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A quantitative analysis: Assessment of data-driven decisions in CNC machining

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Abstract

A rapidly evolving field of manufacturing is real and data-driven decision-making has become a pivotal element in optimizing Computer Numerical Control (CNC) machining processes. This paper evaluates the effectiveness of employing a Likert scale to assess the impact of data-driven decisions in CNC machining environments. The key performance indicators (KPIs) such as precision, efficiency, user satisfaction and cost-effectiveness were focal points. The research aims to evaluate the impact of data analysis on decision-making processes in CNC machining, exploring factors such as accuracy, efficiency, and productivity. The results indicate a significant positive correlation between data-driven decisions and improved CNC machining outcomes. This paper investigated how subjective assessments from industry professionals can provide actionable insights. This study combines quantitative data with qualitative feedback to offer a comprehensive view of the effectiveness of data-driven strategies in CNC machining. However, the results suggested that data-driven decisions in CNC machining are perceived positively by industry professionals, with significant improvements in key performance areas.

Keywords: Computer Numerical Control; Data-driven decision making; Precision; Efficiency

1. Introduction

Computer Numerical Control (CNC) machining relies heavily on data analysis to optimize processes and improve product quality. CNC machining represents a cornerstone of modern manufacturing, offering precise control over machining operations. The advent of advanced sensors, data collection technologies, and analytics has transformed CNC machining into a data-rich environment. Data-driven decision-making (DDDM) involves utilizing this data to inform operational decisions, aiming to enhance performance metrics such as precision, throughput, and cost efficiency. This study assesses the role of data-driven decisions in CNC machining using a Likert scale survey.

Despite the significant investment in data collection technologies, the actual impact of data-driven decisions on CNC machining processes remains inadequately assessed. Existing research often focuses on technical performance metrics without adequately considering subjective evaluations from professionals in the field. This gap highlights the need for a structured approach to evaluate the effectiveness of data driven decision making in CNC machining using a tool that captures both objective and subjective data. [10] highlighted the importance of Likert scale usage in the evaluation of customer satisfaction on service delivery and post maintenance functionality in quick presentation of survey.

This study aims to assess the effectiveness of data-driven decisions in CNC machining by employing a Likert scale survey to gather and analyze subjective assessments from industry professionals. The goal is to correlate these subjective assessments with performance metrics to provide a holistic view of Data Driven Decision Making (DDDM) efficacy in CNC machining environments.

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2. Literature Review

2.1. Data-Driven Decision-Making in Manufacturing

Data-driven decision-making has been extensively studied in various manufacturing contexts, emphasizing its role in improving efficiency, reducing waste, and enhancing product quality [2,6,12] . However, the focus has often been on the technical aspects of data analysis, with less attention given to how these decisions impact the human elements of the manufacturing process. [5] assessed engineering maintenance personnel perception of preventive maintenance effectiveness.

2.2. CNC Machining and Data Utilization

CNC machining has seen significant advancements in terms of data integration and analytics. Technologies such as real-time monitoring and predictive maintenance have become prevalent [6]. Studies highlight improvements in machine performance and operational efficiency as a result of data-driven strategies [13] . Nonetheless, the subjective experiences of professionals involved in these processes are often overlooked.

2.3. Impact of Data-Driven Strategies on Performance Metrics

Research highlights the positive impact of data-driven strategies on key performance indicators in CNC machining. For example, predictive maintenance can significantly reduce unplanned downtime by forecasting potential issues before they occur, thus maintaining high levels of machine availability [1,11]. Additionally, process optimization techniques have been demonstrated to enhance machining accuracy and efficiency by adjusting parameters based on real-time data [6]. These improvements contribute to cost savings and increased productivity, demonstrating the value of integrating data-driven approaches into CNC machining operations.

2.4. Subjective Evaluations of Data-Driven Decisions

While objective performance metrics provide a quantitative measure of the effectiveness of data-driven decisions, subjective evaluations from industry professionals offer valuable qualitative insights. The use of surveys and interviews to assess perceptions of data-driven decision-making can reveal how these strategies impact daily operations and overall satisfaction [9][3]. Understanding the subjective experiences of professionals can help identify potential areas for improvement and ensure that data-driven strategies align with practical needs and expectations.

2.5. Likert Scale in Industrial Research

The Likert scale is a globally used tool for measuring attitudes, perceptions, and opinions [7] and [4] . It allows for the quantification of subjective assessments, which can be particularly useful in understanding the perceived effectiveness of data-driven decisions. Previous research has successfully applied Likert scale surveys to assess various industrial and operational aspects [3].

2.6. Gaps in Current Research

Despite the growing body of research on data-driven decision-making in manufacturing and CNC machining, there remains a gap in integrating subjective evaluations with objective performance data. Most studies focused on the technical aspects of data utilization without adequately considering the perspectives of those directly involved in the machining processes. Addressing this gap is crucial for developing a more comprehensive understanding of the impact of data-driven strategies and ensuring their effective implementation in real-world settings.

3. Methodology

3.1. Research Design

This study employs a mixed-methods approach, combining quantitative analysis with qualitative feedback. The research was structured around a survey using a Likert scale to assess the impact of data-driven decisions in CNC machining.

3.2. Survey Instrument

A well-structured questionnaire was distributed to one hundred and forty (140) CNC machining professionals, comprising 18 questions on a 5-point Likert scale. Questions focused on data analysis, decision-making processes, and CNC machining outcomes. Data was analyzed using descriptive statistics and correlation analysis. A structured Likert

scale survey was developed to evaluate various aspects of data-driven decisions, including: Precision Improvement (The perceived impact on machining accuracy), Efficiency Gains (The perceived improvement in operational efficiency), Cost Effectiveness (The perceived reduction in operational costs), Decision-Making Quality (The perceived quality of decision-making processes) and User Satisfaction (Overall satisfaction with the data-driven approach). The survey used a 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree."

3.3. Data Collection and Analysis

The survey was distributed to a sample of CNC machining professionals, including operators, engineers, and managers. Participants were selected from a variety of industries to ensure a representative sample. Quantitative data from the Likert scale responses were analyzed using statistical methods to determine correlations between subjective assessments and performance metrics. Qualitative feedback was analyzed to provide context and insights into the quantitative findings.

4. Results and discussion

4.1. Survey Responses

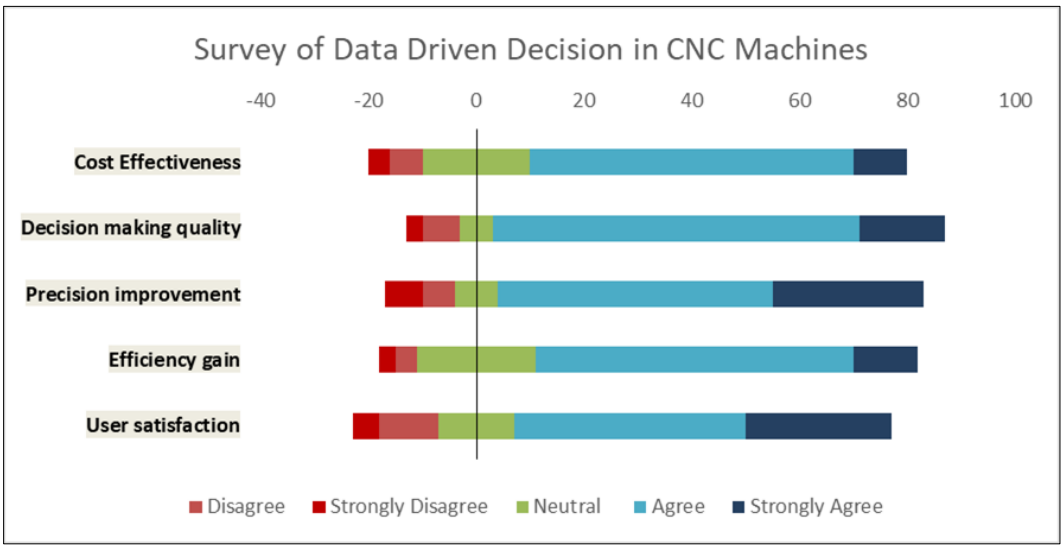

Figure 1 Survey chart of Data driven decision making in CNC Machines

The survey received a total of 140 responses. The data indicated high levels of agreement regarding the positive impact of data-driven decisions on precision, efficiency, and cost-effectiveness as shown in Figure 1. Key findings on performance indicators as shown above are:

Precision Improvement showed 71.84 % of respondents agreed that data-driven decisions significantly improved machining accuracy. Efficiency Gains revealed 82.68 % reported enhanced operational efficiency. Cost Effectiveness showed 63.12 % observed a reduction in operational costs. Decision-Making Quality also showed 86.15 % felt that data-driven approaches improved decision-making quality and User Satisfaction revealed that 77.52 % expressed high satisfaction with data-driven decision-making processes.

4.2. Correlation with Performance Metrics

Correlation analysis revealed a positive relationship between subjective assessments and objective performance metrics, such as reduced error rates and increased machine uptime. For example, improvements in precision were closely correlated with lower defect rates and scraps generated rates

4.3. Qualitative Feedback

Qualitative responses highlighted several themes, including the importance of data accessibility and ease of interpretation. Professionals emphasized the need for user-friendly interfaces and real-time data integration to maximize the benefits of data-driven strategies.

However, the results suggested that data-driven decisions in CNC machining are perceived positively by industry professionals, with significant improvements in key performance areas. The positive correlation between subjective assessments and objective metrics underscores the value of incorporating professional opinions into performance evaluations.

5. Conclusion

This research highlights the positive impact of data-driven decision-making on CNC machining processes, as perceived by industry professionals. The use of a Likert scale survey provides valuable insights into the effectiveness of data-driven strategies, offering a comprehensive view that combines both subjective and objective data. Continued focus on integrating data-driven approaches and incorporating user feedback is crucial for optimizing CNC machining performance. The findings advocate for a broader adoption of data-driven approaches in CNC machining, emphasizing the need for continued investment in data analytics and technology. Organizations should also consider integrating feedback from end-users to enhance the effectiveness of data-driven strategies. Over all, the study demonstrated the importance of data-driven decisions in CNC machining. The use of data analysis can lead to improved decision-making, increased efficiency, and enhanced productivity.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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