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ANALYTICAL FRAMEWORK FOR INNOVATION MANAGEMENT AND MARKETING OF AN ENTERPRISE IN A CHANGING ENVIRONMENT

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АНАЛІТИЧНЕ ЗАБЕЗПЕЧЕННЯ ІННОВАЦІЙНОГО МЕНЕДЖМЕНТУ ТА МАРКЕТИНГУ ПІДПРИЄМСТВА В УМОВАХ ЗМІННОСТІ

The conditions of continuous transformation of markets and technologies create a situation in which enterprises' innovation activities are characterized by an increasingly high level of stochasticity. In particular, new products, technologies, and business models emerge unevenly and unpredictably, which creates significant challenges for strategic planning, operational management, and the creation and delivery of value to consumers. Accordingly, the purpose of this study is to provide a systematic characterization of the components of analytical support for innovation management and marketing at the enterprise level under conditions of volatility. In essence, the integration of analytical support for innovation management and innovation marketing forms a holistic uncertainty minimization system that operates as a continuous cyclical mechanism for transforming fragmented data into well-grounded managerial decisions. Its functioning is based on the integration of data collection, analysis, forecasting, decision support, and performance monitoring processes, which ensures the consistent reduction of information asymmetry and probabilistic uncertainty across all stages of the enterprise's innovation activity. At the stage of accumulating data on market trends,

technological capabilities, consumer behavior, and the competitive environment, the system minimizes uncertainty by identifying potential innovation opportunities and risks. At the analytical stage, the use of statistical, economic-mathematical, and digital methods ensures the structuring of information and the transition from intuitive judgments to formalized conclusions. The forecasting stage transforms uncertainty into a set of probabilistic scenarios for the development of innovations and markets, making it possible to assess not only expected outcomes but also extreme, critically important development paths. Subsequent decision support ensures the rational selection of priority innovation and marketing actions and the optimal allocation of resources, taking into account the stochastic nature of the environment. The final-though not terminal-element of the system is monitoring and adjustment, which form a feedback mechanism and enable the timely adaptation of innovation management and marketing strategies to changes in market, technological, and behavioral conditions.

Умови постійної трансформаційності ринків та технологій формують становище, за якого інноваційна діяльність підприємств характеризується висхідним рівнем стохастичності. Зокрема, нові продукти, технології та бізнес-моделі з'являються нерівномірно та непередбачувано, що створює значні труднощі для якісного стратегічного планування, оперативного управління, створення та постачання цінності для споживачів. Відтак, мета дослідження полягає у системній характеристиці складових аналітичного забезпечення інноваційного менеджменту та маркетингу підприємства в умовах змінності. Фактично інтеграція аналітичного забезпечення інноваційного менеджменту та маркетингу формує цілісну систему мінімізації невизначеності, що функціонує як безперервний циклічний механізм перетворення розрізнених даних у обгрунтовані управлінські рішення. Її дія грунтується на поєднанні процесів збору, аналізу, підтримки прийняття рішень і моніторингу результатів, що забезпечує послідовне зниження інформаційної асиметрії та ймовірнісної невизначеності на всіх етапах інноваційної діяльності підприємства. На етапі акумулювання даних про ринкові тенденції, технологічні можливості, поведінку споживачів і конкурентне середовище система мінімізує невизначеність шляхом ідентифікування потенційних інноваційних можливостей та ризиків. На аналітичному етапі використання статистичних, економіко-математичних і цифрових методів забезпечує структурування інформації та перехід від інтуїтивних суджень до формалізованих висновків. Етап прогнозування трансформує невизначеність у множину ймовірнісних сценаріїв розвитку інновацій і ринків та надає змогу оцінювати не лише очікувані результати, а й крайні, критично важливі варіанти розвитку подій. Етап підтримки управлінських рішень забезпечує раціональний вибір пріоритетних інноваційних і маркетингових заходів та оптимальний розподіл ресурсів з урахуванням стохастичного характеру середовища. Завершальним, але не фінальним елементом системи мінімізації невизначеності є моніторинг і коригування, які формують механізм зворотного зв'язку та дозволяють оперативно адаптувати стратегії інноваційного менеджменту й маркетингу до змін ринкових, технологічних і поведінкових умов.

Key words: cyclical mechanism; innovation management; innovation marketing; market trends; technological capabilities; consumer behavior; competitive environment.

Ключові слова: циклічний механізм; інноваційний менеджмент; інноваційний маркетинг; ринкові тенденції; технологічні можливості; поведінка споживачів; конкурентне середовище.

PROBLEM STATEMENT

The conditions of continuous transformation of markets and technologies create a situation in which firms' innovation activities are characterized by an increasingly high level of stochasticity. These processes shorten the life cycles of products and technologies, accelerate the diffusion of innovations, and intensify the volatility of consumer preferences. In practice, new products, technologies, and business models emerge unevenly and unpredictably, which creates significant challenges for strategic planning, operational management, and value creation for consumers.

Moreover, the implementation of digital, bio-, and nanotechnologies, artificial intelligence, and platform-

based innovations involves the interaction of a large number of actors and technological components. This increases the likelihood of unforeseen effects, disruptions, and synergistic outcomes that cannot be accurately predicted at the stage of managerial decision-making. Institutional and regulatory volatility-particularly changes in standards, safety regulations, environmental requirements, and state support for innovation-constitutes additional sources of uncertainty.

These features emphasize the need for effective analytical support for innovation management and marketing, enabling enterprises to adapt to change, make timely managerial decisions, and optimize marketing strategies.

Thus, a modern enterprise cannot ensure successful innovation activity without an integrated approach to analytical support for management and marketing, especially under conditions of market volatility and unpredictability. It is precisely the integration of analytics with managerial decision-making that enhances enterprise adaptability, reduces risks, and ensures sustainable innovation-driven development.

ANALYSIS OF RESEARCH AND PUBLICATIONS

The problems of analytical support for innovation management and marketing at the enterprise level are addressed in the works of Zaverbnyi A., Nodzhak L., Mishchanchuk S. [3], Berezniak N. V. [1], Kvasha T. K. [1—2], Manaienko I. M., Kravets A. I. [4], Hurman O., Kostenko D., Runcheva N., Bocharova N., and Khytrova O. [5]. In particular, these scholars focus their research on the theoretical and methodological foundations of analytical support for managerial decision-making, the role of analytics in managing enterprises' innovation activities, and the toolkit of marketing analysis.

At the same time, the characteristics of the components of analytical support for innovation management and marketing under conditions of environmental volatility and heightened uncertainty remain insufficiently systematized and comprehensively examined in the existing scientific literature. The absence of clearly structured characteristics of these components hinders the formation of an integrated information and analytical framework, which negatively affects the quality and timeliness of managerial decision-making in the field of innovation management and marketing.

Moreover, insufficient systematization of analytical support leads to fragmented use of analytical and forecasting methods in managerial and marketing activities, complicating their integration into a unified system for supporting enterprise innovation development. Under conditions of increased environmental volatility and uncertainty, the lack of adapted analytical tools limits the ability to timely identify threats and opportunities, thereby increasing the risk of erroneous managerial decisions and financial losses.

In summary, the identified problems highlight the need for further scientific research aimed at developing and improving the analytical support of innovation management and marketing at the enterprise level, taking into account the volatility and uncertainty of the external environment.

FORMULATION OF THE ARTICLE'S OBJECTIVES

The purpose of the study is to provide a systematic characterization of the components of analytical support for innovation management and marketing of the enterprise under conditions of volatility.

THE PAPER MAIN BODY

Within the scope of this study, the category of "analytical support" is considered as a well-established complex of systematized methods for data collection, processing, and interpretation which, according to the studies by Zaverbnyi A., Nodzhak L., and Mishchanchuk S. [3], form the information and analytical basis for making well-founded managerial decisions at the enterprise level.

At the same time, innovation projects are increasingly implemented under conditions of incomplete and asymmetric information regarding future "rules of the game" in markets and the technological environment. This transforms traditional risks into stochastic variables with an asymmetric distribution of potential gains and losses. For instance, during the implementation of digital or environmentally oriented innovations, an enterprise may lack complete information about future changes in regulatory requirements, certification standards, or the scope of government support.

In such a situation, the expected economic outcomes of an innovation project are formed not as fixed values, but as a set of probabilistic scenarios in which potential gains (such as an increase in market share, cost reduction, or access to new markets [4]) coexist with the risk of significant losses in the event of unfavorable institutional or technological changes.

Under such conditions, analytical support, alongside classical analytical tools, is increasingly oriented toward the use of flexible statistical, economic-mathematical, and information methods, as well as their mathematical, algorithmic, or logical-informational constructs. This orientation ensures a focus on continuous monitoring and assessment of the impact of internal and external factors, forecasting trends in market and technological development, and optimizing management strategies under conditions of uncertainty.

It should be emphasized that analytical support within innovation activity should not be considered as a separate static object. Owing to its economic and functional nature, it represents a dynamic, process-oriented system.

Accordingly, it functions as a multi-level functional structure that integrates a set of interrelated methodological elements, in particular:

1. Information collection methods, including surveys, focus groups, in-depth interviews, analysis of market statistics, web analytics, social media data, as well as large-scale datasets (Big Data).

2. Data processing and analysis methods, notably statistical techniques (correlation and regression analysis, clustering), economic-mathematical models (optimization, forecasting, and scenario models), expert judgment and Delphi methods, as well as advanced digital analytical tools, including machine learning, big data analytics, and business intelligence (BI) systems.

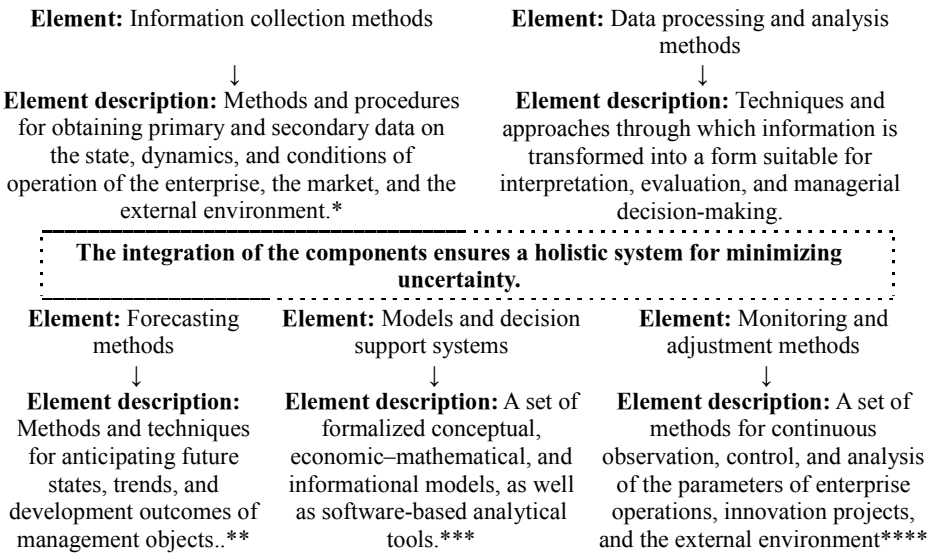

Figure 1. Structural characteristics of analytical support for enterprise innovation management and marketing under conditions of volatility

Note:
* Refers to data that ensure the formation of a reliable, comprehensive, and relevant information base for further analytical processing and managerial decision-making.
** Refers to methods based on the analysis of historical data, current information, and identified patterns, taking into account uncertainty and stochasticity of the external and internal environment.
*** Refers to methods intended for the preparation, justification, evaluation, and selection of managerial decisions based on the analysis of alternatives, forecasting their consequences, and consideration of resource constraints and risks.
**** Refers to methods aimed at the timely identification of deviations from planned objectives, detection of threats and opportunities, and the prompt implementation of corrective managerial decisions.
Source: developed based on [1—3; 5—7].

3. Forecasting methods based on complex algorithms for predicting future trends, outcomes, or indicator values, with the capacity for self-learning using large volumes of historical and real-time data.

4. Models and decision support systems, including intelligent, rule-based, optimization, and resource models that ensure the systematization of alternatives, assessment of the consequences of managerial decisions, and selection of the most appropriate strategic actions.

5. Monitoring and adjustment methods, encompassing dashboards and analytical panels, early warning systems, as well as mechanisms for identifying predictive signals and adjusting managerial decisions in real time.

Thus, analytical support for innovation activity emerges as an integrated system for minimizing uncertainty (see Figure 1), capable of enhancing the validity and robustness of managerial decision-making throughout the implementation of innovation projects.

When examining the role of information collection methods in minimizing uncertainty, it should be noted that this role is associated with the formation of a primary and secondary information base regarding the existing and potential innovation opportunities of the enterprise. For example, marketing research methods (surveys, focus groups, and interviews) enable the identification of current consumer needs, expectations, and behavioral motives; observation of consumers and competitors makes it possible to capture changes in market practices, strategies, and innovation activity; analysis of secondary sources allows for the systematization of existing knowledge about market conditions and dynamics, technological trends, and industry transformations.

In addition, digital data collection (web analytics, social media, and Big Data [4; 5]) expands the temporal and spatial boundaries of analysis, ensuring the timeliness and scalability of information.

When examining the role of data processing and analysis methods within this framework, it should be noted that it is associated with transforming primary and secondary information into a form suitable for systematization, aggregation, comparison, and interpretation of data, as well as for identifying patterns, trends, and correlations. In particular, statistical methods make it possible to detect regularities, interrelationships, and market segmentation features, while economic-mathematical models enable the formalization of economic processes and the evaluation of alternative managerial decisions. Expert judgment and Delphi methods help compensate for the lack of quantitative data by drawing on the professional experience of specialists. Within this group of methods, modern digital and analytical tools are also of particular importance, as they enhance the accuracy, depth, and speed of analysis, which is critical under conditions of high volatility.

With regard to forecasting methods, their significance in reducing temporal uncertainty is determined by their ability to form well-grounded expectations about the future state of markets, technologies, and consumer demand. Within the analytical support system, these methods are key due to their reliance on complex forecasting algorithms that learn from large-scale datasets, thereby enabling the identification of trends, development scenarios, and potential growth points.

Table 1. The role of models and decision support systems in the uncertainty minimization mechanism

Type of models / systems	Model focus	Specifics of alternative systematization	Specifics of assessing managerial decision outcomes	Role in selecting the most appropriate decision
Intelligent models (expert systems, artificial intelligence, neural networks)	Processing complex, weakly structured data and learning from prior experience	Formation of a set of alternatives based on the analysis of large-scale datasets, identified patterns, and hidden interrelationships	Modeling possible development scenarios, forecasting outcomes, and estimating their probabilities	Supporting the selection of decisions taking into account projected effectiveness and risk level
Rule-based models (logical, normative, algorithmic)	Formalizati on of managerial logic and managerial constraints	Structuring of alternatives in accordance with established rules, norms, strategic objectives, and constraints.	Assessing the compliance of alternatives with specified criteria, standards, and acceptable limits.	Ensuring the selection of managerial decisions that are aligned with the enterprise's strategy and regulations
Optimization models (linear, nonlinear, multi-criteria programming)	Identificatio n of the optimal solution based on specified criteria.	Ordering of alternatives into formalized options with clearly defined parameters.	Quantitative evaluation of the consequences of each alternative using a system of indicators.	Selecting decisions that maximize utility or minimize losses.
Resource models (balance, portfolio, simulation models)	Rational allocation and utilization of limited resources.	Grouping of alternatives according to resource requirements and the feasibility of their provision.	Analysis of the impact of each option on resource utilization, system stability, and balance.	Ensuring the choice of a decision that is not only effective but also resource-feasible and sustainable.

Source: developed based on [1—2; 4; 6—7].

When examining the role of models and decision support systems, it should be noted that they effectively ensure the integration of analytical results into the management process. In particular, intelligent, rule-based, optimization, and resource models provide for the systematization of alternatives, assessment of their potential consequences, and selection of the most appropriate managerial decisions, as clearly demonstrated by the data presented in Table 1.

At the same time, the generalization of the models and systems outlined above made it possible to conclude that they reduce the subjectivity of choice, enhance the soundness of managerial actions, and contribute to the minimization of uncertainty under conditions of dynamic change.

Monitoring and adjustment methods are also important due to their value as components supporting the adaptability of the uncertainty minimization mechanism. Control and corrective dashboards enable real-time tracking of key performance indicators, early warning systems allow for the timely identification of deviations and threats, while predictive signals initiate adjustments to strategic and tactical decisions. As a result, the mechanism acquires a cyclical nature and the capacity for self-adjustment.

Taken together, the identified components form an integrated system of analytical support for innovation management and innovation marketing and, consequently, a functional structure for minimizing informational, temporal, and behavioral uncertainty. This structure creates a foundation for proactive innovation management and reduces the risk of strategic errors.

Accordingly, innovation activity is characterized by a high level of uncertainty, unpredictability, and dynamism. This implies that traditional methods of analysis and forecasting require adaptation and extension, as it is necessary to account for rapid technological change, unpredictable market reactions, variability in consumer needs, and the evolving capabilities of competitors.

In essence, analytical support for innovation management encompasses both traditional and advanced methods of collecting, processing, and interpreting data on market trends, technological capabilities, and consumer behavior. These methods are aimed at reducing uncertainty, ensuring the timely identification of innovation opportunities, and improving the accuracy of managerial decision-making. Structurally, such analytical support includes [1—2; 4; 6]:

1. Data collection on market trends, technological innovations, and consumer behavior to identify potential opportunities and risks.

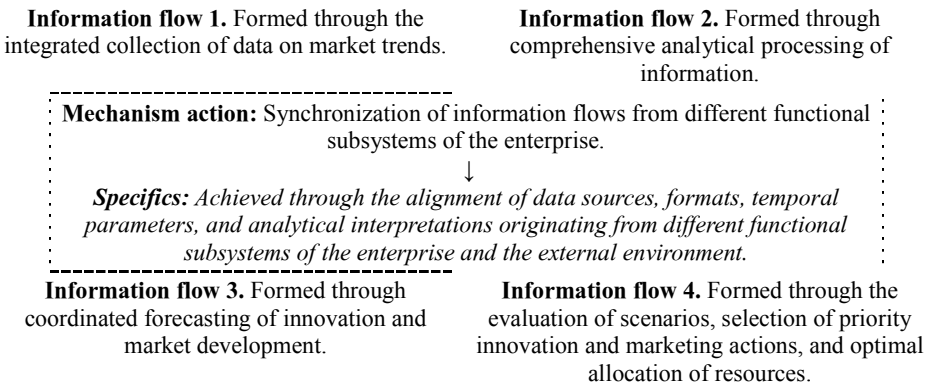

Figure 2. Analytical support for enterprise innovation management and marketing as a continuous cyclical mechanism for transforming fragmented data into well-grounded

Source: developed based on [3; 5—6].

2. Data processing and analysis using statistical, economic-mathematical, and information methods to generate well-grounded conclusions.

3. Forecasting innovation development and assessing potential scenarios for the implementation of new technologies and products.

4. Decision support, ensuring the timely selection of priority innovation projects and the optimization of resource allocation.

5. Monitoring and control of innovation performance to adjust strategies and enhance enterprise adaptability under conditions of volatility.

In turn, analytical support for innovation marketing includes both traditional data collection methods and modern approaches to data analysis related to consumer needs, the competitive environment, the effectiveness of advertising and promotional activities, as well as the assessment of market trends. This enables the development of accurate marketing strategies, demand forecasting, optimization of communication with target segments, and enhancement of enterprise competitiveness. Structurally, analytical support for innovation marketing includes [2; 4; 6—7]:

1. Data collection on consumer needs, target segment behavior, competitors' actions, and market trends.

2. Data processing and analysis using statistical, economic-mathematical, and advanced digital methods to support well-grounded marketing decisions.

3. Demand and market trend forecasting, as well as evaluation of the effectiveness of advertising and promotional activities for marketing strategy planning.

4. Decision support, ensuring the optimization of communication with target segments and the identification of priority marketing actions.

5. Monitoring and evaluation of marketing campaign results, strategy adjustment, and enhancement of the adaptability of the enterprise's marketing activities under conditions of dynamic market change.

It should be noted that the integration of analytical support for innovation management and marketing forms an uncertainty minimization system that operates as a continuous cyclical mechanism for transforming fragmented data into well-grounded managerial decisions.

The implementation of such a mechanism is achieved through the sequential integration of information flows from various functional subsystems of the enterprise, which are synchronized and mutually complemented according to the following algorithm (see Figure 2).

Thus, information flows are formed and synchronized along the following directions:

1. Integrated data collection on market trends, consumer preferences, technological capabilities, and the enterprise's internal resources, which reduces information asymmetry between markets, technologies, and managerial decision-making.

2. Comprehensive analytical processing of information using statistical, economic-mathematical, and digital methods, as a result of which unstructured data are transformed into formalized indicators, metrics, and analytical insights.

3. Coordinated forecasting of innovation and market development, within which the results of managerial analytical calculations are correlated with marketing forecasts of demand, competitive actions, and consumer behavior, enabling the development of alternative scenarios with different probability levels.

4. Scenario evaluation, selection of priority innovation and marketing actions, and optimal resource allocation, taking into account the stochastic nature of the external environment.

CONCLUSIONS

In essence, the integration of analytical support for innovation management and innovation marketing forms a holistic uncertainty minimization system that operates as a continuous cyclical mechanism for transforming fragmented data into well-grounded managerial decisions. Its functioning is based on the integration of data collection, analysis, forecasting, decision support, and performance monitoring processes, which ensures the consistent reduction of information asymmetry and probabilistic uncertainty across all stages of the enterprise's innovation activity.

At the stage of accumulating data on market trends, technological capabilities, consumer behavior, and the competitive environment, the system minimizes uncertainty by identifying potential innovation opportunities and risks. At the analytical stage, the use of statistical, economic-mathematical, and digital methods ensures the structuring of information and the transition from intuitive

judgments to formalized conclusions. The forecasting stage transforms uncertainty into a set of probabilistic scenarios for the development of innovations and markets, making it possible to assess not only expected outcomes but also extreme, critically important development paths.

Subsequent decision support ensures the rational selection of priority innovation and marketing actions and the optimal allocation of resources, taking into account the stochastic nature of the environment. The final-though not terminal-element of the system is monitoring and adjustment, which form a feedback mechanism and enable the timely adaptation of innovation management and marketing strategies to changes in market, technological, and behavioral conditions. Thus, the uncertainty minimization system does not eliminate uncertainty entirely but transforms it from an uncontrolled state into a manageable one, thereby enhancing the accuracy, adaptability, and robustness of managerial decisions in the process of enterprise innovation development.

Prospects for further research are associated with deepening the formalization of the integrated system of analytical support for innovation management and marketing, in particular through the development of adaptive economic-mathematical models and digital tools capable of accounting for the stochastic nature of markets and technologies in real time and enhancing the accuracy of managerial decision-making.

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