this field includes developing mathematical models for evaluating the efficiency of outsourced processes in the supply chain and managing the logistics risks of a company.

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