INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH AND INNOVATIVE STUDIES
IJSRIS journal
ISSN: 2820-7157
Advancing Knowledge, Inspiring Innovation
www.ijsrisjournal.com
INDEXED JOURNAL
PEER REVIEWED Rigorous & Transparent | DOI: CROSSREF Member | OPEN ACCESS For Global Visibility | BI-MONTHLY Timely Publication | WIDE READERSHIP High Impact & Visibility | AUTHOR FRIENDLY Fast | Supportive | Reliable

RECEIVED 19 June 2026 | ACCEPTED 10 July 2026 | PUBLISHED 1 August 2026
August 2026 | Volume 5 | Number 4
Pages from: 499 to 505

Enhancing Production Automotive Industry Performance with Ishikawa's 5M Method and Fuzzy Logic

Abdeljalil BECHCHAR 1, Abdelaziz SOULHI 2, O. AKOURRI 1

[1]Faculty of Sciences and Techniques of Tangier (FST Tanger), Abdelmalek Essaâdi University, Tangier, Morocco,
bechchar.abdeljalil@etu.uae.ac.ma, oakourri@uae.ac.ma
[2]National Higher School of Mines of Rabat (ENSMR), Rabat, Morocco, soulhi@enim.ac.ma

Crossref doi
PREFIX : 10.63883
IJSRIS JOURNAL

ABSTRACT

The digitalization in the dynamic landscape of the automotive industry, achieving optimal production processes is a fundamental imperative. This article delves into a robust approach that combines Ishikawa's 5M method and fuzzy logic to significantly enhance production performance. The 5M method, encompassing Manpower, Machinery, Material, Method, and Measurement, serves as the foundational framework for dissecting factors influencing production. Meanwhile, fuzzy logic, a contemporary mathematical framework, introduces flexibility to decision-making in handling complex, uncertain variables.

The assessment of Manpower Expertise, Machinery Condition, Material Quality, Method Efficiency, and Measurement Accuracy is essential. In the automotive industry, the proficiency of the workforce, machine reliability, material quality, operational efficiency, and precision of measurements collectively define success. Ishikawa's 5M method offers a structured approach to dissecting and addressing these crucial elements.

Fuzzy logic, on the other hand, bridges the gap between qualitative assessments and quantifiable outputs. By assigning linguistic variables and membership functions, it allows for nuanced analysis. Rule-based decision-making in fuzzy logic draws connections between input and output variables, aiding in the interpretation of complex relationships. This adaptive system evolves with time, enhancing its accuracy and predictive capabilities.

The integration of Ishikawa's 5M method and fuzzy logic results in a powerful tool for enhancing production performance. Quality, productivity, safety, and customer satisfaction—integral outcomes in the automotive industry—are no longer subjective measures. Instead, they are quantified, analyzed, and optimized through a synergistic approach. By leveraging both time-tested methodologies and modern techniques, manufacturers can navigate the challenges of the industry and usher in a new era of excellence.

This article serves as a guide to harnessing the potential of Ishikawa's 5M method and fuzzy logic in achieving remarkable production performance in the automotive industry. Through a deeper understanding of the interplay between human expertise, machinery reliability, material quality, method efficiency, and measurement accuracy, coupled with the dynamic capabilities of fuzzy logic, manufacturers are empowered to elevate their production processes to unparalleled heights.

Keywords: Ishikawa, 5M, Fuzzy logic, automotive industry, performance.

Introduction

In the fast-paced and competitive automotive industry, optimizing production processes is crucial for achieving high-quality products, improved productivity, enhanced safety measures, and increased customer satisfaction. The application of proven methodologies such as Ishikawa's 5M method, combined with modern techniques like fuzzy logic, can significantly contribute to achieving these goals. This article explores how the integration of Ishikawa's 5M method and fuzzy logic can enhance production performance in the automotive industry.

In the realm of the automotive industry, where precision, quality, and efficiency are paramount, optimizing production processes is not merely a goal, but a necessity. To achieve this, a combination of time-tested methodologies and cutting-edge techniques is often the key. This article delves into the integration of Ishikawa's 5M method, a proven framework for identifying and mitigating production-related issues, with the power of fuzzy logic, a modern approach to handling complex, uncertain variables. This combined approach holds the potential to significantly enhance production performance while ensuring productivity, quality, safety, and customer satisfaction.

I. Ishikawa's 5M Method: Understanding the Foundation

Ishikawa's 5M method, also known as the Fishbone diagram, provides a comprehensive framework to identify and analyze the potential causes of a problem or an effect in a production process. The five categories. Each category plays a vital role in influencing production processes and potential issues. Ishikawa's 5M method, rooted in the teachings of renowned quality control expert Kaoru Ishikawa, provides a structured approach to dissecting the various factors that influence production processes. The 5Ms—Manpower, Machinery, Material, Method, and Measurement—are the cornerstones of this method, each playing a pivotal role in shaping the outcome of the production process.

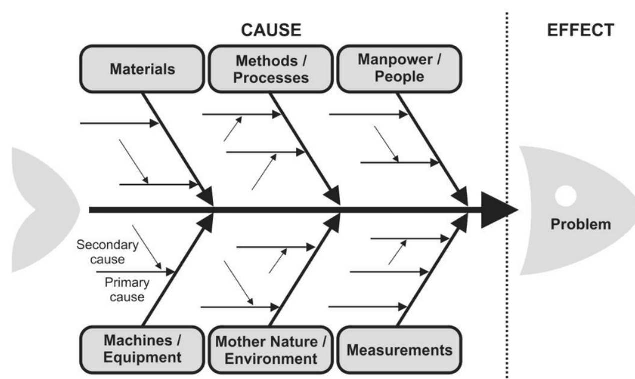

Figure 1: Ishikawa 6M model

Manpower:

Skillful Minds and Expertise Manpower encapsulate the workforce's skill level, knowledge, and expertise. In the automotive industry, where precision is crucial, the proficiency of the workers directly impacts product quality. This category also accounts for factors such as workload distribution and communication between team members.

Inadequate training can lead to errors and inefficiencies. Fuzzy logic can help quantify the expertise level and suggest training programs based on historical data and performance assessments.

Manpower: This category includes the human resources involved in the production process. Manpower-related factors can significantly impact production processes and potential issues.

For example:

- Skill level: Insufficient training or inadequate skills among workers can lead to errors or inefficiencies in the production process.
- Workload: Overworked employees might make mistakes or become fatigued, affecting the quality and speed of production.
- Communication: Poor communication among team members can lead to misunderstandings, delays, and errors.

Machinery:

Beyond Hardware Machinery involves the physical assets—equipment and tools—that orchestrate the production process. The condition of these machines, their calibration accuracy, and reliability are critical determinants of both quality and efficiency. Proper maintenance and timely calibration prevent disruptions and ensure consistent output like a production efficiency and product quality. Fuzzy logic can analyze machine performance data and recommend maintenance schedules and calibration routines, minimizing downtime and maintaining consistent quality.

This category includes the physical equipment and machinery used in the production process. Machine-related factors can have a direct impact on production efficiency and product quality.

For instance:

- Equipment maintenance: Poorly maintained machinery can lead to breakdowns, causing production delays and disruptions.
- Equipment calibration: Incorrectly calibrated machines can produce products that do not meet quality standards.
- Equipment reliability: Unreliable machinery can lead to inconsistent output and increased downtime.

Material:

From Raw to Refined The quality of materials used in production is a linchpin of the final product's durability and performance. This category extends beyond the raw materials themselves to encompass supply chain management. Ensuring the right materials are available at the right time is essential to prevent bottlenecks and delays. Quality and Supply Chain Material quality affects the end product's durability and performance. By integrating fuzzy logic, the material quality assessment can become more robust, considering factors like supplier history, raw material characteristics, and production variations.

This category encompasses all the raw materials, components, and supplies required for production. Issues related to materials can affect product quality and production timelines.

For example:

- Poor-quality materials: Substandard materials can result in defective products that don't meet quality standards.
- Supply chain disruptions: Delays or shortages in material supply can lead to production delays and increased costs.
- Incorrect specifications: Using the wrong type or size of materials can lead to products that don't meet desired specifications.

Method:

Streamlining Operations Methods are the standard operating procedures that guide production. Their efficiency, standardization, and adaptability are crucial. By continuously optimizing methods, manufacturers can streamline operations, reduce wastage, and improve overall output. Efficiency and Standardization The efficiency of production methods determines overall productivity. Fuzzy logic can aid in assessing method efficiency by analyzing historical production data and suggesting process improvements, resulting in streamlined operations.

This category refers to the processes and procedures used to carry out production. Issues related to methods can lead to inefficiencies and defects in the final product.

For example:

- Process complexity: Overly complicated processes can lead to confusion and errors during production.

- Lack of standardized procedures: Inconsistent methods can result in variations in product quality.

- Inadequate equipment usage: Improper use of machinery or tools can cause defects and safety hazards.

Measurement:

The Precision Paradox Accurate measurement is fundamental to maintaining consistent quality. The measurement category evaluates the accuracy of the tools used for quality control. A minor discrepancy in measurement can have cascading effects on the final product. Accuracy and Analysis Accurate measurement is vital for quality control. Fuzzy logic can assist in identifying measurement inaccuracies by analyzing measurement data trends over time and suggesting recalibration procedures.

This category involves the metrics and measurements used to monitor and control the production process. Measurement-related issues can impact quality control and process optimization.

For instance:

- Inaccurate measurement tools: Using faulty measurement instruments can result in incorrect product dimensions or characteristics.

- Lack of data analysis: Failure to analyze production data can lead to missed opportunities for process improvement.

- Inadequate quality control: Insufficient monitoring and quality checks can allow defective products to reach customers.

II. Fuzzy Logic: A Modern Approach to Enhance Analysis

Fuzzy logic is a mathematical approach that extends classical binary logic to handle uncertainty and imprecision. It was introduced by Lotfi Zadeh in the 1960s as a way to model and reason with vague or uncertain information. Here's a more detailed explanation of the method of fuzzy logic:

1. Fuzzy Sets:

Fuzzy logic begins with the concept of fuzzy sets. In a traditional (crisp) set, an element is either a member or not. In a fuzzy set, elements have degrees of membership between 0 and 1, indicating how well they belong to the set.

Membership functions define these degrees of membership. They are typically represented graphically and describe the relationship between an element and a fuzzy set.

Linguistic Variables and Terms:

Fuzzy logic introduces linguistic variables and terms to describe imprecise values. Instead of using precise numerical values, terms like "high," "low," "warm," and "cold" are used to express conditions in a more human-readable way.

Each linguistic term corresponds to a fuzzy set with its membership function.

2. Fuzzy Rules:

Fuzzy logic employs a set of if-then rules to model relationships between input variables and output variables. These rules are often expressed in the form of "IF <input is> THEN <output is>."

Each rule contains linguistic variables and terms, and the rules collectively define the system's behavior.

3. Fuzzy Inference:

Fuzzy inference involves using the fuzzy rules to determine the output based on the given input. The process combines the degrees of membership from the input fuzzy sets to determine the degrees of membership of the output fuzzy sets.

There are various methods for combining these memberships, such as the Mamdani and Sugeno methods.

4. Defuzzification:

Once the fuzzy inference process is complete, the fuzzy output sets need to be converted into crisp values for practical use. This process is called defuzzification.

Defuzzification methods include finding the center of gravity (centroid) of the fuzzy output sets, which represents a single crisp value.

III. Benefits of Combining Fuzzy Logic and 5M

Comprehensive Analysis: The 5M (Man, Machine, Material, Method, Measurement) framework provides a structured way to analyze potential root causes of issues. By integrating fuzzy logic, you can quantify the impact of each factor on the desired KPIs, considering the uncertainty inherent in real-world data.

Holistic Understanding: The 5M approach encourages a holistic understanding of production processes. Fuzzy logic then adds a layer of sophistication by considering the complex relationships and interactions between these factors, enhancing your predictive capabilities.

Uncertainty Handling: Fuzzy logic accommodates the uncertainty and imprecision often present in real-world data. This is particularly valuable in the 5M context, where factors might not have clear-cut boundaries between categories.

Domain Expertise Integration: The 5M framework encourages involving domain experts in the analysis. When combined with fuzzy logic, experts can contribute not only qualitative insights but also quantitative assessments of the factors' impacts through fuzzy rules.

Improved Decision-Making: The combination allows for more informed decision-making by providing a clearer understanding of the potential outcomes under different scenarios. This helps operators and managers make proactive choices to optimize production.

IV. Linguistic Variables and Membership Functions

Linguistic Variables and Membership Functions Linguistic variables such as "Low," "Moderate," and "High" are assigned membership functions that describe their relevance to each category. These membership functions help in quantifying qualitative assessments. For example, "Moderate" expertise in manpower can be quantified using a membership function that captures a range of skill levels.

Manpower:

- Low: People with minimal training and experience.
- Medium: Moderately skilled individuals with some experience.
- High: Highly skilled and experienced personnel.

Machinery:

- Poor: Equipment with frequent breakdowns and maintenance issues.
- Moderate: Equipment that functions reasonably well but might have occasional issues.
- Good: Reliable and well-maintained machinery.

Materials:

- Inferior: Poor quality or inconsistent materials.
- Average: Materials that meet basic quality standards.
- Excellent: High-quality and consistent materials.

Methods:

- Inefficient: Processes that are prone to errors and delays.
- Standard: Well-defined processes with occasional variations.
- Optimal: Highly efficient and standardized processes.

Measurement:

- Inaccurate: Measurements with a high degree of uncertainty.
- Moderate: Measurements with reasonable accuracy but some variability.
- Precise: Highly accurate and consistent measurements.

Rule-Based Decision-Making Fuzzy logic utilizes rule-based decision making. For instance, if machinery condition is "Good," manpower expertise is "High," and material quality is "High," fuzzy logic can conclude that production quality is "Good," productivity is "High," safety is "High," and customer satisfaction is "High."

Continuous Improvement Fuzzy logic systems can evolve with time by incorporating new data, allowing continuous improvement. As the system learns from historical data, it becomes more accurate in predicting outcomes and suggesting interventions. making it a dynamic tool that enhances its accuracy and predictive capabilities over time.

These rules outline the relationships between input and output variables in a fuzzy logic system. You would implement these rules in MATLAB using fuzzy logic membership functions and inference methods to compute the final output values based on given input values.

Defining the rules for the fuzzy logic system is a crucial step in making accurate assessments of the output variables (productivity, quality, safety, and customer satisfaction) based on the input variables (Manpower Expertise, Machinery Condition, Material Quality, Method Efficiency, and Measurement Accuracy). Below are the rules that can be used in the fuzzy logic system:

By defining these rules and applying them within the fuzzy logic framework, you can create a system that effectively translates the input variables' qualitative assessments into quantifiable output variables, providing a comprehensive analysis of production performance in the automotive industry.

To implement the fuzzy logic model in MATLAB, you need to define all possible combinations of input variable values and their corresponding output variable values based on the rules. Here's a comprehensive list of rules for the given input variables (Manpower Expertise, Machinery Condition, Material Quality, Method Efficiency, and Measurement Accuracy) and output variables (Productivity, Quality, Safety, and Customer Satisfaction):

Rules for Productivity:

- Rule_P1: IF Manpower Expertise is Low THEN Productivity is Low.
- Rule_P2: IF Manpower Expertise is Moderate THEN Productivity is Moderate.
- Rule_P3: IF Manpower Expertise is High THEN Productivity is High.

Rules for Quality:

- Rule_Q1: IF (Manpower Expertise is Low) OR (Machinery Condition is Poor) OR (Material Quality is Low) OR (Method Efficiency is Inefficient) OR (Measurement Accuracy is Low) THEN Quality is Poor.
- Rule_Q2: IF (Manpower Expertise is Moderate) AND (Machinery Condition is Fair) AND (Material Quality is Average) AND (Method Efficiency is Adequate) AND (Measurement Accuracy is Moderate) THEN Quality is Moderate.
- Rule_Q3: IF (Manpower Expertise is High) AND (Machinery Condition is Good) AND (Material Quality is High) AND (Method Efficiency is Efficient) AND (Measurement Accuracy is High) THEN Quality is Good.

Rules for Safety:

- Rule_S1: IF (Manpower Expertise is Low) OR (Machinery Condition is Poor) OR (Material Quality is Low) OR (Method Efficiency is Inefficient) OR (Measurement Accuracy is Low) THEN Safety is Low.
- Rule_S2: IF (Manpower Expertise is Moderate) AND (Machinery Condition is Fair) AND (Material Quality is Average) AND (Method Efficiency is Adequate) AND (Measurement Accuracy is Moderate) THEN Safety is Moderate.
- Rule_S3: IF (Manpower Expertise is High) AND (Machinery Condition is Good) AND (Material Quality is High) AND (Method Efficiency is Efficient) AND (Measurement Accuracy is High) THEN Safety is High.

Rules for Customer Satisfaction:

- Rule_C1: IF (Manpower Expertise is Low) OR (Machinery Condition is Poor) OR (Material Quality is Low) OR (Method Efficiency is Inefficient) OR (Measurement Accuracy is Low) THEN Customer Satisfaction is Low.
- Rule_C2: IF (Manpower Expertise is Moderate) AND (Machinery Condition is Fair) AND (Material Quality is Average) AND (Method Efficiency is Adequate) AND (Measurement Accuracy is Moderate) THEN Customer Satisfaction is Moderate.
- Rule_C3: IF (Manpower Expertise is High) AND (Machinery Condition is Good) AND (Material Quality is High) AND (Method Efficiency is Efficient) AND (Measurement Accuracy is High) THEN Customer Satisfaction is High.

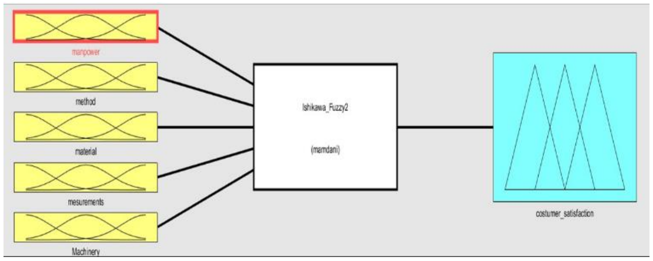

Figure 2: 5M Fuzzy model designed in MATLAB

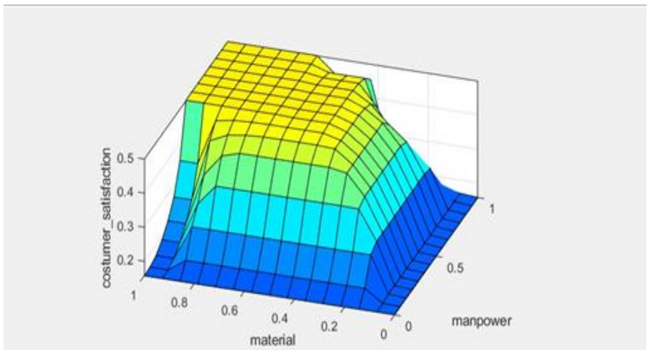

Figure 3: Customer satisfaction

V. Interpretation and practical Application

Manufacturers can use this interpretation to make informed decisions. If they notice that customer satisfaction is low, they might investigate their workforce's expertise. If it's identified as a contributing factor, they can invest in training and skill development programs to raise expertise levels, thus potentially increasing customer satisfaction.

Alternatively, if customer satisfaction is already high, they may want to maintain or further improve the workforce's expertise to sustain their competitive edge in the market.

This interpretation illustrates how variations in one of the 5M factors (Manpower Expertise) can influence customer satisfaction. Fuzzy logic allows for a more nuanced assessment, providing actionable insights for automotive manufacturers to make informed decisions and enhance customer satisfaction by addressing workforce expertise.

Conclusion

In the dynamic landscape of the automotive industry, optimizing production processes is paramount. The integration of Ishikawa's 5M method with fuzzy logic provides a powerful framework for achieving this optimization. By analyzing and addressing issues within the 5M categories using fuzzy logic-driven assessments, automotive manufacturers can enhance production quality, improve productivity, ensure safety, and maximize customer satisfaction. This synergy of established methodologies and modern techniques promises to propel the automotive industry toward even greater heights of performance and excellence.

In the dynamic, demanding landscape of the automotive industry, achieving production excellence requires a multi-faceted approach. By amalgamating Ishikawa's 5M method and the prowess of fuzzy logic, manufacturers can transcend traditional boundaries of analysis. This holistic approach ensures that the factors influencing production — manpower expertise, machinery condition, material quality, method efficiency, and measurement accuracy—are not just examined, but quantified, integrated, and optimized for maximum productivity, superior quality, unwavering safety, and unparalleled customer satisfaction. The amalgamation of legacy methodologies with contemporary techniques is the vanguard of automotive production's future, paving the way for a new era of excellence.

References

1. Guide to Quality Control. Asian Productivity Organization. Juran, J.M. (1992). Juran on Quality by Design. Free Press.

2. Ishikawa, K., 1986. Guide to Quality Control. Asian Productivity Organization, Tokyo, Japan.

3. Juran, J.M., 1992. Juran on Quality by Design: The New Steps for Planning Quality into Goods and Services. Free Press, New York, NY, USA.

4. Zadeh, L.A., 1965. Fuzzy sets. Information and Control, 8(3), pp.338–353.

5. Mushiri, T. and Mbowhwa, C., 2018. Fuzzy Logic Dynamics and Machine Prediction for Failure Analysis. IGI Global, Hershey, PA, USA.

6. Aziz, S., Hayat, S., Hammadi, S. and Borne, P., 1999. New strategy for decision-making aid based.

7. fuzzy inference in the traffic regulation of an urban bus network. In: Proceedings of the IEEE.

8. International Conference on Systems, Man and Cybernetics (SMC), IEEE, Tokyo, Japan.

9. Soumaia, T. and Soulhi, A., 2021. Road Traffic Management with a Fuzzy Logic Approach. Technical Report, [University], Morocco.