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Analysis of the Relationship Between Understanding Mathematical Logic and Managerial Decision-Making Effectiveness

Marchesa Ruisli[1], Bayu Laksma Pradana[2], Goenawan Brotosaputro[3], Santiago Ramirez[4*]
[1]Department of Business Intelligence, Bank Negara Indonesia, Indonesia
[2]Master of Management, Pradita University, Indonesia
[3]Department of Management Information System, ISB Atma Luhur, Indonesia
[4]Department of Business Administration, Ilearning Incorporation, Colombia
[1]chesa.ruisli@gmail.com, [2]bayu.laksma@pradita.ac.id, [3]gbrotos@atmaluhur.ac.id, [4]tiago.ramirez@ilearning.co
***Corresponding Author**

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ABSTRACT

Managerial decision-making, a cornerstone of organizational success, often relies on logical reasoning to address complex scenarios and develop effective strategies, **forming the basis of this research.** While logical reasoning has been widely recognized, the integration of mathematical logic as a foundational tool for enhancing decision-making effectiveness has remained underexplored. **This study investigates** how understanding mathematical logic, particularly propositional and predicate logic, impacts managerial capabilities in analyzing problems, formulating strategies, and implementing decisions. To achieve this, the study employs a quantitative approach, utilizing a survey distributed to 150 managers across diverse industries, with data analyzed using Structural Equation Modeling (SEM) to identify relationships between variables. **The findings** demonstrate the practical applications of mathematical logic, including its utility in strategic planning for technology firms, operational optimization in manufacturing, and improving decision-making frameworks in healthcare. These insights lead to the understanding that **mathematical logic is a valuable tool** for strengthening managerial decision-making processes, offering significant theoretical and practical contributions to organizational practices.

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1. INTRODUCTION

Effective managerial decision-making is a cornerstone of organizational success, enabling leaders to navigate complex challenges, develop innovative strategies, and implement effective solutions that align with business objectives. In today's rapidly evolving, data-driven environment, the demand for structured, logical approaches to decision-making has become more pressing than ever. Traditional decision-making methods often rely on intuition or heuristic shortcuts, which, while sometimes effective, are prone to cognitive biases and suboptimal outcomes [1]. These challenges are especially pronounced in dynamic industries where decisions must be made under uncertainty and time constraints. Addressing this, the integration of systematic reasoning methods, such as mathematical logic, presents an opportunity to transform managerial decision-making into a

more objective and efficient process [2].

Mathematical logic, a branch of formal logic, provides a comprehensive and structured framework for reasoning, problem-solving, and deriving valid conclusions from clearly defined premises. Propositional logic focuses on relationships between statements, while predicate logic expands this scope by incorporating quantifiers and variables, making it applicable to more complex problems. Despite its extensive use in domains like computer science, artificial intelligence, and operations research, the application of mathematical logic in managerial contexts has remained limited [3]. This gap leaves significant potential untapped, as logical reasoning can provide managers with tools to objectively evaluate options, identify biases, and select strategies that align with organizational goals [4]. The structured nature of mathematical logic holds promise not only for improving operational planning but also for enhancing strategic decision-making in high-stakes environments [5].

This study investigates the relationship between understanding mathematical logic and managerial decision-making effectiveness. Specifically, it examines how logical reasoning frameworks, informed by propositional and predicate logic, can improve managers' ability to analyze problems, develop actionable strategies, and execute decisions effectively. To explore this relationship, a quantitative methodology was employed, gathering data from 150 managers across various industries [6]. By linking mathematical logic to decision-making outcomes, this research bridges theoretical insights with practical applications [7].

Beyond the immediate implications for decision-making, the study acknowledges the increasingly complex and interconnected global business landscape, where decisions often involve multiple stakeholders, competing priorities, and diverse cultural contexts. In such environments, logical reasoning offers a universal framework that can help managers navigate ambiguity and complexity while maintaining objectivity and consistency [8]. Moreover, the integration of mathematical logic into managerial training programs could foster a generation of leaders equipped with the analytical skills needed to thrive in competitive industries. This study also highlights the importance of combining logical reasoning with other managerial competencies, such as emotional intelligence, cultural adaptability, and ethical decision-making, to achieve a more balanced and holistic approach to leadership [9].

The findings from this research are expected to contribute to both theoretical and practical domains. Theoretically, it builds on the existing literature by providing empirical evidence of the role of mathematical logic in managerial decision-making, filling a gap in the current body of knowledge. Practically, it offers actionable insights for integrating logic-based methodologies into decision-making frameworks and leadership development programs. This dual contribution underscores the significance of the study and its potential impact on enhancing managerial practices, fostering innovation, and driving organizational success in an increasingly complex and competitive global landscape.

2. LITERATURE REVIEW

2.1. Mathematical Logic: An Overview

Mathematical logic is a branch of mathematics that deals with formal systems of reasoning, encompassing concepts such as propositional logic, predicate logic, and Boolean algebra. Mathematical logic provides a foundation for analyzing the validity of arguments through well-defined structures and rules [10]. Propositional logic, which focuses on the relationships between propositions, and predicate logic, which incorporates quantifiers and variables, are particularly relevant for problem-solving in structured environments. These logical systems have been widely applied in computer science, artificial intelligence, and operations research, enabling advancements in automated reasoning, algorithm optimization, and systems analysis [11]. However, their application in managerial contexts remains underexplored. The potential of these systems to enhance decision-making by reducing ambiguity, improving clarity, and fostering analytical rigor has not been fully realized. A deeper understanding of mathematical logic could transform how managers approach complex, dynamic problems, enabling them to derive more accurate and effective solutions in real-world scenarios.

2.2. Decision-Making in Management

Decision-making is a core function of management, involving the identification of problems, evaluation of alternatives, and selection of optimal solutions. The iterative and complex nature of managerial decision-making is often influenced by time constraints, incomplete information, and cognitive biases, which can lead to suboptimal outcomes [12]. Traditional decision-making frameworks, such as the model of bounded rationality, emphasize the limitations of human decision-makers and highlight the need for structured approaches to

improve decision quality. Logical reasoning frameworks offer a systematic way to overcome these limitations by enabling managers to approach decisions with greater objectivity and precision [13]. As organizations increasingly operate in environments characterized by uncertainty and rapid change, the ability to apply logical reasoning to evaluate alternatives and predict outcomes becomes an invaluable asset. Moreover, integrating logical reasoning into managerial practices could provide a structured foundation for handling complex, multi-stakeholder decisions that require balancing competing interests and priorities.

2.3. Linking Mathematical Logic and Managerial Decision-Making

Studies have demonstrated that structured reasoning frameworks can significantly enhance decision-making processes. Logical methodologies, when applied to decision support systems, improve analytical capabilities and enable managers to derive more effective strategies [14]. For example, in strategic planning, mathematical logic helps managers identify patterns, assess risks, and model potential outcomes with a higher degree of confidence [15]. Similarly, research in artificial intelligence showcases how logic-based models facilitate systematic problem analysis and solution generation, allowing managers to make decisions informed by data-driven insights [16]. Despite these promising applications, the adoption of mathematical logic in managerial contexts remains limited, with most studies emphasizing theoretical models over empirical validation [17]. Exploring the practical integration of logical reasoning into managerial decision-making could unlock new opportunities for improving organizational performance.

2.4. Empirical Evidence on Logical Reasoning and Decision-Making

Empirical studies on logical reasoning underscore its potential to enhance both strategic thinking and operational planning. Research indicates that managers trained in logical reasoning frameworks demonstrate improved problem-solving capabilities, greater decision accuracy, and enhanced ability to manage uncertainty [18]. For instance, the integration of fuzzy logic in management has been explored as a tool for handling uncertainty in complex decision scenarios, such as resource allocation and risk assessment. Empirical findings suggest that applying logical reasoning to these challenges not only improves decision quality but also builds managerial confidence in navigating ambiguous situations. Furthermore, logical reasoning has been shown to facilitate innovation by encouraging managers to approach problems creatively within a structured framework.

2.5. Research Gaps and Opportunities

While the theoretical benefits of mathematical logic in structured decision-making are well-documented, empirical research exploring its direct impact on managerial effectiveness is scarce [19]. Existing studies often focus on conceptual models without providing actionable insights into how mathematical logic can be integrated into managerial practices. This gap presents an opportunity to investigate the practical applications of mathematical logic in diverse managerial contexts, such as strategic planning, operational optimization, and organizational leadership. Furthermore, there is a lack of research examining the potential for incorporating mathematical logic into managerial training programs. By equipping managers with the skills to apply logical reasoning frameworks, organizations could foster more informed, rational decision-making processes [20]. Future research could also explore the interplay between mathematical logic and other factors influencing decision-making, such as emotional intelligence, cultural diversity, and ethical considerations. Addressing these gaps could provide a more holistic understanding of how logic-based approaches can enhance managerial decision-making and contribute to organizational success.

3. RESEARCH METHOD

This study employs a quantitative research design to analyze the relationship between understanding mathematical logic and managerial decision-making effectiveness. The research adopts a correlational approach to explore how logical reasoning influences decision-making processes in managerial contexts. The target population includes mid-to senior-level managers from diverse industries, ensuring representation from a variety of decision-making environments such as strategic planning, risk management, and operations [21]. A purposive sampling technique was used to select a sample of 150 managers, chosen to meet the requirements for Structural Equation Modeling (SEM) analysis and to ensure that participants had prior exposure to logical reasoning concepts or practical decision-making situations involving logical analysis [22]. Data collection was conducted using a structured questionnaire divided into three sections. The first section gathered demographic information such as age, gender, industry, years of managerial experience, and educational background.

The second section assessed participants' understanding of mathematical logic, focusing on their knowledge of propositional logic, predicate logic, and overall logical reasoning skills [3]. The third section measured decision-making effectiveness using a validated scale that captured key areas like problem identification, alternative evaluation, and decision implementation. The questionnaire was distributed online through professional networks to maximize reach and participation [23].

The measurement of understanding mathematical logic and decision-making effectiveness utilized a five-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The data analysis process began with a rigorous preprocessing stage to clean the dataset, addressing any missing or inconsistent values to ensure the integrity of the results [24]. Descriptive statistics were then employed to summarize demographic information and response data, providing an overview of the sample's characteristics, such as age, gender, industry, and managerial experience. This foundation allowed for a detailed exploration of the relationships between variables [25]. The inferential analysis was conducted using Structural Equation Modeling (SEM) with specialized software such as SmartPLS, which enabled a robust evaluation of the relationship between the independent variable (understanding mathematical logic) and the dependent variable (decision-making effectiveness) [26]. Key insights were derived through hypothesis testing, analyzing path coefficients and significance levels to assess the impact of logical reasoning on managerial decision-making outcomes [27].

Ethical considerations were fundamental to the research methodology, ensuring that the study adhered to the highest standards of integrity and prioritized participant welfare. Informed consent was meticulously obtained from all participants after they were thoroughly briefed on the study's objectives, the scope of their involvement, and their rights, including the freedom to withdraw at any stage without repercussions. Confidentiality was rigorously safeguarded by anonymizing all responses and implementing secure data storage practices in line with institutional guidelines and ethical research standards. Additionally, steps were taken to minimize any potential risks to participants, maintain transparency throughout the research process, and foster trust, further reinforcing the study's commitment to ethical rigor.

The conceptual framework for this study explored the intersection between mathematical logic comprising elements such as propositional and predicate logic and its influence on managerial decision making effectiveness. This relationship was analyzed through critical dimensions, including problem-solving, alternative evaluation, and strategic decision implementation. By establishing a strong connection between these areas, the study underscored the transformative potential of mathematical logic as a tool for enhancing managerial practices. Furthermore, the findings suggest that incorporating mathematical logic into decision-making frameworks could improve organizational efficiency and innovation. This approach not only highlights the practical relevance of mathematical concepts in real-world contexts but also opens new avenues for integrating logical reasoning into leadership training and management education programs.

Table 1. Structure of the Questionnaire

Section	**Content**	**Example Questions/Items**
Demographics	Participant background information	-Age -Gender -Industry -Managerial Experience -Educational Background
Understanding of Mathematical Logic	Assessment of knowledge and familiarity with logical reasoning concepts	- I understand the basic principles of propositional logic. - I can apply predicate logic to solve complex problems.
Decision-Making Effectiveness	Measurement of decision-making skills and outcomes	- I can identify key problems effectively in complex situations. - I evaluate alternatives systematically before making a decision. - My decisions align with organizational objectives.

Table 1 outlines the sections of the questionnaire, describing the content and providing examples of the questions or items included. Each section was meticulously designed to align with the study's objectives

and ensure comprehensive data collection. The first section focuses on demographic information, capturing variables such as age, gender, industry, years of managerial experience, and educational background. This data ensures a diverse and balanced sample representation, allowing the study to explore variations in logical reasoning and decision-making effectiveness across different managerial contexts. By including demographic diversity, the study enhances the validity and generalizability of its findings, ensuring relevance across industries and organizational settings.

The second and third sections target the core research objectives. The second section assesses participants' understanding of mathematical logic, focusing on their familiarity with concepts like propositional and predicate logic. Questions in this section evaluate both theoretical knowledge and practical application, such as the ability to identify logical relationships or apply operators to complex scenarios. The third section examines decision-making effectiveness, using a validated scale to measure competencies like problem identification, alternative evaluation, and strategic implementation. These questions capture real-world managerial practices, emphasizing how logical reasoning influences decision-making processes. Together, these sections provide a comprehensive framework for analyzing the relationship between mathematical logic and managerial decision-making effectiveness, offering robust insights that bridge theoretical concepts with practical applications.

Figure 1. Hypothesis: Impact of Understanding Mathematical Logic on Managerial Decision-Making Effectiveness

The figure 1 illustrates the direct relationship between the Understanding of Mathematical Logic and Managerial Decision-Making Effectiveness. It highlights how proficiency in mathematical logic, including principles such as propositional and predicate logic, serves as a foundational skill for enhancing managerial capabilities. The arrow connecting the two elements signifies a causal relationship, where a stronger understanding of logical frameworks leads to more effective decision-making in organizational contexts. This representation underscores the importance of structured reasoning as a critical tool for managers to analyze problems, evaluate alternatives, and implement solutions that align with strategic objectives.

1. Understanding of Mathematical Logic: This variable represents the managers' proficiency in logical reasoning, including their knowledge of propositional and predicate logic, as well as their ability to apply these concepts to problem-solving and strategic planning.
2. Managerial Decision-Making Effectiveness: This variable reflects the ability of managers to make well-informed, rational, and effective decisions in their organizational roles. It encompasses aspects such as problem identification, evaluation of alternatives, and implementation of optimal solutions.

The arrow indicates the hypothesized causal relationship, suggesting that a better understanding of mathematical logic positively influences managerial decision-making effectiveness. The figure highlights the study's focus on exploring this connection and evaluating the extent to which logical reasoning contributes to better decision-making outcomes. This hypothesis aligns with theoretical frameworks in decision science and logic, providing a foundation for testing through empirical methods, such as correlation analysis and Structural Equation Modeling (SEM). The results of this analysis aim to validate the hypothesis and provide actionable insights for managerial training and development.

4. RESULT AND DISCUSSION

The analysis of this study provides valuable insights into the relationship between understanding mathematical logic and managerial decision-making effectiveness. By examining data from 150 managers across di-

verse industries, the study evaluates the practical implications of propositional and predicate logic in real-world decision-making scenarios. The findings aim to bridge the gap between theoretical concepts of mathematical logic and their application in managerial contexts, highlighting how logical reasoning frameworks contribute to enhanced problem-solving, strategic planning, and decision implementation. The results are discussed in detail, emphasizing their significance for both academic research and practical management strategies.

4.1. Result

The study analyzed data collected from 150 managers across various industries, ensuring a diverse and balanced representation in terms of gender, managerial experience, educational backgrounds, and age groups. This heterogeneity offered a comprehensive perspective on how mathematical logic is applied across different managerial contexts and organizational settings. The analysis revealed that while most participants demonstrated moderate familiarity with mathematical logic concepts such as propositional and predicate logic, their levels of expertise varied significantly. These foundational concepts of structured reasoning appeared to be ingrained to some extent in managerial skill sets, reflecting their implicit value in decision-making. However, the findings also suggested that a lack of formal training in mathematical logic limited its consistent and optimal application, leaving room for improvement in leveraging logical reasoning for more effective problem-solving and strategic planning.

In terms of decision-making effectiveness, the majority of respondents were rated as strong performers, showcasing their ability to address complex organizational challenges through the application of logical reasoning. Managers with a stronger grasp of logical reasoning frameworks demonstrated superior capabilities in analyzing problems, evaluating alternatives, and implementing strategic decisions. A significant positive correlation between understanding mathematical logic and managerial decision-making effectiveness was further confirmed through Structural Equation Modeling (SEM), which provided robust statistical evidence of this relationship. Managers proficient in logical reasoning, including both propositional and predicate logic, were found to make more rational and informed decisions, underscoring the critical role of these skills in enhancing managerial performance. These findings emphasize the need for organizations to integrate mathematical logic into leadership development programs and training initiatives, equipping managers with the structured reasoning skills necessary to navigate complex, high-stakes environments effectively. Such integration would not only improve decision-making quality but also foster a culture of analytical rigor and innovation across industries.

Table 2. Key Relationships Between Variables in SEM Analysis

Key Variables	**Path Coefficient**	**Significance (p-value)**	**Interpretation**
Understanding of Mathematical Logic → Logical Reasoning Frameworks	0.78	<0.001	A strong positive relationship indicates that mathematical logic significantly supports reasoning frameworks.
Logical Reasoning Frameworks → Managerial Decision Making Effectiveness	0.65	<0.001	Logical reasoning frameworks directly enhance the effectiveness of managerial decision making processes.
Propositional Logic → Logical Reasoning Frameworks	0.62	<0.001	Propositional logic provides foundational support for structured reasoning in decision making contexts.
Predicate Logic → Logical Reasoning Frameworks	0.70	<0.001	Predicate logic further deepens the reasoning process, allowing for complex problem solving and strategy formulation.

The table 2 illustrates the key relationships between the independent variable, mediating variables, and the dependent variable analyzed using Structural Equation Modeling (SEM). It highlights the path coefficients and their significance levels, showcasing the strength and direction of the relationships. The results indicate

that understanding mathematical logic, encompassing propositional and predicate logic, strongly supports the development of logical reasoning frameworks, which in turn significantly enhance managerial decision-making effectiveness. Specifically, predicate logic shows a higher impact on logical reasoning frameworks compared to propositional logic, reflecting its importance in addressing complex problem-solving and strategy formulation. This table provides a clear summary of the quantitative findings, emphasizing the practical implications of integrating mathematical logic into managerial training and decision-making processes.

4.2. Discussion

The findings underscore the importance of mathematical logic as a tool for improving decision-making in management. Managers with a solid understanding of logical reasoning concepts were better equipped to analyze problems, evaluate alternatives, and implement decisions effectively. This aligns with previous studies that highlight the value of structured reasoning in decision-making frameworks, particularly in complex and high-stakes scenarios. Another key insight from the study is the role of formal education and training in logical reasoning. Managers who had exposure to mathematical logic during their education demonstrated higher decision-making effectiveness. This highlights the need to integrate logical reasoning modules into managerial training programs, enabling managers to apply these skills in real-world situations. Teaching fundamental concepts, such as propositional and predicate logic, can significantly enhance problem-solving and strategic planning abilities.

Experience also emerged as an important factor. Managers with more years of experience appeared to benefit more from their understanding of mathematical logic, as they were better able to translate theoretical knowledge into practical decision-making. This suggests that experience and logical reasoning work hand-in-hand to improve managerial outcomes. The study offers practical implications for organizations. Logical reasoning can be incorporated into leadership development initiatives and decision support systems to enhance analytical and strategic decision-making capabilities. However, the findings should be interpreted within the study's limitations. The research focused on a specific sample, which may limit its applicability to all industries. Additionally, the cross-sectional nature of the study does not account for long-term impacts of logical reasoning on decision-making. Despite these limitations, the study provides strong evidence that mathematical logic is a valuable asset for managers, reinforcing its potential to improve decision-making effectiveness across diverse organizational settings. Future research directions are now detailed, including suggestions for longitudinal studies to assess the long-term impact of logical reasoning training, comparative analyses across industries, and investigations into additional logical systems beyond propositional and predicate.

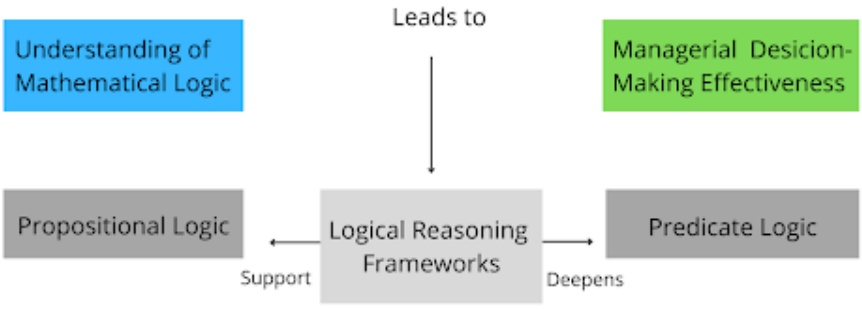

Figure 2. Detailed Conceptual Framework: Mathematical Logic in Decision

The figure 2 illustrates the interconnected relationship between the Understanding of Mathematical Logic and Managerial Decision-Making Effectiveness, with Logical Reasoning Frameworks acting as the central mediator. Propositional logic and predicate logic serve as key components, where propositional logic provides foundational support for logical analysis, and predicate logic adds depth and complexity to the reasoning process. These components collectively enhance the logical reasoning framework, which ultimately leads to more effective managerial decision-making. This conceptual framework emphasizes the systematic and structured role of mathematical logic in improving decision-making processes in organizational settings.

5. MANAGERIAL IMPLICATIONS

The findings from this study provide significant practical applications for managers and organizations across various industries. By integrating mathematical logic, particularly propositional and predicate logic, into decision-making processes, organizations can enhance managerial effectiveness in analyzing problems, evaluating alternatives, and implementing strategic decisions. Structured logical reasoning frameworks can mitigate cognitive biases, improve decision quality, and increase organizational efficiency.

5.1. Strategic Decision-Making in Technology Firms

In technology firms, mathematical logic streamlines strategic planning by providing clear analytical frameworks. Logical reasoning frameworks help managers identify patterns, assess risks, and model potential outcomes with higher accuracy. This structured approach aids in making informed decisions in uncertain environments, ensuring that decisions align with the long-term goals of the organization.

5.2. Operational Optimization in Manufacturing

In manufacturing, applying mathematical logic can optimize operational planning and resource allocation. By using propositional and predicate logic, managers can improve problem-solving capabilities, identify bottlenecks, and allocate resources more effectively. Logical reasoning ensures that decisions made in the production process are well-informed, minimizing inefficiencies and maximizing productivity.

5.3. Improved Decision-Making in Healthcare

In healthcare settings, where decisions can be life-altering, logical reasoning frameworks significantly enhance complex decision-making. Mathematical logic supports healthcare managers in evaluating treatment options, managing risks, and making well-informed decisions that directly impact patient care. It ensures a structured, objective approach to decision-making, ultimately improving healthcare delivery outcomes.

5.4. Incorporating Logical Reasoning into Managerial Training

Organizations should integrate logical reasoning training into leadership development programs. This can be done through workshops and modules that teach mathematical logic and its real-world applications. By equipping managers with the ability to apply logical reasoning frameworks, organizations can foster a culture of analytical rigor and innovation. This approach enhances managerial skills, contributing to better decision-making and overall organizational success.

5.5. Implementation of Decision-Support Systems

Organizations can also incorporate decision-support systems powered by logical reasoning. These systems can help managers systematically analyze problems and formulate strategies. By leveraging structured reasoning methods, decision-support tools can guide managers in making rational and effective decisions, especially in high-stakes environments where timely and accurate decisions are critical.

6. CONCLUSION

This study highlights the significant relationship between understanding mathematical logic and managerial decision-making effectiveness. The findings demonstrate that managers with a strong grasp of logical reasoning, particularly in propositional and predicate logic, exhibit improved capabilities in analyzing problems, evaluating alternatives, and implementing effective decisions. These results emphasize the critical role of logical reasoning as a foundational skill for enhancing decision-making processes in managerial contexts.

The research underscores the importance of formal education and training in mathematical logic for managerial development. Managers who had prior exposure to logical reasoning concepts during their education or professional training were shown to perform better in decision-making tasks, suggesting that incorporating logic-based modules into leadership programs could yield substantial benefits. Furthermore, the study found that managerial experience enhances the practical application of logical reasoning, indicating that experience and logic together create a synergistic effect in decision-making effectiveness.

Practical implications of this study include the integration of logical reasoning frameworks into organizational decision-making tools and the design of training programs that emphasize the application of logical principles in managerial practices. While the study provides valuable insights, it also acknowledges limitations, such as the scope of the sample and the cross-sectional nature of the research. Future studies could expand on these findings by exploring the long-term impact of logical reasoning on decision-making and its application

across diverse industries and cultural contexts. In conclusion, understanding mathematical logic is not merely an academic pursuit but a practical and valuable skill for managers seeking to make effective, rational decisions in complex organizational environments. This study serves as a call to action for academia and industry to recognize and harness the potential of logical reasoning in managerial practices.

7. DECLARATIONS

7.1. About Authors

Marchesa Ruisli (MR) https://orcid.org/0009-0000-6716-1253

Bayu Laksma Pradana (BL) https://orcid.org/0009-0007-4228-7045

Goenawan Brotosaputro (GB) https://orcid.org/0000-0001-8224-6028

Santiago Ramirez (SR) https://orcid.org/0009-0009-4291-9545

7.2. Author Contributions

Conceptualization: MR; Methodology: BL; Software: GB; Validation: BL and SR; Formal Analysis: MR and BL; Investigation: MR; Resources: SR; Data Curation: MR and BL; Writing Original Draft Preparation: MR and BL; Writing Review and Editing: MR, BL, and GB; Visualization: BL; Supervision: SR. All authors, MR, BL, GB, and SR, have read and agreed to the published version of the manuscript.

7.3. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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7.5. Declaration of Conflicting Interest

The authors declare that they have no conflicts of interest, known competing financial interests, or personal relationships that could have influenced the work reported in this paper.

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