

Econometric Modeling of Risks in the Direct Public Procurement Process in Public Healthcare

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Abstract. *The principles adopted by the European Union, as expressed in the Treaty on the Functioning of the European Union (TFEU), are reflected across numerous domains, including public procurement. Until 15 January 2014, public procurement in Europe was governed by Directive 2004/18/EC on the coordination of procedures for the award of public works, supply and service contracts; Directive 2004/17/EC coordinating procurement procedures in the water, energy, transport and postal services sectors; and Directive 2009/81/EC concerning the coordination of procedures for the award of certain works, supply and service contracts by contracting authorities or entities in the fields of defence and security, amending Directives 2004/17/EC and 2004/18/EC.*

Keywords: procurement, risk, management, e-procurement, business.

Introduction

In defining the problem, one can start from the well-known popular saying, full of wisdom and philosophical connotations: “If a man knew what would happen to him in advance, he would take precautions!” The predictability of the evolution of an organization’s subsystems is a very important attribute of management, often decisive for the institution’s performance [1].

Every organization, among its multiple secondary objectives subordinate to the central goal, also has the objective of avoiding unforeseen expenses. Regardless of the level of organizational and managerial culture and performance, these expenses cannot be completely eliminated, because it is inherent in the logic of things that chance will manifest, no matter how well organized, structured, and planned this type of expense may be.

From the perspective of the hospital as a public organization providing health services and products, the additional expenses generated in the process of public procurement are unforeseen expenses. They cannot be fully budgeted, or, in any case, their budgeting is under the aegis of uncertainty, as is always the case with unexpected costs. It follows that an aim of hospital management is to approximate as closely as possible the real value of unforeseen expenses, which raises the issue of predictability. Indeed, the most reliable way to eliminate unforeseen expenses is to transform them into normal expenses. Therefore, it is first necessary to clarify in which category these additional expenses can be classified [2-4].

From an economic perspective, the additional expenses that may arise in the process of public procurement represent economic risks and should be treated as such. Since this association simplifies the approach and can open the way for research, it must be properly justified. In the Romanian Explanatory Dictionary (DEX), the first definition of risk is the possibility of encountering danger, facing trouble, or sustaining a loss; a potential hazard. All other meanings also include the notion of loss; and additional expenses fall precisely into this category: that of losses.

The specialised literature does not offer a clear and (quasi-)universally accepted definition of the concept of risk; rather, numerous definitions exist, but almost all circumscribe the idea of the possibility of loss or suffering harm.

The concept of risk and its derivative, economic risk, should be considered from two different perspectives:

- focusing on undesirable events that may cause harm and on avoiding such events; clearly, this pertains to what is called the **pure risk perspective**;
- obtaining the information necessary for making a correct, well-founded decision, so that the associated risk is minimized - that is, to reduce the unforeseen as much as possible.

This second perspective aligns most closely with performance-based management, which necessarily includes a component for organizing the risk management process within a public entity (organization). There are numerous concepts related to risk: residual risk, risk appetite and tolerance, impact and probability, etc. However, the present research does not aim to focus on these, as they are not the subject of this study.

In what follows (Figure 1), only the model illustrating the partial overlap of activities within the stages of risk management will be detailed. Practically, this figure also reflects the logic of the entire research work, contributing to the definition of its object and the subsequent establishment of the research objectives.

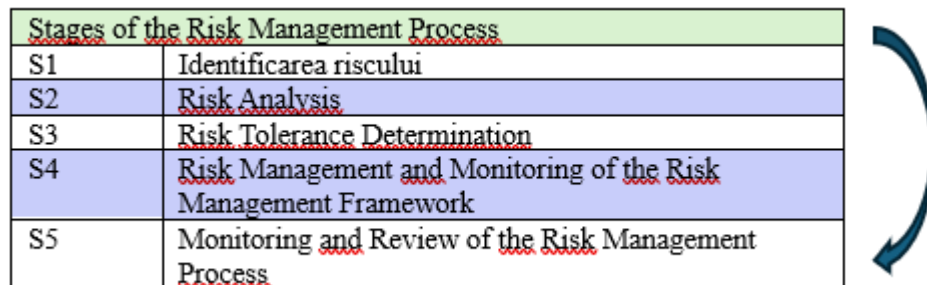


Figure 1. Stages, actions and reasoning within the risk management process

Source: authors' own processing.

Current State of Knowledge and Research

The principles governing public procurement analysis, evaluation, and award procedures, as stipulated by Law No. 98/2016, include non-discrimination, transparency, equal treatment, mutual recognition, accountability, and proportionality.

To enhance transparency in public procurement, Law No. 98/2016 introduced the obligation for all contracting authorities to publish semi-annually the Annual Public Procurement Plan (APPP) in SEAP. Any subsequent modification must be published within a maximum of five working days.

When initiating a new procurement procedure in SEAP, the contracting authority selects the procedure from the APPP, enabling the automatic upload of key data such as estimated value, procurement object, CPV code, estimated initiation and completion dates, execution modality (online or offline), and funding source.

Attitudes and behaviors toward online purchasing among SMEs are recognized as key factors influencing purchasing potential. Psychological factors such as motivation, perception, learning, beliefs, and attitudes significantly affect their purchasing decisions. SMEs often face complex purchasing decisions due to high transaction values, technical and economic considerations, and interactions across organizational levels.

SMEs are motivated to engage in online procurement to achieve an optimal balance between price and quality. Given their importance in the economy, SMEs must keep pace with technological changes and adopt new business tools to remain competitive. Online procurement offers opportunities to compare product quality and costs, access specifications, evaluate prices, and operate continuously [5].

Internet-based technologies enhance firms' market presence and operational efficiency, enabling small firms to overcome size limitations and compete in larger markets. Research suggests that the Internet has expanded international opportunities for SMEs.

A significant proportion of organizational resources is allocated to managing interorganizational processes such as procurement, collaborative product development, and financial transactions. Business-to-business (B2B) procurement often represents the largest cost component, accounting for 50–60% of organizational revenues.

Despite this, IT applications have primarily focused on structured processes such as manufacturing, leaving procurement processes relatively inefficient. Procurement can be classified as direct or indirect. Direct procurement involves raw materials incorporated into final products, whereas indirect procurement concerns goods and services supporting internal operations.

Examples include IT equipment, office supplies, and consumables. Indirect procurement is highly decentralized and involves diverse and often incompatible requests, making it challenging to manage using traditional IT systems.

The use of Internet-based procurement systems has generated significant interest due to their potential to reduce costs and enhance strategic sourcing. B2B electronic marketplaces have expanded procurement options. Four main online procurement system models have been identified, reflecting different transaction execution methods, each creating value in distinct ways.

These include buyer-side systems, private marketplaces, industry-wide exchanges, and third-party marketplaces. Such systems improve search capabilities, accelerate processing, and reduce communication and coordination costs, influencing key B2B operations such as searching, order processing, monitoring, control, and coordination [6].

Methodology

In establishing the research methodology and its stages, it must be stated from the outset that the lack of similar prior studies in the specialized literature greatly limits the use of the basic method of comparison. Comparison—as a research method—can be applied only to the extent that data and information such as means or dispersions of a general nature become available, which can substantiate the validity of certain intermediate conclusions, or insofar as some values of the studied characteristics can be compared with standardized values (for example, for the purpose of identifying certain types of relationships or the degree of similarity between empirical and theoretical distribution curves).

By its nature and structure, the research will primarily rely on probability calculation methods and procedures, as well as on mathematical statistics. Among the established statistical methods, the use of the following is required:

- method of data grouping and aggregation;
- verification of the representativeness of the dataset (possibly through significance testing methods);
- calculation of mean indicators;
- calculation of dispersion indicators and the coefficient of variation;
- the correlation method and the calculation of correlation ratios;
- the regression method.
- verification of hypotheses using statistical significance testing methods.

In order to identify the causes of risks and to disentangle their contributions to the variation of economic effects, a methodology derived from mathematical logic will be applied. The measurement of the contribution (importance) and intensity of the factors will be carried out using the chain substitution method, widely employed in economic disciplines, particularly in economic and financial analysis.

The primary dataset to be observed and subsequently aggregated and processed is limited to the data and information contained in the following working documents or archival records at the level of the county emergency hospital where the case study was conducted:

- Problem Identification and Analysis Sheets (FIAP), resulting from public internal audit missions, in which the identified dysfunctions are defined in terms of their essential parameters;
- Irregularity Finding and Reporting Forms (FCRI), also prepared within internal audit missions;
- Interim internal audit reports;
- A quantitative analysis of the history of direct procurement in SEAP for specific hospital products, namely culture media and reactive dyes.

Among all the aforementioned documents, the most relevant informational feedback for the objectives of this research is provided by the Problem Identification and Analysis Sheets (FIAP). Accordingly, the present research is based primarily on these documents. Specifically, FIAP documents covering the period January–June 2025 will be subjected to an observation process and, where appropriate, to random selection, resulting in a representative sample with a selection size of 100 units.

This sample will subsequently be subjected to observation and statistical–econometric analysis, after its representativeness has first been verified using at least one established method.

The stages of the research were designed in the following sequence (with the possibility of revisiting one or more stages, depending on the evolution of the scientific approach):

1. random selection of the sample;
2. data aggregation and grouping;
3. verification of the representativeness of the sample;
4. statistical–econometric processing of the data;
5. calculation of probabilities;
6. verification of the corresponding probability distribution;
7. determination of scores and their ranking;
8. identification of influencing factors;
9. establishment of the type and intensity of the relationships;
10. estimation of the parameters of the regression model;
11. analysis of the results and formulation of conclusions regarding the validity of the hypotheses and the degree of achievement of the research objectives;
12. verification of compliance with the performance criterion;
13. development of a set of proposals regarding possible extensions of the research or the opening of new research perspectives;
14. review of the author’s original contributions and formulation of the final conclusion.

It should be noted that this staging, as envisaged at the outset of the study, is not rigid; as the research progresses through these stages, additional stages may be interposed if required by the logic of the research or by the needs of data processing.

In any rigorous scientific endeavor, a performance criterion must be established, and throughout the research process the researcher should strive to meet it or to come as close to it as possible. Subjective assessments should preferably be avoided, and the criterion should be measurable, expressed through numerical indicators that can be compared with an ideal or optimal benchmark.

For the present research, the performance criterion is defined as the cumulative fulfillment of two conditions, namely:

- a) verification of the validity of the seven research hypotheses;
- b) achievement of the partial research objectives at a minimum level of 80 percent, either by fulfilling each partial objective to this extent, or by obtaining an average coefficient of fulfillment of the partial objectives (K_{om}) of at least 80%.

This coefficient will be calculated as a weighted average of the degree of fulfillment of each partial objective, the weights being the importance coefficients assigned to the objectives, according to the following formula:

$$\frac{G_i \times K_i}{K_{om}}$$

where

G_i - degree of achievement of the objective i ;

K_i – importance coefficient of objective i

- The calculation of the average coefficient of fulfillment of the partial objectives (K_{om}) requires two observations:

the partial objectives are subordinate to the general objective; therefore, by extension, the degree of achievement of the general objective (and implicitly the degree of success of the research) is considered equal to the average coefficient of fulfillment of the objectives;

- in calculating K_{om} as a weighted average, the starting premise is that the partial objectives do not have equal importance; in practice, they cannot have equal importance because, on the one hand, they do not have the same relevance for the overall research framework and do not contribute equally to the achievement of the general objective, and, on the other hand, the volume of information involved and the effort required to fulfill each partial objective differ.

In order to eliminate subjectivity in the calculation of K_{om} , it is necessary to assign importance coefficients to the partial objectives from the outset. A simple approach consists of ranking the objectives, with the importance coefficients representing the complement to 8 of each ranked objective, as shown in the following table:

Table 1. Importance coefficients of the partial objectives

No	Symbol of the secondary objective	Rank within the overall framework	Importance coefficient (K_i)
1.	O1	4	4
2.	O2	1	7
3.	O3	5	3
4.	O4	6	2
5.	O5	3	5
6.	O6	2	6
7.	O7	7	1
TOTAL			28

Source: Authors' own research.

In order to comply with the object of the research and ultimately arrive at the two lines of reasoning presented in Figure no. 1 - namely, the outlining of ways to reduce subjectivity in managerial decision-making (R1) and the determination of the consequences of risk materialization in terms of additional expenditures (R2) - the research must start from a set of hypotheses whose validity or invalidity will be tested throughout the scientific process. This minimum set of hypotheses is formulated as follows:

- I1:** The economic risks in the public procurement process carried out by public healthcare entities are predictable and exhibit a certain degree of measurable predictability;
- I2:** The economic consequences of risk materialization are foreseeable and measurable;
- I3:** The set of events within the public procurement process is a convex, compact, and dense set and is subject to the natural laws of statistics;
- I4:** The events within the set are normally distributed, according to a probability function;
- I5:** The causes of risks can be identified and separated, and the extent to which they influence the consequences can be measured;
- I6:** There are statistical phenomenological cause–effect relationships, of a stochastic (probabilistic) nature, between the causes and the consequences of risk materialization;
- I7:** The causal relationships within the system are predominantly linear.

Based on this set of hypotheses, the research structure can be developed, but it should be noted that during the course of the study, new or supplementary hypotheses may arise. The researcher's task is to identify them, report them appropriately, and, if necessary, include them in the research - without deviating from the original seven hypotheses.

Public procurement is a highly relevant domain, given that, from an economic perspective, it represents either a gateway to waste or to savings of public funds. SEAP (the Electronic Public Procurement System) serves as the marketplace where public institutions meet suppliers, i.e., companies specializing in products, services, or works, according to different fields of activity. Within this virtual marketplace, public procurements are carried out in accordance with established rules and principles.

We consider that the principles of public procurement - non-discrimination, equal treatment, mutual recognition, transparency, proportionality, and accountability - should not compromise the principle of economic efficiency, that is, the objective of obtaining advantageous contract prices for a hospital, even if this entails entering into annual contracts following a direct procurement through SEAP. Therefore, direct procurement should not be restricted, but rather thoroughly regulated, in such a way as to provide a method of cost-saving for public entities.

For this reason, focusing attention on direct procurement is part of the mission of the present research, but it should also be a major concern for internal public auditors, materializing through audit missions on this topic, in order to highlight the role of direct procurement in the proper functioning of a healthcare-providing institution.

To ensure that the data are relatively recent and that the prices of products on the SEAP market reflect reality as closely as possible, the Problem Identification and Analysis Sheets (FIAP) from 2025 were used. From the total of 387 sheets, 100 were randomly selected, as detailed in Appendix 1. The mechanical selection method was applied: the FIAPs were arranged in chronological order (which ensures a first condition of random selection), and every fourth FIAP was extracted until the required number of 100 sheets was reached to compose the sample.

A more detailed observation of the data shows that there are only two outlier values, both greater than 3,000 lei (FIAP no. 37 and 49), while the remaining values cluster toward the lower end, within the first interval. This necessitates a different approach, with the selection of a smaller grouping interval, and the two outlier values being included in an open class at the upper boundary of the values.

The main risks of public procurement have been identified, and the data have been consolidated in Table 2.

Table 2. Determination of the probabilities of occurrence and the effect of the risks

No	Risk definition	Symbol	Nai	Psmi	Vei	Psei
1.	Entering inaccurate data in the statement of requirements	R ₁	10	0,123	738,81	0,177
2.	Inaccuracy of stock levels displayed in SEAP	R ₂	32	0,395	1638,59	0,393
3.	Relatively low product price coupled with low quantitative demand	R ₃	15	0,185	919,00	0,220
4.	Conditioning the purchase on the acquisition of a mandated minimum quantity	R ₄	24	0,297	876,56	0,210
TOTAL			81	1,000	4172,96	1,000

It can be observed that both probabilities represent a stochastic function; relative to the first, this is only one step. By calculating the statistical–mathematical probability of occurrence, as well as the statistical–economic probability of risk materialization, the partial research objective O2 has been fully achieved. Furthermore, the research hypotheses H1, H2, and H3 are moving toward confirmation, even though it cannot yet be stated with certainty whether they are fully validated.

Results and discussions

Denoting the four risks as R1, R2, R3, and R4, as defined in the previous table, we obtain the following graphical representations:

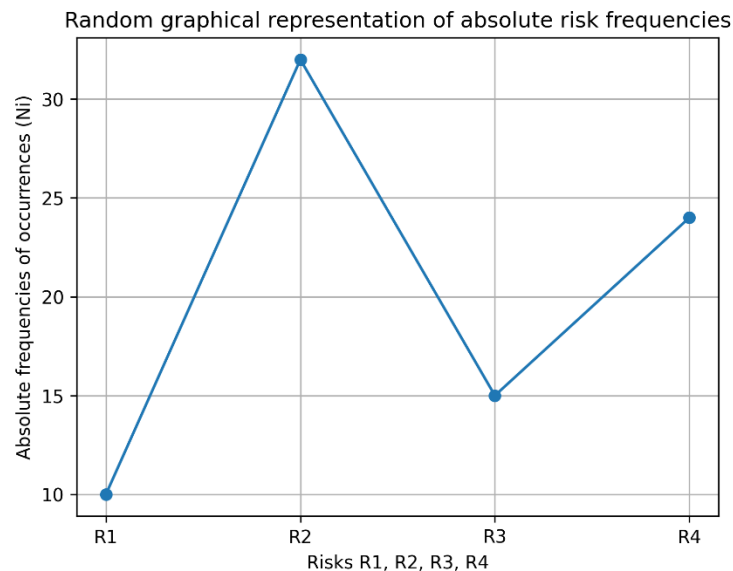


Figure 2. Random graphical representation of the absolute frequencies of risk occurrences

Source: own design and processing.

The random and independent values of the absolute frequencies of risk occurrences, as well as their non-criteria-based distribution along the x-axis, lead to the idea of a normal probability distribution, which can be observed by reordering the x-axis according to the maximum criterion, as shown in the following figure.

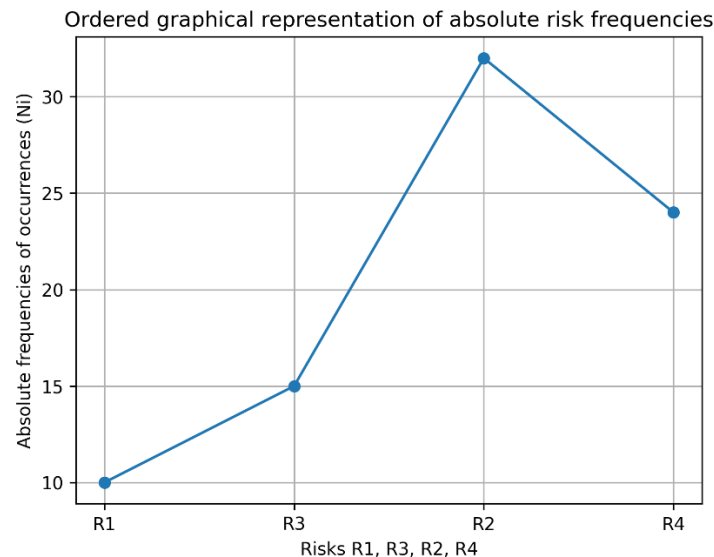


Figure 3. Random graphical representation of the absolute frequencies of risk occurrences; reordered according to the maximum criterion

Source: own design and processing.

Moreover, it can be observed that, regardless of how the events (risks) are placed along the x-axis, relative to the maximum element R2, an approximate Gaussian bell-shaped segment will result - something predictable and expected, given that the sample of 100 FIAPs was constituted according to all the rules of statistics, i.e., it was randomly constructed.

The statistical - mathematical probability distribution of occurrence exactly reproduces the distribution of absolute frequencies, being nothing more than the distribution of relative frequencies. We can state that the relative frequencies of risk occurrences follow a probability distribution function, and the research will proceed according to all the rigor of probability calculations.

Statistical - economic probabilities are strongly influenced by the statistical-mathematical probabilities, which condition their existence and, to some extent, determine their level. For this reason, there are sufficient grounds to speak of probabilities. The graphical representation of the economic probabilities for the four risks is shown in Figure 3, revealing a graph of a normal probability function, in line with the predictions.

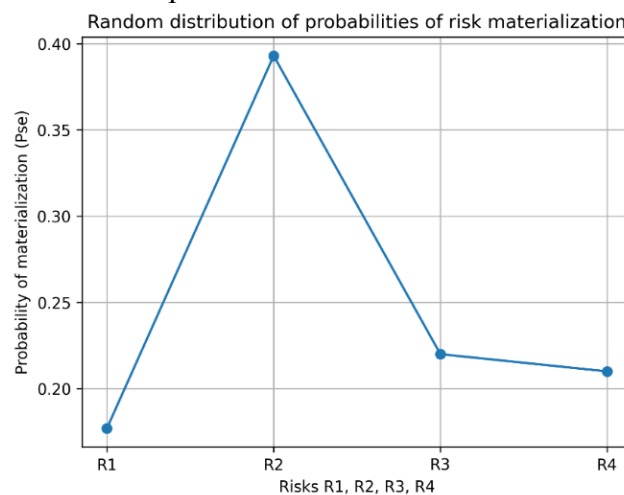


Figure 4. Random graphical representation of the absolute frequencies of risk occurrence; reordered according to the maximum criterion

Source: own design and processing.

By redistributing the risks along the horizontal axis in the order of the previous ones, the following graph is obtained, which is even closer to a probability function:

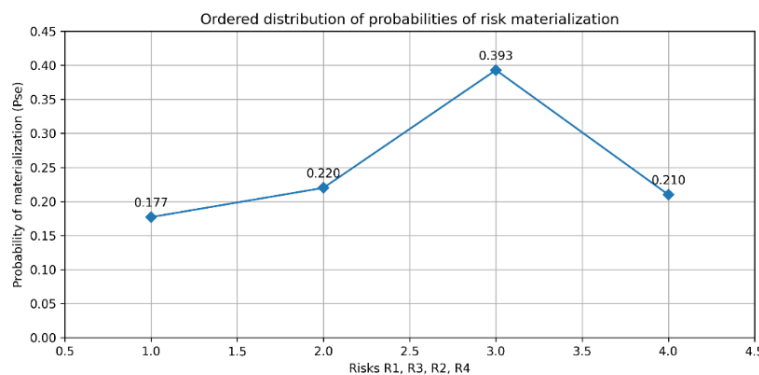


Figure 5. Ordered distribution of the probabilities of risk materialization

Source: own processing.

Starting from the premise of the random composition of the sample and observing the shape of the distribution curves, which are very similar to a probability function, parametric verification of the distribution curves can be omitted, concluding that the determined probabilities follow the probability distribution law.

As a result of the calculations and graphical representations performed, the partial objective **O3 - Determination of the characteristics and shape of the probability distribution curves** - has been fully achieved. However, since the calculations regarding the function parameters were not performed in order to maintain the objectivity of the research, the degree of achievement of this objective can be adjusted by 15%, considering it partially achieved to 85%.

The hypotheses H1, H2, H3, and H4 are fully confirmed.

Conclusion

The present research addressed the issue of economic risk modeling in the process of direct public procurement within public healthcare institutions, starting from the premise that additional, unforeseen expenditures generated by procurement activities represent economic risks that can be identified, measured, and partially predicted through statistical and econometric tools.

By conceptualizing these additional costs as manifestations of economic risk, the study contributes to a clearer analytical framework that allows the transformation of uncertainty into quantifiable and manageable elements. The research demonstrates that risks associated with direct procurement are not random anomalies, but follow identifiable statistical patterns, provided that the underlying data set is constructed according to the rules of representativeness and randomness.

Using a representative sample of 100 FIAP documents extracted from internal audit activities, the study successfully identified four major categories of risk specific to the direct procurement process. For each of these risks, both the statistical-mathematical probability of occurrence and the statistical-economic probability of materialization were determined. The results confirm that the probabilities of materialization are strongly conditioned by the probabilities of occurrence, supporting the assumption that economic risk materialization is a stochastic process governed by statistical laws.

Graphical representations of both absolute frequencies and probabilities revealed distribution curves closely resembling the normal (Gaussian) distribution. The reordering of risks according to the maximum criterion further strengthened this conclusion, indicating that the analyzed phenomena comply with the natural laws of probability distribution. Consequently, the study validated the hypothesis that risk events in public procurement form a convex and dense set that follows a probabilistic distribution.

The research objectives were largely achieved. Objective O2, concerning the determination of statistical-mathematical and statistical-economic probabilities of risk occurrence and materialization, was fully accomplished. Objective O3, focused on identifying the characteristics and form of probability distribution curves, was substantially fulfilled, with a degree of realization estimated at 85%, due to the deliberate exclusion of parametric estimation in order to preserve the objectivity of the analysis.

All hypotheses formulated at the beginning of the research were confirmed, either fully or within the accepted methodological limits. In particular, the findings support the predictability and measurability of economic risks in public procurement, the existence of causal relationships between risk factors and economic consequences, and the predominance of linear and stochastic relationships within the system.

From a managerial and practical perspective, the study highlights the importance of directing greater attention toward direct procurement processes, not only as instruments of operational flexibility, but also as potential sources of significant economic risk. The results underline the need for enhanced involvement of internal public auditors in evaluating direct procurement activities and for integrating probabilistic risk assessment into managerial decision-making processes.

Finally, the research opens new perspectives for further investigation, including the estimation of distribution parameters, the development of predictive econometric models, and the extension of the methodology to other categories of public institutions. By providing an objective, data-driven approach to risk analysis, this study contributes to improving transparency, efficiency, and economic discipline in public healthcare procurement systems.

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