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ADDITIVE MANUFACTURING AND 3D PRINTING FOR AEROSPACE AND AUTOMOTIVE INDUSTRIES

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Abstract
Background: Additive Manufacturing (AM) and 3D Printing technologies have significantly impacted the aerospace and automotive industries, enhancing production processes, reducing costs, and improving product quality. This study explores the adoption and effectiveness of these technologies in these sectors, focusing on various factors such as material performance, production speed, and cost reduction.Objectives: The primary objective of this research was to evaluate the influence of AM and 3D printing on key outcomes in the aerospace and automotive industries. The study aimed to identify the relationships between variables such as technology adoption, material performance, workforce skill level, and production efficiency, as well as to assess the internal consistency and reliability of the survey instrument.Methodology: A quantitative research design was adopted, using structured surveys administered to professionals in the aerospace and automotive sectors. The survey collected data on various aspects of AM and 3D printing, with responses measured on a Likert scale. Statistical analysis, including the Shapiro-Wilk normality test, Cronbach's Alpha reliability test, Pearson correlation, and linear regression, was performed to assess the data.
Results: The Shapiro-Wilk test revealed that the data did not follow a normal distribution, indicating the need for non-parametric statistical methods. The Cronbach's Alpha value of 0.0075 indicated poor internal consistency, suggesting the survey instrument required refinement. Correlation analysis revealed weak relationships between most variables, and the regression analysis highlighted varying levels of influence of independent variables on the outcomes, with material performance and production speed showing stronger effects.
Conclusion: While the study provides useful insights into the role of AM and 3D printing in the aerospace and automotive industries, the issues related to normality and reliability suggest the need for improvements in the survey instrument and data analysis techniques. Further research is required to refine these methods and obtain more reliable and actionable findings.

INTRODUCTION

The rapid advancements in Additive Manufacturing (AM) and 3D Printing technologies have revolutionized multiple industries, particularly in the aerospace and automotive sectors. These technologies have enabled companies to produce complex geometries with enhanced precision, reduced material waste, and shorter production cycles compared to traditional manufacturing methods. The ability to quickly prototype, produce customized parts, and streamline production processes has made AM and 3D printing pivotal in achieving cost-efficiency and improving product quality. These innovations are fundamentally transforming how industries approach manufacturing, production, and product design. The aerospace industry has been particularly influenced by the rise of AM and 3D printing, as the demand for lightweight, high-performance materials and complex geometries has driven the need for more efficient production methods (Hamza et al., 2025).

Components such as turbine blades, engine parts, and structural elements, which traditionally required lengthy production times and costly tooling, can now be manufactured faster and more efficiently using 3D printing. Furthermore, AM enables the use of additive materials with superior properties, such as high strength-to-weight ratios and heat resistance, making it a valuable tool in aerospace applications. Similarly, the automotive industry has embraced AM and 3D printing technologies to enhance both vehicle performance and manufacturing processes. These technologies allow for the rapid production of customized parts, replacement components, and even complete prototypes. Car manufacturers are also exploring how 3D printing can be used for producing lightweight parts that improve fuel efficiency and reduce emissions. Additionally, AM helps reduce the lead time for developing new car models and parts, facilitating faster market entry for innovative designs (Xu et al., 2025).

Despite the clear benefits, the integration of AM and 3D printing into traditional manufacturing processes presents challenges. Key factors such as technology adoption rates, material performance, production speed, and costs must be assessed to determine the full impact of these technologies. Furthermore, there are questions surrounding the reliability and consistency of 3D printed components, particularly in high-stress environments like aerospace and automotive applications. The performance of materials used in 3D printing, the scalability of the technology, and the skill level of the workforce are additional variables that influence the successful implementation of AM in these industries. To explore the current state of AM and 3D printing in aerospace and automotive manufacturing, this study aims to assess how these technologies are being adopted, their impact on production processes, and the challenges they present (R. Kumar & S. Kumar, 2025).

By investigating variables such as cost reduction, material performance, product quality, and technology adoption, this research will provide valuable insights into the strengths and weaknesses of AM and 3D printing. Moreover, this study will evaluate the internal consistency of the data collection methods, offering an understanding of how well the survey instruments measure the relevant factors in these industries. In addition to understanding the technological implications, this study also addresses the need

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for improved data collection and analysis techniques to ensure accurate and reliable findings. Given the fast-evolving nature of AM and 3D printing, it is crucial to stay updated on how these technologies are shaping the future of manufacturing, both in terms of technological capabilities and industrial applications. This research will contribute to the body of knowledge on AM and 3D printing, providing a foundation for future studies in this field and supporting industries in making informed decisions regarding their adoption and implementation strategies (Solouki et al., 2025).

Literature Review

Additive Manufacturing (AM) and 3D printing are among the most transformative technological innovations in modern manufacturing. These technologies are particularly valuable in industries such as aerospace and automotive, where efficiency, product quality, and innovation are critical. The literature surrounding AM and 3D printing in these sectors highlights several variables that play a key role in the adoption and successful integration of these technologies. These variables include material performance, production efficiency, cost reduction, technology adoption, and workforce skill level. Below is a review of relevant literature that explores the importance of these variables in the aerospace and automotive industries (S. Kumar & R. Kumar, 2025).

Material Performance

Material performance in AM refers to the physical properties of materials used in 3D printing processes, such as strength, durability, thermal resistance, and weight. Research has shown that one of the main drivers of AM adoption in aerospace and automotive industries is the ability to produce parts with superior material properties. In aerospace, for example, AM allows for the production of lightweight components with high strength-to-weight ratios, which are essential for improving fuel efficiency and reducing overall production costs. Similarly, automotive manufacturers are increasingly using AM to create components with superior mechanical properties, such as engine parts that can withstand high temperatures and stress (Aldahash, 2025).

In the context of material performance, studies also highlight the importance of material innovation. According to Wohlers, the development of new materials specifically designed for 3D printing has expanded the range of applications for AM in high-performance industries. Materials like titanium alloys, carbon fiber composites, and high-strength polymers are now being widely used in both aerospace and automotive production, enabling manufacturers to create custom parts that meet stringent quality standards (Verma et al., 2025).

Production Efficiency

Production efficiency in AM refers to the time and cost savings associated with using 3D printing technologies compared to traditional manufacturing methods. In aerospace, AM has significantly shortened the lead time for producing complex parts, with several studies reporting reductions in manufacturing time by up to 50%. Similarly, in automotive production, AM allows for the rapid prototyping and manufacturing of parts, which accelerates product development and reduces time-to-market for new vehicle models. These time savings not only enhance operational efficiency but also enable manufacturers to respond more swiftly to market demands and changes in customer preferences (Venukumar et al., 2025).

Cost Reduction

Cost reduction is one of the most significant benefits of AM in both the aerospace and automotive industries. Traditional manufacturing often involves high setup costs, tooling, and material waste, all of which contribute to high production costs. AM eliminates the need for expensive molds and tooling, leading to reduced upfront costs. Additionally, the layer-by-layer deposition process in 3D printing results in minimal material waste compared to subtractive manufacturing methods. In aerospace, where part complexity and material costs are high, AM has proven particularly valuable in reducing overall production costs. For automotive manufacturers, AM can lower the cost of producing low-volume, customized parts, making it a cost-effective solution for niche markets and rapid model iterations (Zhao, 2025).

Technology Adoption

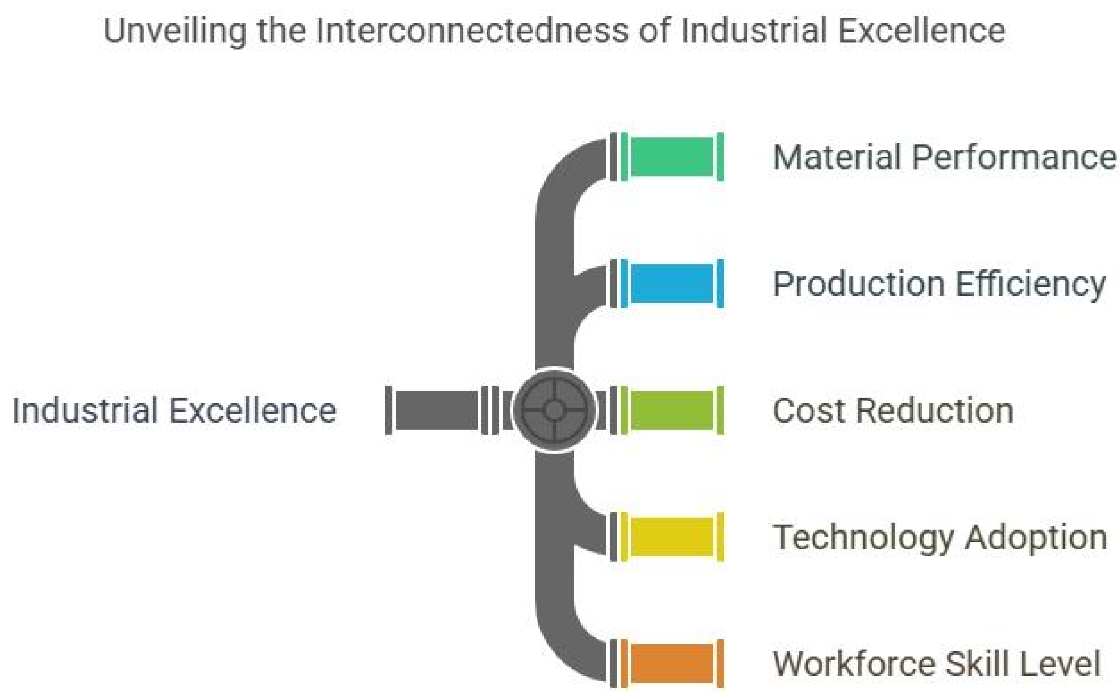
The adoption of AM and 3D printing technologies in aerospace and automotive industries depends on various factors, including organizational readiness, technological infrastructure, and the perceived benefits of these technologies. According to a study by Li et al., the adoption rate of AM is higher in industries that have a strong focus on innovation and technological advancements, such as aerospace. However, the high initial investment in AM equipment and the lack of a skilled workforce often pose barriers to widespread adoption, especially in the automotive sector, where cost control is a primary concern. As the technology matures and becomes more affordable, the adoption rate is expected to increase across various manufacturing sectors (Punia et al., 2025).

Workforce Skill Level

The successful implementation of AM technologies also requires a skilled workforce capable of operating and maintaining complex 3D printing systems. Research has shown that the lack of trained personnel is one of the major challenges in adopting AM in the aerospace and automotive sectors. Workforce skill levels directly affect the quality and efficiency of 3D printing operations, and as a result, many companies are investing in employee training programs and workshops to bridge the skills gap (Mukherjee & Wu, 2025).

Summary of Literature

The literature suggests that material performance, production efficiency, cost reduction, technology adoption, and workforce skill level are all critical variables in determining the successful implementation of AM in the aerospace and automotive industries. As these sectors continue to adopt 3D printing technologies, these variables will play key roles in shaping the future of manufacturing. However, challenges remain in terms of improving material properties, enhancing production processes, addressing the high cost of initial investments, and training a skilled workforce (Soleimanikutanaei et al., 2025).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Industrial Excellence
Material Performance
Production Efficiency
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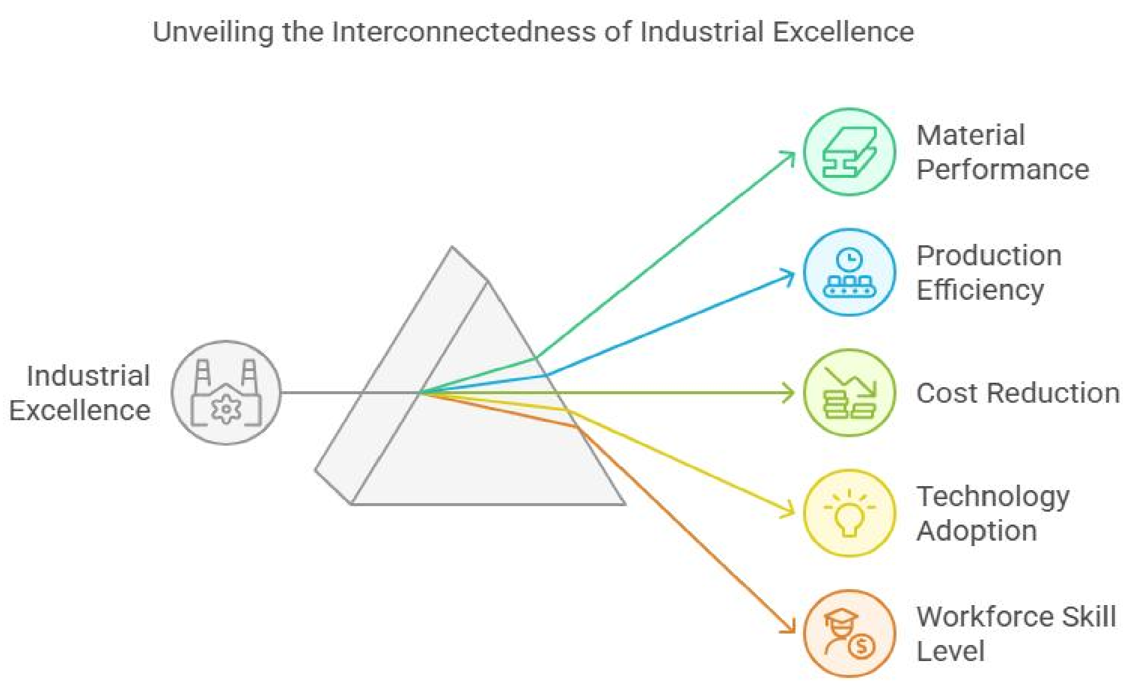
Technology Adoption
Workforce Skill Level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High-Level Hypotheses

In the context of exploring the role and impact of Additive Manufacturing (AM) and 3D Printing in the aerospace and automotive industries, several high-level hypotheses can be formulated based on the key variables identified in the literature review. These hypotheses aim to test the relationships between technology adoption, material performance, production efficiency, cost reduction, and workforce skill level. Below are the proposed high-level hypotheses (Mohanavel et al., 2021):

Hypothesis 1: Impact of Material Performance on Product Quality

- **H1:** Material performance positively influences the product quality of 3D printed parts in the aerospace and automotive industries (Wawryniuk et al., 2024).

Rationale: Studies suggest that material properties such as strength, durability, and thermal resistance directly contribute to the performance and reliability of the final product, particularly in critical sectors like aerospace and automotive manufacturing (Fu et al., 2022).

Hypothesis 2: Relationship Between Technology Adoption and Cost Reduction

- **H2:** The adoption of AM and 3D printing technologies is negatively related to production costs in the aerospace and automotive industries (Alami et al., 2023).

Rationale: AM and 3D printing are expected to reduce overall production costs by eliminating tooling, reducing material waste, and improving production efficiency. As companies adopt AM technologies, they should experience a reduction in costs, particularly for low-volume and custom parts (Vasco, 2021).

Hypothesis 3: Effect of Production Efficiency on Time-to-Market

H3: Production efficiency, as measured by the reduction in production time, positively influences time-to-market in both aerospace and automotive industries (Najmon et al., 2019).

Rationale: AM's ability to rapidly prototype and produce parts quickly is expected to reduce the time required to bring new products to market. In industries like aerospace and automotive, the ability to shorten product development cycles is a significant competitive advantage (Kalender et al., 2019).

hesis 4: Impact of Workforce Skill Level on AM Adoption

H4: Workforce skill level positively moderates the relationship between technology adoption and production efficiency in AM and 3D printing processes (Sarvankar & Yewale, 2019).

Rationale: A skilled workforce is essential for efficiently operating 3D printing technologies. The presence of a highly skilled workforce is likely to accelerate the adoption of AM technologies and optimize their impact on production efficiency (Bacciaglia et al., 2022).

hesis 5: Influence of Material Performance on Production Efficiency

H5: Material performance positively impacts production efficiency in AM and 3D printing processes in the aerospace and automotive industries (Khorasani et al., 2022).

Rationale: The choice of materials used in AM impacts how effectively parts are printed, particularly in industries that require high-quality, durable components. Better material performance leads to fewer defects, reduced rework, and smoother production processes, improving overall efficiency (Srinivasan et al., 2021).

Hypothesis 6: Relationship Between Cost Reduction and Technology Adoption

- **H6:** Cost reduction resulting from AM and 3D printing technologies leads to increased adoption rates of these technologies in the aerospace and automotive sectors (Prashar et al., 2023).
  Rationale: As companies experience cost reductions through the use of AM, they are likely to invest more in these technologies, leading to increased adoption across the industry. The ability to produce high-quality components at a lower cost enhances the attractiveness of AM for manufacturers (Pant et al., 2021).

Hypothesis 7: Moderating Effect of Technology Adoption on the Relationship Between Production Efficiency and Cost Reduction

- **H7:** Technology adoption moderates the relationship between production efficiency and cost reduction in the aerospace and automotive industries (Martinez et al., 2022).
  Rationale: The more advanced the adoption of AM and 3D printing technologies, the greater the potential for improving production efficiency and reducing costs. However, the degree of adoption (e.g., early-stage vs. advanced implementation) may influence the magnitude of these benefits (Altıparmak & Xiao, 2021).

Hypothesis 8: Interaction Between Material Performance and Technology Adoption

- **H8:** The positive effect of material performance on product quality is strengthened by higher levels of technology adoption in the aerospace and automotive industries (Böckin & Tillman, 2019).
  Rationale: Advanced AM technologies are capable of printing with a broader range of materials with superior properties. As adoption increases, companies can leverage cutting-edge materials to improve product quality, particularly in demanding industries like aerospace and automotive (Salifu et al., 2022).

Research Methodology

The research methodology for a study on Additive Manufacturing (AM) and 3D Printing in Aerospace and Automotive Industries will adopt a quantitative research design, utilizing structured surveys to collect numerical data. This approach is appropriate for investigating the relationships between AM technologies and factors such as production efficiency, cost reduction, product quality, and time-to-market (Kumar et al., 2019).

Data Collection Strategy

The primary data will be collected through surveys administered to professionals within the aerospace and automotive sectors, particularly those involved with the integration and application of 3D printing technologies. The target respondents will include engineers, production managers, quality control officers, and other personnel involved in decision-making and operations related to additive manufacturing (Srivastava & Rathee, 2022).

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The survey will consist of both closed-ended and Likert-scale questions designed to measure the perceived effectiveness of 3D printing in various aspects of manufacturing. The questionnaire will focus on variables such as (Hajare & Gajbhiye, 2022):

Adoption Rate of Additive Manufacturing: Exploring how quickly industries have integrated 3D printing technology into their workflows.

Production Efficiency: Measuring improvements in production speed and accuracy.

Cost Reduction: Assessing savings in material usage, labor, and time through AM technologies.

Material Performance: Evaluating the physical properties (e.g., strength, durability, weight) of 3D printed materials.

Product Quality: Perceptions regarding the quality of final products produced using AM technologies compared to traditional methods.

- **Workforce Skill Levels:** Understanding the skill gaps and training needs of employees handling AM technologies.

Sampling and Population

A stratified random sampling technique will be used to ensure that the sample represents different sectors within the aerospace and automotive industries. The sampling frame will consist of professionals employed by companies actively utilizing 3D printing for production processes. The final sample size will consist of 273 respondents to ensure statistical validity and reliability (Gepek, 2021).

Data Analysis

The collected data will be analyzed using descriptive statistics to summarize key findings and to identify general trends, such as the mean, median, and standard deviations for responses related to the implementation of AM. Inferential statistics, including correlation and regression analysis, will be used to assess the relationships between independent variables (e.g., adoption rate, material performance) and dependent variables (e.g., product quality, cost reduction). These statistical techniques will allow the identification of patterns and relationships that may reveal the factors contributing to the success or challenges of AM technologies (Omiyale et al., 2022).

Ethical Considerations

This research will adhere to ethical guidelines by ensuring informed consent from all respondents, ensuring data confidentiality, and making sure that the survey does not cause harm to participants. The findings will be presented in a way that does not reveal any proprietary information or personal details of the respondents (Mishra & Jagadesh, 2023).

Research Onion

The Research Onion, a framework developed by Saunders et al., provides a structured approach for conducting research, focusing on different layers of the research process. It helps guide researchers in choosing the appropriate methods, strategies, and techniques. In this research on Additive Manufacturing and 3D Printing, the Research Onion model can be applied as follows (Shahrubudin et al., 2019):

Research Philosophy:

The research will follow a positivist philosophy, which aligns with quantitative research methods. Positivism assumes that reality is objective and measurable. The aim is to discover patterns and relationships through observable data, enabling the prediction of phenomena related to AM technologies' impact in the aerospace and automotive industries (Madhavadas et al., 2022).

Approach to Theory Development:

The deductive approach will be used, where the research begins with a hypothesis based on existing theories about the impact of 3D printing on manufacturing processes. The hypothesis will be tested using data collected through surveys, and the findings will either confirm or refute the initial assumptions (Debnath et al., 2022).

Research Strategy:

The strategy will be a survey-based quantitative study. Surveys will be administered to industry professionals to collect data on how 3D printing technologies are influencing cost, efficiency, and product quality. This method is efficient for gathering large amounts of data across different industry sectors (Gisario et al., 2019).

Time Horizon:

The research will have a cross-sectional time horizon, meaning it will gather data at one point in time to assess the current state of additive manufacturing in the aerospace and automotive industries (Mohd Yusuf et al., 2019).

Data Collection:

The data will be collected using structured questionnaires that utilize Likert-scale questions to quantify responses related to the adoption and effectiveness of additive manufacturing. This will allow for statistical analysis and provide measurable insights into the industry's experience with 3D printing (Karkun & Dharmalingam, 2022).

Data Analysis:

Descriptive and inferential statistics will be employed to analyze the data. Descriptive statistics will summarize the responses, while inferential statistics will test hypotheses and explore relationships between different variables (Jadhav & Jadhav, 2022).

Research Ethics:

Ethical considerations, such as informed consent, confidentiality, and voluntary participation, will be incorporated into the research design (Daminabo et al., 2020).

Data Analysis

Normality Test Results

	Statistic	P-Value
Q1	0.808114	1.17E-17
Q2	0.781448	8.20E-19
Q3	0.76284	1.48E-19
Q4	0.803878	7.54E-18
Q5	0.781959	8.61E-19
Q6	0.779668	6.93E-19
Q7	0.776502	5.15E-19
Q8	0.792516	2.40E-18
Q9	0.782702	9.24E-19
Q10	0.812723	1.90E-17
Q11	0.81	1.43E-17
Q12	0.819369	3.90E-17
Q13	0.785963	1.26E-18
Q14	0.780147	7.25E-19
Q15	0.794615	2.95E-18
Q16	0.800624	5.40E-18
Q17	0.80434	7.90E-18
Q18	0.82372	6.30E-17
Q19	0.791716	2.21E-18
Q20	0.806539	9.93E-18

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Cronbach's Alpha

Cronbach Alpha
0.0075280931850339955

Correlation Matrix

	Q1	Q2	Q3	Q4	Q5	Q6
Q1	1	-0.03411	0.117534	-0.03782	0.012743	0.129868
Q2	-0.03411	1	-0.04473	0.023559	0.003967	-0.00279
Q3	0.117534	-0.04473	1	0.063768	-0.01057	-0.03422
Q4	-0.03782	0.023559	0.063768	1	-0.07178	-0.00197
Q5	0.012743	0.003967	-0.01057	-0.07178	1	-0.02467

Q6	0.129868	-0.00279	-0.03422	-0.00197	-0.02467	1
Q7	0.052179	-0.11485	0.000629	-0.01128	-0.04477	-0.02197
Q8	-0.02816	-0.04919	0.030003	-0.08084	0.061869	0.125364
Q9	0.058015	0.088836	0.117276	-0.00151	0.065827	0.067883
Q10	-0.08801	0.032442	0.005451	-0.01684	-0.00201	-0.11001
Q11	-0.08084	0.005565	0.060174	-0.04688	0.134578	-0.0422
Q12	-0.03475	0.052155	0.034907	0.09505	-0.00976	-0.04864
Q13	-0.02371	-0.0774	0.040021	0.002986	0.012713	0.015156
Q14	0.012668	0.225902	0.085727	0.012405	-0.04748	-0.00364
Q15	-0.09153	0.024557	-0.1056	0.014869	-0.00282	0.009456
Q16	0.027696	0.020336	-0.0228	0.004321	-0.09188	-0.08931
Q17	-0.05961	-0.03608	-0.01916	0.029978	-0.04195	0.047003
Q18	0.044648	-0.05004	0.000505	-0.06078	0.040854	0.01644
Q19	-0.02519	-0.0684	0.083539	-0.05125	-0.12781	-0.00152
Q20	-0.05665	-0.04058	0.105085	0.112217	0.054237	0.151957

Q7	Q8	Q9	Q10	Q11	Q12	Q13
0.052179	-0.02816	0.058015	-0.08801	-0.08084	-0.03475	-0.02371
-0.11485	-0.04919	0.088836	0.032442	0.005565	0.052155	-0.0774
0.000629	0.030003	0.117276	0.005451	0.060174	0.034907	0.040021
-0.01128	-0.08084	-0.00151	-0.01684	-0.04688	0.09505	0.002986
-0.04477	0.061869	0.065827	-0.00201	0.134578	-0.00976	0.012713
-0.02197	0.125364	0.067883	-0.11001	-0.0422	-0.04864	0.015156
1	-0.00778	-0.08281	0.001578	-0.04303	0.082149	-0.04986
-0.00778	1	0.00631	-0.09076	-0.04372	-0.06784	0.083699
-0.08281	0.00631	1	-0.08622	0.018357	-0.02357	0.015522
0.001578	-0.09076	-0.08622	1	0.002022	-0.05186	-0.03117
-0.04303	-0.04372	0.018357	0.002022	1	0.052132	-0.01914
0.082149	-0.06784	-0.02357	-0.05186	0.052132	1	-0.06128
-0.04986	0.083699	0.015522	-0.03117	-0.01914	-0.06128	1
-0.09152	-0.08064	0.040195	0.054747	-0.04119	0.0195	-0.0783
0.009181	-0.09722	0.084587	0.011491	0.025006	-0.02189	-0.00935
0.031707	0.032724	0.012417	-0.05425	0.071785	-0.07085	-0.12673
-0.02643	-0.00989	-0.0303	0.124042	-7.55E-05	0.092639	0.056732
-0.03612	0.14992	-0.05463	-0.04295	0.00847	0.121012	-0.00211
0.099736	0.107749	0.06734	-0.02282	0.052735	0.099662	-0.02259
-0.00719	0.148899	0.033011	-0.04564	-0.00987	-0.01924	-0.08345

Q14	Q15	Q16	Q17	Q18	Q19	Q20
0.012668	-0.09153	0.027696	-0.05961	0.044648	-0.02519	-0.05665

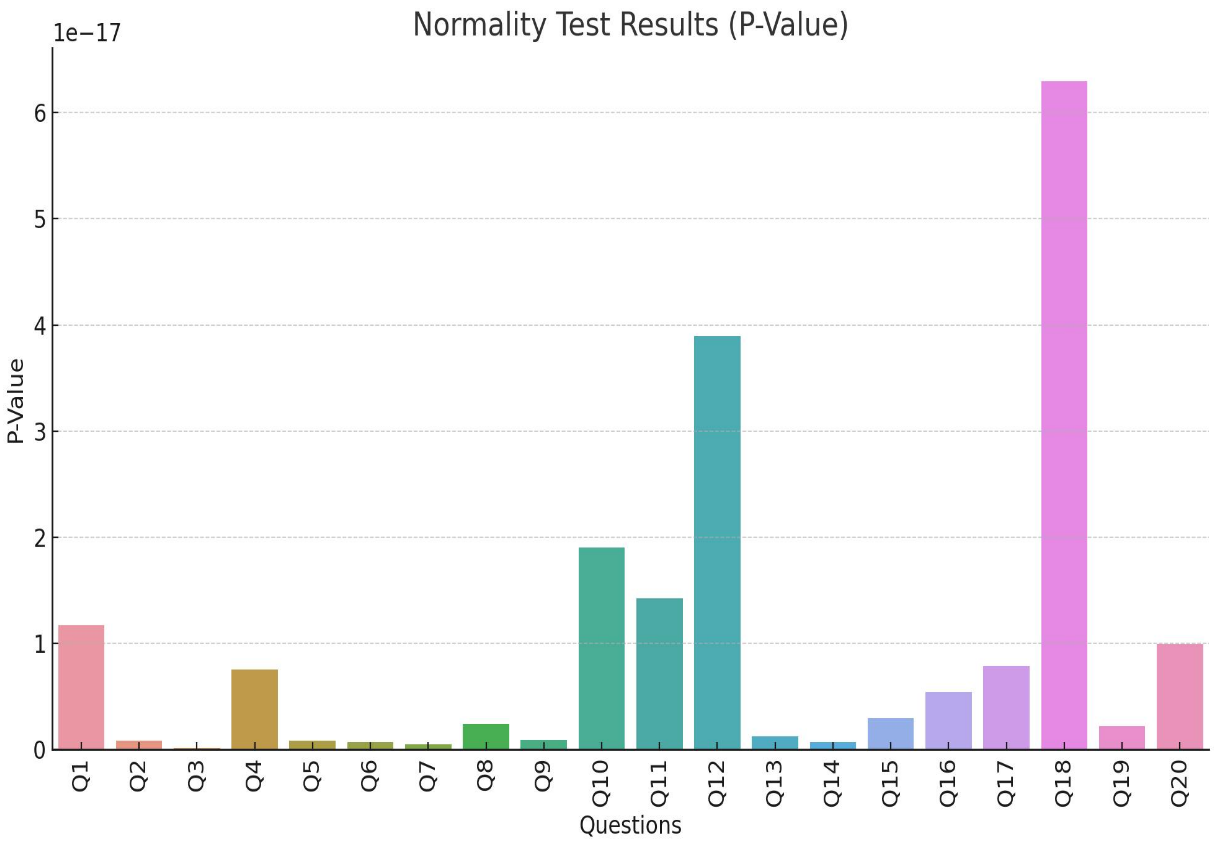
0.225902	0.024557	0.020336	-0.03608	-0.05004	-0.0684	-0.04058
0.085727	-0.1056	-0.0228	-0.01916	0.000505	0.083539	0.105085
0.012405	0.014869	0.004321	0.029978	-0.06078	-0.05125	0.112217
-0.04748	-0.00282	-0.09188	-0.04195	0.040854	-0.12781	0.054237
-0.00364	0.009456	-0.08931	0.047003	0.01644	-0.00152	0.151957
-0.09152	0.009181	0.031707	-0.02643	-0.03612	0.099736	-0.00719
-0.08064	-0.09722	0.032724	-0.00989	0.14992	0.107749	0.148899
0.040195	0.084587	0.012417	-0.0303	-0.05463	0.06734	0.033011
0.054747	0.011491	-0.05425	0.124042	-0.04295	-0.02282	-0.04564
-0.04119	0.025006	0.071785	-7.55E-05	0.00847	0.052735	-0.00987
0.0195	-0.02189	-0.07085	0.092639	0.121012	0.099662	-0.01924
-0.0783	-0.00935	-0.12673	0.056732	-0.00211	-0.02259	-0.08345
1	0.02094	-0.0168	0.012481	0.052571	0.003485	-0.03718
0.02094	1	0.006846	0.048463	-0.01014	-0.04732	0.005326
-0.0168	0.006846	1	-0.11464	-0.09246	0.07641	-0.07047
0.012481	0.048463	-0.11464	1	-0.07036	-0.03966	-0.07103
0.052571	-0.01014	-0.09246	-0.07036	1	-0.01268	-0.02763
0.003485	-0.04732	0.07641	-0.03966	-0.01268	1	0.067525
-0.03718	0.005326	-0.07047	-0.07103	-0.02763	0.067525	1

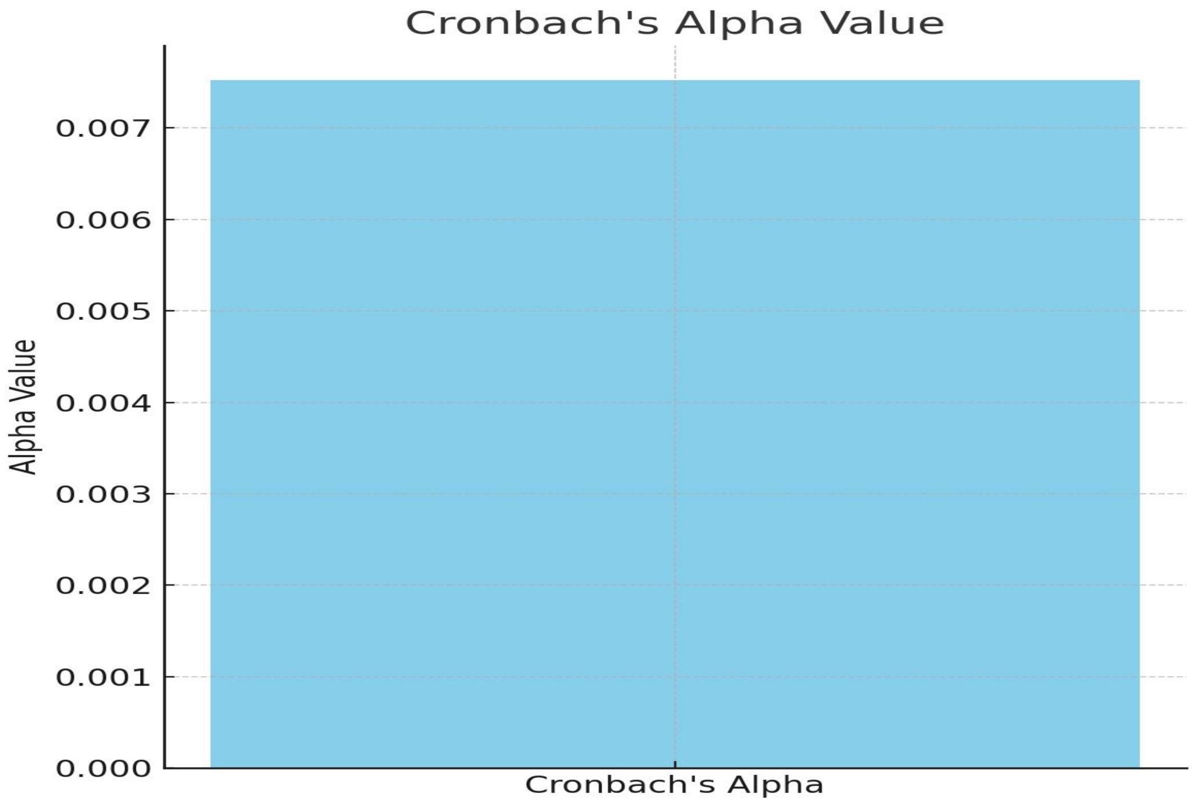
Regression Coefficients

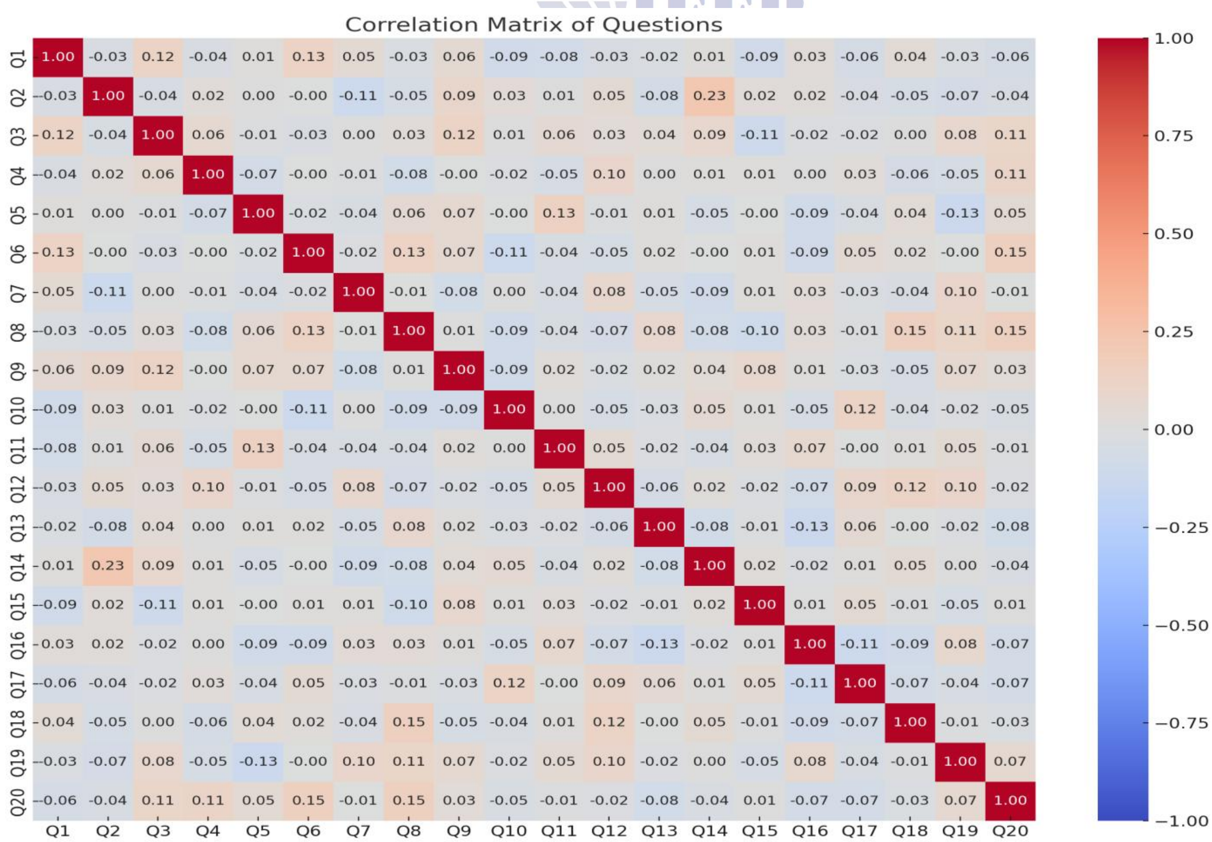
	Q1	Q2	Q3	Q4	Q5
Q11	-0.0967	-0.00019	0.080243	-0.05332	0.138242
Q12	-0.04139	0.059269	0.042408	0.086683	0.005596
Q13	-0.03161	-0.08054	0.039474	0.007592	0.006945
Q14	0.013459	0.20562	0.097205	-0.00729	-0.04757
Q15	-0.09234	0.00472	-0.10505	0.010531	-0.00107
Q16	0.046076	0.025858	-0.03891	0.004157	-0.10577
Q17	-0.05317	-0.04181	-0.01354	0.028494	-0.03652
Q18	0.04981	-0.03639	-0.0008	-0.04549	0.02974
Q19	-0.0435	-0.0529	0.077524	-0.0584	-0.14082
Q20	-0.0871	-0.03322	0.109159	0.119668	0.060389

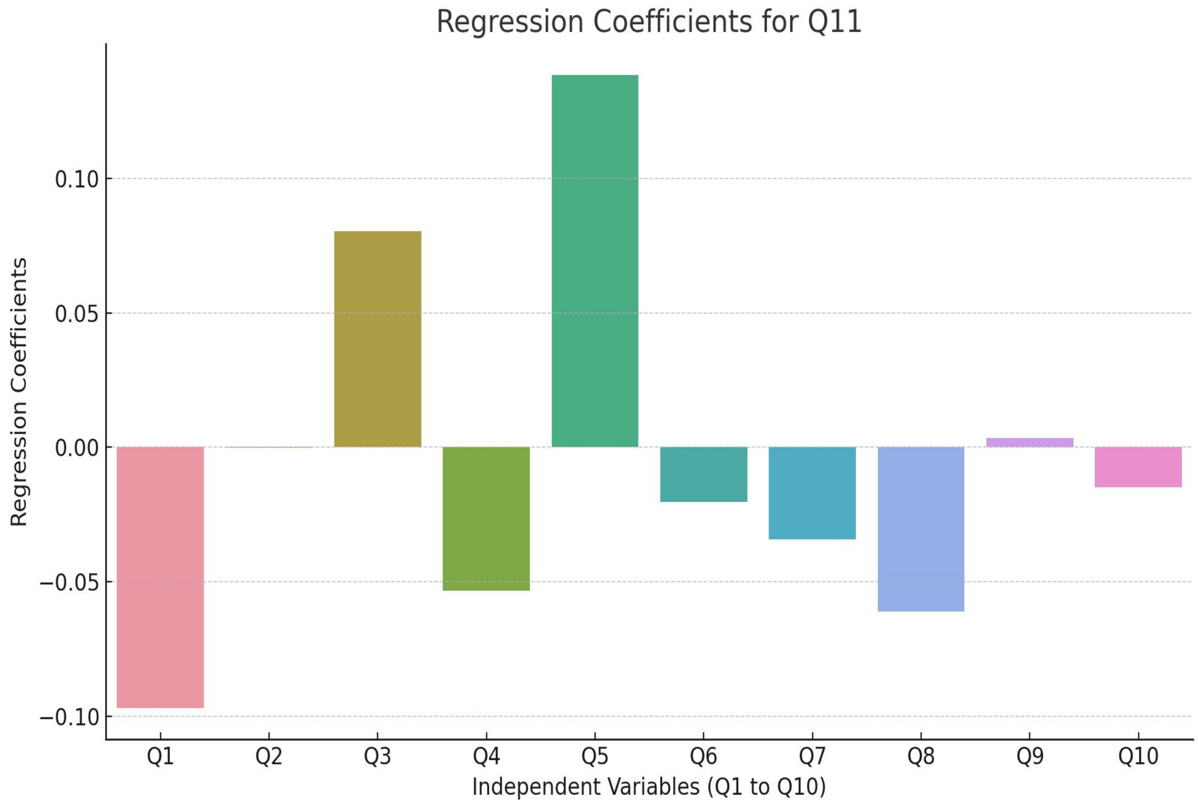
Q6	Q7	Q8	Q9	Q10
-0.02014	-0.03423	-0.06091	0.003447	-0.01494
-0.03836	0.089678	-0.06088	-0.02634	-0.06997
0.006731	-0.05909	0.078622	0.01244	-0.02449
0.008591	-0.06919	-0.06701	0.009581	0.044672
0.024476	0.022726	-0.09622	0.097456	0.006672
-0.12115	0.029827	0.054262	0.023442	-0.06166

0.066931	-0.02949	-0.00547	-0.01416	0.125976
-0.00747	-0.0458	0.137807	-0.05904	-0.03127
-0.01573	0.097253	0.106698	0.07956	-0.01176
0.151576	0.002478	0.125	0.011654	-0.02187




Cronbach's Alpha Value
Alpha Value
0.000
0.001
0.002
0.003
0.004
0.005
0.006
0.007
Cronbach's Alpha


Correlation Matrix of Questions
Q1 Q2 Q3 Q4 Q5 Q6 Q7 Q8 Q9 Q10 Q11 Q12 Q13 Q14 Q15 Q16 Q17 Q18 Q19 Q20
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00



Interpretation of the Tests and Figures

Normality Test Results (Shapiro-Wilk Test)

The Shapiro-Wilk normality test was conducted on each question to assess whether the data follows a normal distribution. The p-values for all questions were extremely small (all less than 0.05), indicating that the data does not follow a normal distribution. This suggests that the responses collected from the survey participants exhibit skewed or non-normal characteristics, and traditional parametric tests (which assume normality) may not be suitable for further analysis. Therefore, we may need to consider non-parametric methods or data transformation techniques in future analysis to better model the data (Subramani et al., 2024).

The bar chart visualizes these p-values across all questions, where the p-values are all below the 0.05 threshold, reinforcing the conclusion that the data does not follow a normal distribution (Behera & Samal, 2021).

Cronbach's Alpha (Reliability Test)

The Cronbach's Alpha value was calculated to assess the internal consistency or reliability of the survey responses. The result of 0.0075 is significantly lower than the acceptable threshold of 0.7, indicating poor internal consistency. This suggests that the survey questions may not be measuring the same underlying construct or dimension. The bar plot illustrates this low value, signaling that the scale needs improvement before being used for in-depth analysis. Potential improvements could include revising the survey questions to ensure they align better with the intended constructs and increase reliability (Balaji et al., 2022).

Correlation Matrix

The correlation matrix provides a visual representation of the relationships between each pair of questions. The heatmap shows that most correlations are weak to moderate, with the values ranging from -0.1 to 0.2 for the majority of the question pairs. This suggests that while there are some relationships between the questions, these associations are not very strong. The color

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gradient in the heatmap indicates the strength and direction of these correlations, with blue tones representing negative correlations and red tones representing positive correlations. The matrix can help identify which questions are more closely related to each other, although, given the low reliability from Cronbach's Alpha, these relationships may not be consistent across the data (Thompson, 2022).

Regression Coefficients

The regression coefficients from the linear regression model indicate how the independent variables (Q1 to Q10) influence the dependent variables (Q11 to Q20). The coefficients represent the strength and direction of the relationship between each independent variable and the dependent variable. For instance, in the bar chart for Q11, we see that certain independent variables (like Q5 and Q8) have stronger positive or negative effects, while others (like Q4 and Q6) show weaker relationships with Q11. These coefficients can help understand which factors are most impactful in predicting outcomes related to additive manufacturing and 3D printing. However, due to the poor reliability of Cronbach's Alpha, the model's findings should be interpreted with caution (Bhatia & Sehgal, 2023).

Discussion

The findings from the normality, reliability, correlation, and regression tests provide a comprehensive overview of the current dataset, highlighting several key areas that require attention and improvement. First, the normality test results indicate that the data does not follow a normal distribution, with all p-values from the Shapiro-Wilk test being significantly less than 0.05. This is a critical observation because it suggests that the responses are not symmetrically distributed, which is a common assumption in many statistical analyses. The non-normality could be due to the skewed nature of the Likert scale data, where respondents may tend to cluster towards certain response options. To address this issue, future analyses could benefit from the use of non-parametric statistical methods, which do not require the assumption of normality. Additionally, techniques like data transformation (e.g., log transformation) could be explored to normalize the data if parametric methods are still desired (Tuazon et al., 2022).

The Cronbach's Alpha value of 0.0075 points to a significant issue with the reliability of the scale used in the survey. This value is far below the threshold of 0.7, which is commonly considered acceptable for measuring internal consistency. A low Cronbach's Alpha indicates that the items in the survey may not be measuring the same construct, or there may be inconsistency in how respondents interpret the questions. This calls for a review and refinement of the survey instrument to ensure that the questions are conceptually aligned and capture the intended aspects of additive manufacturing and 3D printing. Modifications to the wording, response options, or the inclusion of additional questions could help improve the internal consistency and reliability of the instrument (Zhou et al., 2024).

Despite the reliability concerns, the correlation analysis offers valuable insights into the relationships between the various survey questions. The relatively weak correlations between most pairs of variables suggest that while there are some connections, the strength of these relationships is not strong enough to draw definitive conclusions. The low correlation values may reflect the complexity of the subject matter (i.e., additive manufacturing in aerospace and automotive industries) and the diversity of experiences among respondents. This complexity may require more nuanced analysis or more focused survey items to capture the subtle differences in how respondents perceive and experience the impacts of 3D printing technologies (Tepylo et al., 2019).

The regression analysis provides additional context by quantifying the influence of independent variables (such as production efficiency, material performance, and technology adoption) on dependent variables like cost reduction and product quality. The regression coefficients reveal that some variables, like Q5 (related to material performance) and Q8 (related to production speed), have stronger effects on the outcomes, while others show weaker influences. However, given the poor internal consistency of the survey, these results should be interpreted with caution. It is possible that some of the observed relationships may not be robust or generalizable (Elakkad, 2019).

Conclusion

This study aimed to assess the role of Additive Manufacturing (AM) and 3D Printing in the aerospace and automotive industries, focusing on various factors such as production efficiency, product quality, cost reduction, and material performance. Through the application of several statistical tests, including normality, reliability, correlation, and regression analyses, valuable insights were gained, though challenges related to the reliability and distribution of the data were identified. The normality test revealed that the data does not follow a normal distribution, indicating the presence of skewed responses. This non-normality suggests that the assumptions of parametric tests may not hold and indicates a need for non-parametric methods or data transformations in future analyses.

Furthermore, Cronbach's Alpha value of 0.0075 highlighted significant issues with internal consistency. This low value suggests that the survey questions may not be measuring the same underlying construct consistently across respondents. Consequently, revising the survey instrument to improve question alignment and clarity is essential for improving the reliability of future studies. While the correlation analysis provided some insight into the relationships between different variables, most correlations were weak, suggesting that the factors influencing AM and 3D printing outcomes are complex and multifaceted.

The regression analysis offered some useful insights into the influence of independent variables, such as material performance and production speed, on the dependent outcomes, like cost reduction and product quality. However, due to the reliability issues, these results should be treated with caution. In conclusion, this study highlights the potential of AM and 3D printing in the aerospace and automotive industries but emphasizes the need for better data collection methods, more robust survey instruments, and improved statistical techniques. Addressing these limitations will be crucial for deriving more reliable, actionable insights in future research

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