Enhancing Decision-Making Efficiency through Contextual Application of Probabilistic Models in Crisis Management

By Inna Hordieieva[1], Halyna Tarasiuk[2], Nadiia Vasylieva[3], Iryna Kalmykova[4], Igor Paryzkyi[5]

ABSTRACT:
The current economic crisis makes the research and implementation of new methods of making managerial decisions and managing their alternatives particularly relevant. This article is devoted to a study on applying probability theory to managerial decisions under uncertainty. This study used a general approach that includes diagnostics, synthesis, generalisation, description, induction, deduction and abstraction. The article establishes the rationale for a crisis management strategy. A crisis prevention system is also developed, revising the principles of strategy formation under conditions of uncertainty. Finally, considering the current economic environment, new methods of improving crisis management are proposed. The article presents the results of applying probabilistic models in management decisions that require consideration of the system's significant internal and external factors. It also emphasises the need to improve the probabilistic management system in economic instability. A model of the mechanism of the anti-frontal system for implementing a crisis management strategy is proposed, which includes undesirable factors along with a block of local unpredictable actions. This methodology aims to increase the potential and practical effectiveness of systematic planning, theoretically facilitating the implementation of erosion strategies, especially in economic supervision.

Keywords: probabilistic models, management in crisis conditions, economic feasibility, risk management, strategic development, state regulation, public administration, innovative approaches in public management.

1. Introduction

Ensuring and implementing the most effective management decisions and actions is one of the most challenging problems in studying and modelling complex economic systems. Decision-making, especially in conditions of destabilisation, becomes more complicated to the point where the issue being decided in a system or area ceases to exist. The lack of preventive information about changes in the economy, the impossibility of formalising crisis shocks in the socio-economic system, the diversity of reactions of

|[1]Department of Intellectual Property and Project Management, Faculty of Machine Design and Environmental Protection, Ukrainian State University of Science and Technologies, Dnipro, Ukraine.
[2] Faculty of Business and Service Sector, Zhytomyr Polytechnic State University, Zhytomyr, Ukraine.
[3]Department of Technology Management, Lviv Business School, Ukrainian Catholic University, Lviv, Ukraine.
[4]Department of Tourism Business and Recreation, O. O. Preobrazhenskyi Educational and Scientific Institute of Hospitality and Travel Industry and Enology, Odesa National University of Technology, Odesa, Ukraine.
[5]Department of Marketing, Economics, Management and Administration, National Academy of Management, Kyiv, Ukraine.

economic actors, the competitiveness and diversity of interests of disorder, and the multifactorial nature of determining the essential conditions of complications all contribute to the deepening of the dynamics of the expected potential of economic processes.

Modern concepts of the development of management processes assimilate several main directions: innovative media and integrated communications, targeting and personalization, visual communication and digital content, audience involvement and crowdsourcing, crisis communication, actualization of trust and ethics. The growing popularity of digital media is a determining factor in the formation of public opinion.

Probabilistic models allow you to process uncertainty and variability, which is an integral part of digital data and processes. In particular, many machine learning algorithms used in digital analytics are based on probabilistic modeling. Thus, neural networks with a probability distribution or logistic regression allow you to identify patterns in information data arrays, make predictions, classify and differentiate.

In terms of practical implications for managers adapting to the digital era, digitalization optimizes decision-making processes, simplifies complex systems, and provides greater reliability and accuracy to models. Practical examples of the synergy of digitalization and probabilistic modeling include recommender systems, recognition algorithms, audits, etc.

Adapting and improving corporate governance strategies in the face of economic uncertainty is one of today's most challenging issues. For example, some scholars who study managerial changes in the digital era note that this significantly changes the way management decisions are modelled (Levenchuk et al., 2021; Izmailova et al., 2022).

Numerous contemporary researchers have noted that government strategies, including systems of management actions, are necessary for the effective management of economic processes in modern states (Debela, 2021).

At the same time, in substantiating the views on crisis and public administration in international concepts, Chorna et al. (2017) argue that these concepts are constantly changing shape due to the impact of internal and external forces on business competitiveness.

However, scientists note that the use of probabilistic modelling with a sample approach needs to be refined in management during economic instability. This particular concept is in evolution and requires further research and scientific study. Less attention has been paid to the development of practical algorithms for formulating management strategies to mitigate volatility's effect on decision accuracy and efficiency. This article seeks to analyse the impact of probabilistic models on the rational choice of a managerial decision, particularly in dealing with the consequences of uncertain situations.

2. Literature review

The research of both domestic and foreign scholars forms the theoretical and methodological basis for the formation of approaches to management under conditions of uncertainty. Considerable attention is paid to modelling in management processes during crises and unstable conditions.

It is worth noting that developing a crisis management system becomes pedagogical and routine during socio-economic and political instability. It is usually a significant media and PR event. Ukrainian scientists Litvinov and Zhurenko (2017) focus on the theoretical, methodological, and technical details of management under uncertainty. Their research examined the (ordinal) management mechanisms, their classification, and the specifics of using the relevant instruments.

Mokhnenko and Antonov (2023) note that efforts are generally focused on improving forecasting and assessing the performance of economic activity under conditions of uncertainty, which is equally important for supporting growth and promoting innovation.

In contrast, other researchers – Podderiohin et al. (2017) emphasise that the controllability of operational decisions in the management system is a critical factor that affects not only the results but also the continuity of business operations.

Tulchynska and Kyryliuk (2023) consider it challenging to model the effectiveness of management decisions in crises and instability of economic systems.

Researchers Pellegrino et al. (2021) emphasise that global economic shifts have accelerated the evolution of the business process. Failure to properly adopt modern decision-making modelling paradigms can lead to losing critical areas of competitive advantage.

The need for practical application of probabilistic modeling of the management situation is caused by the complexity or impossibility of conducting experiments in real life. The key specificity of the model is the maximum simplification of the real situation by eliminating secondary details, which increases the ability of managers to adequately perceive the situation and identify priority problems.

An example can be solving the problem of determining the level of quality of medical services, for which modeling the quality of diagnostic systems in medicine is used, taking into account the basic principles and methods of qualimetry and ontology of the subject area in the field of health care. This allows you to increase the reliability of the results of assessing the level of quality of requirements for the quality of medical care and services.

Despite significant scientific achievements in this area, the problem of implementing probabilistic modelling methods in the management decision-making process remains. In addition, the scientific community faces the difficult task of developing a flexible paradigm of strategic management of an organisation under uncertainty, which rapidly changing market conditions can quickly modify. This necessitates further in-depth and detailed study of the problem.

3. Methods

The basis of this study is a scientifically sound methodology, including abstract-logical, functional, structural analysis, synthesis, generalisation, specification, induction, deduction and theoretical modelling. One of the foundations of this study is the results obtained, which allowed us to study the subject of research in its complex systemic structure as a set of elements and interrelationships. The study of the primary properties

of the object, modern management strategies, and transformational capabilities was carried out using a systematic, integrated approach.

In this case, the inductive method was used to predict the accuracy and success of management decisions in quantitative modelling. In addition to abstraction as a way of identifying the cause-and-effect relationships of a scenario, operators such as generalisation have allowed for forming a conceptual basis for modern management paradigms. At the stage of researching primary achievements, i.e., defining definitions, management through systematic probabilistic modelling in management paradigms exists in many forms, including without considering rapid globalisation and crises.

4. Results

In the context of socio-economic instability, crisis, and management in an information-saturated environment, the uncertainty of modern management concepts is a key problem of management strategy, which does not allow to fully reveal the potential of modern management concepts. The crisis generates instability of the influence of a number of factors and complicates forecasting and strategic management.

Uncertainty is the second aspect that has a very negative impact on the functioning of enterprises. To overcome such characteristics, crisis management is developed, which consists of current and future strategies for achieving results (Sniazhko, 2019).

Such actions could raise the state, the governance systems themselves, and the crisis management matrices to the second level, both at the regional and national levels. Such economic modelling in socio-economic data has excellent functionality since socio-economic systems are built with complex structures, and the threats and risks of the system, in turn, are formed under their construction. Modifying the averaged data that form the boundaries in internal management systems is a step that can significantly increase the effectiveness of management actions within the limits caused by uncertainty (Polehenka, 2016).

The study of the main trends in the methodological support of sustainable economic development in the context of socio-economic and socio-political instability indicates the growing importance of integrated methods. Such an approach is the most productive since it considers the peculiarities of management processes in terms of their change in a state of uncertainty.

Economic activity's sustainability is dependent mainly on random and probabilistic factors. That is why the analysis of such systems can be based on the introductory provisions of the theory of random processes. Various linearisation methods can be used to find the best solutions to management problems, facilitating constructive and decisive changes in the system.

Creating and improving management mechanisms in times of instability requires correlating all external and internal system variables. This allows for the individual deployment of self-sufficient analytics for each random variable that has a significant impact on the system (Santacruz, 2019).

Modelling is crucial in times of uncertainty. It is the main scientific tool for developing forecasts and assessing the potential outcomes of alternative management decisions. Every management concept defines the need for an articulated procedural

model of the mechanism that will help in strategic decision-making and formulating effective, albeit unmanageable, models of powerlessness.

The importance of innovation in public administration can be argued with specific examples. Public sector reform, adaptive management and the real implementation of probabilistic systems are closely linked. Governments can realistically integrate these tools to navigate an unpredictable socio-economic environment. Examples of the implementation of probabilistic models in management can be:

1) Project management, in particular:

- assessment of project duration and cost (PERT method – Program Evaluation and Review Technique – allows you to assess the probability of completing a project within a given budget and time frame);

- project risk management (identification of potential risks and assessment of their impact);

- optimization of project planning (prioritization, resource allocation);

2) Financial analytics, in particular, assessment of investment portfolio risks (VaR (Value at Risk) models);

3) Risk assessment for decision-making under uncertainty.

The integration of these tools into the functioning format of modern governments will allow for effective risk prevention, decision-making under uncertainty, and optimization of management processes. This is explained by their ability to take into account random factors and their impact on performance.

The initial step in exploring probabilistic modelling is to complete a comprehensive analysis framework. The availability of time and relevant information is central to deciding on a management modelling method. However, an important factor in this phenomenon is the innovative approach of public administration based on adaptability, flexibility and openness to new technologies (Rishniak, 2003).

In terms of formalising governance processes, the following key components of the model can be distinguished among political techniques:

- alternatives that form a single interconnected network;
- objectives and functions;
- systems of openings designed for specific conditions (Filipenko, 2016).

Solving the problem of probabilistic models is usually carried out by applying a mathematical method, which, when chosen, should take into account the nature and degree of complexity of the system under study.

To adequately use the results of model-based probabilistic studies, it is necessary to monitor the model and continuously assess its relevance to reality. Previous experience creating and using such models determines their high efficiency, so the current version of the model requires constant adaptation due to the dynamic change of the operating environment. Modelling makes it possible to justify the optimal choice of alternative management decisions, thus ensuring effective management (Klasing, 2017).

Today, digital systems can calculate all linear processes within the probabilistic modelling framework. Regarding the complexity of obtaining accurate analytical solutions, you can resort to the asymptotic representation apparatus or other mathematical constructs. Management systems under uncertainty should begin with the most detailed

analysis of all known factors affecting the system, focusing primarily on the most important economic processes.

Based on the above-mentioned factors, specific tasks should include putting in order the identification of potential threats in the face of uncertainty. In this context, in times of crisis, state regulation should actively act as a source of stability about the central management components of the system, which, in turn, should maintain systemic integrity (Moshkivska, 2023).

Among the main tasks solved by quantitative economic analysis using strategy formation algorithms through computer modelling are economic development and limiting the consequences of certain negative factors. Such models are often implemented using specially developed algorithms for individual simulation and empirical probabilistic modelling.

This leads to new opportunities for organising experimental exploration work using modern digital technologies and economic and mathematical analysis. Explicitly, the process or several stages of this probabilistic programming technology can be concentrated in an algorithm that adapts it to specific socio-economic conditions through the step-by-step development of an adaptive practical probabilistic model (Figure 1).
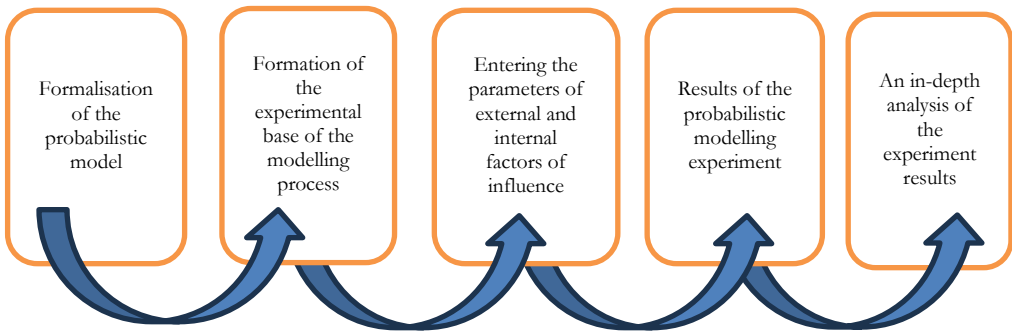

Figure 1: *The standard algorithm for implementing probabilistic modelling*
Source: author's elaboration based on (Shuban, n.d.)

In analysing Figure 1, the probabilistic model is designed to combine individual elements of economic activity. This is useful for developing a model description that contains quantitative elements of the distribution of variables.

According to this study's results, a normal distribution with fixed model parameters best approximates economic processes under conditions of instability.

The limitations of the study are provided by the complexity of experimental verification of theoretical conclusions. Also, among the limitations of the study, it is worth focusing on the invalidity of the assumption of normality of data in crisis conditions.

Against the background of crisis phenomena, it is considered advisable to use non-parametric or hybrid models as more reliable alternatives. Hybrid models often combine probabilistic approaches and expert assessments. Hybrid models that combine several approaches allow for more accurate prediction of the development of management processes. They are used to optimize resource allocation, analyze the impact of various

decisions on the final result, and identify critical points that may serve as obstacles to effective management.

Examining the results of calculations obtained through in-depth data analysis is one of the main functions that help create a probabilistic model. This process is based on estimating the probability that a particular value falls within a specific range and predicting specific outcomes estimated to have a certain probability. This approach is a powerful tool for developing management anti-crisis strategies under conditions of uncertainty, improving decision-making processes, and the effectiveness of strategic management systems.

In this regard, the central government is expected to introduce either direct forms of administrative control or indirect regulatory controls. Administrative methods include legal norms and mechanisms of persuasion and coercion, while regulatory approaches include incentives, democratisation of governance, public initiatives, and commissioning of social services (Zanora, 2014).

In the context of socio-economic instability, probabilistic models allow for more thorough quantitative assessments and analytical evaluations of the effectiveness of management decisions. This approach raises the decision-making system to an entirely new level of accuracy and validity.

The management field benefits considerably from such a "professional" application of probability, facilitating the organisation of previously untouched intuitive assumptions, thus increasing decisions' consistency, order and reliability. In addition, such models offer an elegant solution to the problem of combining the power of intuition with practical experience to make optimal management decisions (Ian Dew-Becker, 2017).

Decision options based on probabilistic models make alternative management decisions. As a result, they improve the choice of more accurate and efficient administrative actions. However, the inability to use them in the face of ambiguity can significantly impair the overall effectiveness of the management system. Finally, resolutions developed with the help of probabilistic models should be noted because they require much more careful analysis and constant monitoring of the results achieved.

5. Discussion

Changing approaches to the management of market participants under conditions of uncertainty requires a relatively rapid formulation of management decisions. As noted by Hovorushko (2008) the ability of enterprises to respond adequately to an unstable economic environment is crucial.

According to Kovtunenko (2014) the impact distribution within the probabilistic modelling framework involves a modern approach based on classical risk management. This methodology includes probabilistic indicators and the degree of their impact on management processes.

According to modern scientific developments by Levenchuk et al. (2021) an important factor in achieving high-quality and productive management decisions is modifying management algorithms through computer modelling of processes. Levenchuk argue that introducing process modelling methods in the field of innovation using

information technology increases the effectiveness of management in an organisation during times of crisis.

Naumenko and Havrylko (2010) complement the idea of the importance of developing preliminary long-term plans in the management framework in unstable conditions. They also emphasise the principle of economic feasibility and note that a large amount of information can be processed using a powerful analytical tool – modelling. The scientists' conclusions are consistent with our research results, which confirmed that modern methods of probabilistic modelling contribute to the coordination of management processes and their effective adaptation to an unstable environment.

Modern business process management strategies are considered the basis for successful business in the face of uncertainty in obtaining information on time and in full. For this reason, these scientists point to the controversial need for innovative solutions to management problems. Such solutions involve more thorough analysis and forecasting tools, including through interaction. These methods should be implemented in addition to actively supporting innovations in developing management processes (Zaitseva, 2014).

Not all modern sciences agree with these facts, namely with the growing importance of modular programming, which allows management decisions in conditions of economic or political uncertainty. The mechanisms of crisis management have changed. This reality makes it imperative to have an effective manager who can surround himself with the necessary resources. With this trend, a minimal progressive element of strategic management remains an outdated management regime (Herz, 2011).

It is worth noting that when modelling decision-making under uncertainty, a whole range of incomplete aspects must be considered. Undoubtedly, the theory and algorithms of modelling have already been widely studied, but, for example, in the engineering sector, it is highly effective to use implemented techniques, not to mention other sectors with similarly unstable economic conditions.

It is challenging; however, implementing things like mobilising everything for the brain, which is superior, to manipulate instead of analysts would be simply inexcusable.

Digital marketing is becoming an important tool for state administrative bodies that seek to increase the efficiency of their services and interaction with citizens. In particular, this issue has been paid attention to by scientists Yankovets and Vyshnevska (2020). The authors' research has shown that the introduction of digital technologies significantly increases the efficiency of interaction between society and state administrative bodies.

The researchers call the following key advantages of this interaction:
- simplification of administrative requests and procedures;
- quick access to administrative services;
- increased transparency and openness of the administrative process.

This represents a positive effect of digitalization in the context of service quality. At the same time, scientists have identified a number of shortcomings, such as limited access to digital services for certain categories of society. It is obvious that such a situation can serve as a cause of inequality in access, which determines the need to develop inclusive strategies for administrative development.

The main directions of future research include the evaluation of real-time decision-making tools that combine probabilistic modeling with artificial intelligence for

dynamic strategy review. The use of artificial neural networks, in particular, agent modeling and machine learning with elements of intelligence, allows you to automate certain stages of modeling, as well as increase the accuracy of forecasts. Ultimately, this allows you to gain a deeper understanding of the dynamics of the systems under study.

Among the advantages of involving artificial intelligence are the optimization of the scenario generation process, parameter optimization and model calibration, as well as advanced analysis of simulation results. Therefore, it is necessary to deepen the prospects for further integration of artificial intelligence into simulation models.

6. Conclusion

The methodological approach to ensuring the stability of economic indicators in an unstable socio-economic environment involves coordinating efforts to develop effective management strategies, flexibility, and prompt response to market conditions.

The structural approach to solving these problems and the rational use of these external and internal factors lead to the adoption of management decisions that are easy to implement. This helps maintain enterprises' competitiveness in the face of market instability and contributes to balanced and sustainable business development.

Digital marketing strategies for business competitiveness are closely related to probabilistic models in a management context, which can serve as a promising direction for extended research on the issues considered in this article. During crisis situations, the implementation of digital marketing technologies contributes to improving the quality of public services and improving communication with citizens. The main elements of digital marketing used in public administration are websites and portals, social networks, content marketing, display advertising, search engine optimization (SEO), mobile applications, chatbots, video advertising.

Recommendations are provided to improve the accessibility of digital services, which will ensure equal access to services for all citizens and improve their use.

This study analysed the possibilities of optimising marketing strategies to increase competitiveness and effectively promote goods and services in a crisis environment. The study results confirmed that the use of modern digital technologies in marketing systems helps to increase productivity and significantly strengthens companies' competitive advantages in a challenging market environment.

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