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A Machine Learning Decision Tree Approach to 3D Printing Technology Adoption: Industry Awareness and Trends

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ABSTRACT

The adoption of 3D printing technology is of paramount importance due to its transformative impact across various aspects. Firstly, it revolutionizes the manufacturing process by enabling rapid prototyping, increased design flexibility, and reduced waste, resulting in improved operational efficiency and cost savings. The ability to quickly create prototypes and iterate designs significantly accelerates product development cycles. Additionally, the customization capabilities of 3D printing empower individuals and organizations to bring their ideas to life, fostering innovation and creativity. Moreover, 3D printing offers significant environmental benefits compared to traditional manufacturing methods. It reduces waste by minimizing material usage and enables more precise manufacturing, leading to reduced energy consumption. This aligns with sustainability goals and contributes to a greener future. The adoption of 3D printing technology also enhances market competitiveness, revenue growth, and brand positioning for industries that embrace its capabilities. The ability to produce complex and customized products on demand provides a competitive edge in meeting consumer needs. By embracing 3D printing, companies can differentiate themselves, improve customer satisfaction, and expand their market share. This research explores the adoption of 3D printing technology and its implications across various industries. In this research, a hierarchical decision tree model was utilized to analyse and it highlights the higher knowledge and awareness of the technology among employed respondents, emphasizing the importance of industry awareness and trends.

Keywords: Industry 4.0, IoT Technologies, 3D Printing, Adoption, Manufacturing Industry, Awareness, Sustainability, Challenges, Decision Tree

INTRODUCTION

The manufacturing industry in India plays a significant role in its growing economy, with a contribution of 16% to the GDP and employment of over 54 million people. India has emerged as a global manufacturing hub, being attracted by multinational companies due to its skilled labour pool, low labour costs, and favourable government

policies. The manufacturing sector is a key driver of economic growth in India. However, the sector faces a number of challenges, such as low productivity, poor infrastructure, and inadequate skills. The government needs to take steps to address these challenges in order to boost the manufacturing sector and achieve its economic growth goals (Varajão, J et al., 2022). Industry 4.0 represents the fourth industrial revolution, marked by the integration of cyber-physical systems, the Internet of Things (IoT), and big data. It holds immense potential to revolutionize the global economy. However, several hurdles must be overcome to fully leverage its benefits. These obstacles encompass the necessity for acquiring new skills and the potential displacement of jobs (Opawole, Akintayo et al, 2022). The importance of Industry 4.0 has been recognized by India, with the integration of advanced technologies like AI, IoT, and robotics into manufacturing. Initiatives such as the "Smart Manufacturing" program and the "Digital India" campaign promote the adoption of Industry 4.0.

There are several factors that can impact the acceptance of IoT technologies. In the context of home use, acceptance is likely to be influenced by the perceived benefits, ease of use, privacy and security concerns, as well as the social acceptability of the technology (Holzmann et al., 2018). Additionally, 3D printing, also known as additive manufacturing, has brought about a global transformation in the manufacturing process, enabling rapid prototyping and efficient product development. Over the past years, 3D printing has emerged as a revolutionary tool with the potential to revolutionize various industries. However, there is a research gap in understanding the industry-specific factors that influence its adoption. The factors that drive the adoption of 3D printing across industries such as manufacturing, retail, healthcare, education, government, automobile, and technology have been identified. Among these drivers, the perceived relative advantage and performance expectancy exert a stronger influence on the intention to adopt 3D printing, compared to factors such as complexity and effort expectancy (Shahrubudin et al, 2019)

Existing studies have not thoroughly examined the unique characteristics, requirements, and challenges faced by different industries in adopting 3D printing. This gap hampers the development of targeted strategies to promote its wider adoption and successful implementation. To address this gap, this study aims to conduct a comprehensive analysis of industry awareness and trends regarding 3D printing technology. It will delve into industry-specific adoption drivers, barriers, challenges, and requirements, considering the diverse needs of each sector. Furthermore, the study aims to evaluate the awareness levels within various industries and investigate the distinct trends and applications of 3D printing technology in each sector. By addressing this research gap, these findings can provide valuable guidance for the design and implementation of focused interventions, educational initiatives, and innovation strategies. This will promote broader adoption and enable the maximization of the benefits offered by 3D printing technology in diverse industries.

RELATED WORK

The industrial sector is currently experiencing a significant transformation referred to as "Industry 4.0" which involves the utilization of advanced technology to enhance flexibility, efficiency, and customer service. This transformation may lead to the emergence of new business models and the creation of synergies. Industry 4.0 requires the adoption of new job roles and the acquisition of new skill sets to cope with the need for adaptability

in terms of product quality, design, manufacturing volume, and scheduling. It aims to achieve improved resource efficiency, cost reduction, enhanced client services, as well as the development of new corporate strategies and methods to foster synergies. Although Industry 4.0 is a complex and evolving subject, it holds the potential to completely revolutionize the industrial sector (Ukobitz, D.V, 2021).The fourth industrial revolution, known as Industry 4.0, relies on the integration of cyber physical systems to enhance efficiency, safety, and transparency in industrial processes. This is achieved through decentralized decision-making and communication among various technologies. There are seven key technology families that serve as the foundation of this revolution: Internet of Things (IoT), Artificial Intelligence (AI) and Machine Learning (ML), robotics and drones, cellular wireless communications, 3D printing, virtual and augmented realities, and blockchain. These technologies are built upon advancements in computing, nanotechnology, biotechnology, materials, energy, and CubeSats. While they can greatly impact the productivity of a single production entity, one downside is that they may result in fewer job opportunities compared to a less automated factory (Oztemel, E et al, 2018).

The field of Internet of Things (IoT) is experiencing rapid growth and holds immense potential for transforming various industries. Collaborative efforts by IoT developers and researchers aim to expand the technology on a large scale and maximize its benefits for society. However, there are several hurdles that must be overcome for IoT to achieve its full potential. These challenges encompass security, privacy, and scalability. Additionally, the vast amount of data generated by IoT presents challenges in terms of storage and analysis. Utilizing big data analytics can help tackle these obstacles and enhance the functionality of IoT systems (Haleem A et al, 2019). Professionals in the construction industry of developing economies have limited knowledge about 3D printing, leading to its underutilization. To address this issue, stakeholders, professional organizations, and government agencies should collaborate to establish an environment conducive to training and awareness. One primary obstacle encountered was the hesitance of certain professionals to participate in surveys. By increasing awareness and understanding of 3D printing, the emerging economy's construction sector can adopt sustainable practices (Lasi, H et al, 2014). The manufacturing industry is experiencing the influence of 3D printing. Although the adoption of consumer 3D printers is currently limited, this technology is continuously progressing and has the capability to revolutionize conventional manufacturing practices. Consumer 3D printed products are becoming increasingly cost-competitive with traditionally manufactured goods. However, additional research is necessary to better understand manufacturers' perspectives and the potential disruptive effects of consumer 3D printing (Tsaramirsis, G et al, 2022)

The dental field is extensively utilizing 3D printing in various areas such as prosthodontics, restorative dentistry, orthodontics, implantology, and instrument production. This technology has broadened the possibilities for diagnosis, treatment, and education, leading to a transformative effect on digital dentistry. Dental professionals are keen on incorporating 3D printing into their practice and anticipate positive outcomes. To facilitate knowledge exchange on 3D printing, it is recommended to establish a platform, such as digital communities and workshops, where professionals can come together and share their expertise (Oke, A et al, 2022).The utilization of 3D printing technology in building construction in Nigeria was investigated to assess awareness, application, drivers, and barriers. The study revealed that a mere 19.2% of companies had directly employed the technology, indicating a low adoption rate. Among those aware of 3D printing, a significant 80.8% gained knowledge through research

and professional discussions rather than practical exposure. These findings indicate that 3D printing is a novel prospect for construction in Nigeria (Ukobitz, D, 2020). The acceptance of smart meters in Malaysia is influenced by various factors. Notably, having knowledge about electricity-saving practices and possessing environmental awareness are strong indicators of the willingness to adopt smart meters. Policymakers and technology providers should prioritize efforts to enhance consumers' understanding of electricity-saving techniques and raise awareness about environmental concerns. These initiatives will contribute to the promotion and widespread adoption of smart meters (Steenhuis, H. J et al, 2016) The study focuses on enhancing our understanding of how high school teachers perceive and accept new technology, as well as their intention to utilize it. The findings demonstrate that teachers display a strong inclination to adopt novel technology. The research identifies specific personal and environmental factors that influence the adoption of new technology. Among these factors, the perception of potential irreversible errors or apprehension towards technology negatively affects an individual's intention to use 3D printing. On the other hand, a positive attitude towards technology emerges as the third significant predictor, positively impacting teachers' behavioural intention to embrace new technology (Mehta et al, 2017)

CONCEPTUAL FRAMEWORK

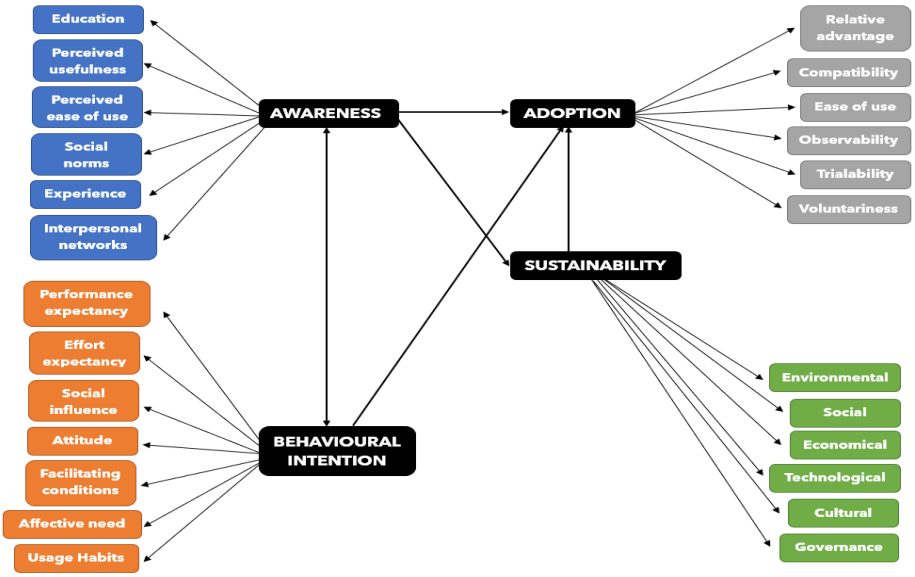

Fig. 1. Conceptual Model

The above figure shows that the dependent variable (Adoption) and its controlling/independent variables of adoption that is awareness, behavioural intention, sustainability and their sub-factors. It includes the sub-factors affecting the adoption variable as well.

STATEMENT OF THE PROBLEM

The adoption of this technology is not universal across all industries, and there is limited research on the factors that influence the adoption of 3D metal printing technology. Therefore, the problem statement for this study is: Despite the potential benefits of 3D printing technology, there is a lack of research on the factors that influence its adoption. Specifically, there is a need to understand the level of industry awareness and trends regarding the adoption of this technology in order to identify the key drivers and barriers to adoption. By addressing this

research gap, this study aims to provide insights that can inform the development of strategies to promote the adoption of 3D metal printing technology and improve the competitiveness of the manufacturing industry

OBJECTIVES

1. To understand the industry trends in adoption of 3D printing technology
2. To ascertain the factors in adoption of 3D printing technology in different industries.
3. To find out the level of awareness about 3D printing technology in different industries.

Hypothesis: "The level of industry awareness, behavioural intention, and sustainability and adoption trends of 3D printing technology across different industries are significantly correlated."

METHODOLOGY

A questionnaire is used in this descriptive study to gather information from experts in various sectors. The respondents' knowledge of 3D printing technology, their familiarity with it, and their opinions on its advantages and drawbacks were all the subjects of the inquiries. Various businesses, including manufacturing, healthcare, and education, were represented among the participants. Through the use of a Google Forms-based questionnaire, the main data was gathered. The organised survey asked questions on the participants' 3D printing experiences. 100 people from the Bangalore based industry in total were contacted through practical sampling.

ANALYSIS AND RESULTS

DEMOGRAPHIC ANALYSIS AND INTERPRETATION:

Age:

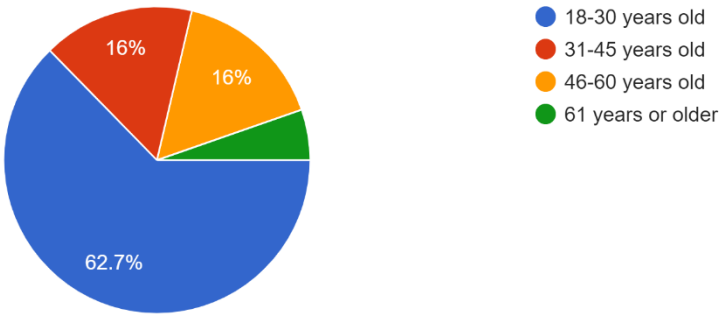

Fig. 2

The above bar chart shows the information of respondents from different age groups starting from 18 years old to above 61 years old above, however majority of the responses between the age group 18-30, age group between

31-45 and 46-60 years old moderate responses for the survey and the age 61 years and above not as much of responses got from the millennials.

Gender:

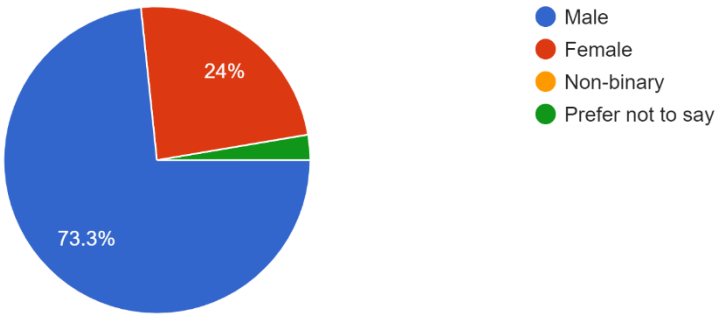

Fig. 3

Male respondents are higher in comparison to Female while few preferred not to reveal their gender.

Education:

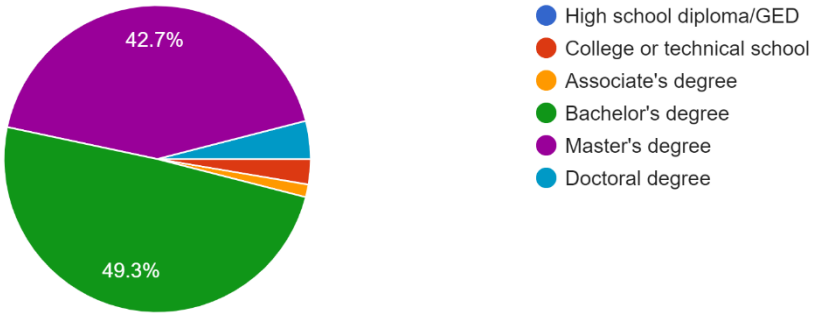

Fig. 4

The education of the respondents was about 49.3% of Bachelor's degree. 42.7% were
Master's degree holders. The remaining included the Diploma, Technical school, Doctoral degree.

Occupation:

This question will help us get the results in terms of the average of the average occupation of the respondents.

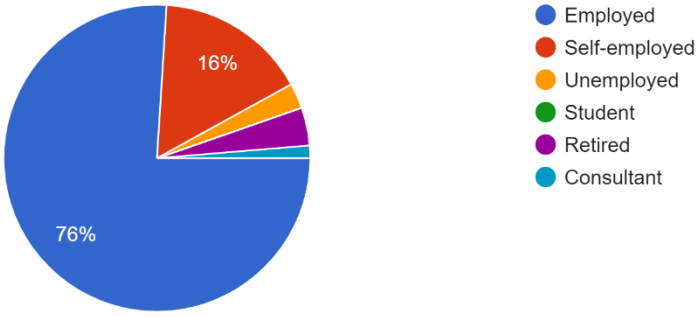

Fig. 5

It is important for the purpose of the study that we get major respondents who are working professionals from various industries with 76% shown in the chart above, we can get to an understanding that the employed professionals were majorly targeted for the study. As this study is done for the industry awareness, it is interesting to note that there are less unemployed (2.7%) and 5.3% government employees.

Industry:

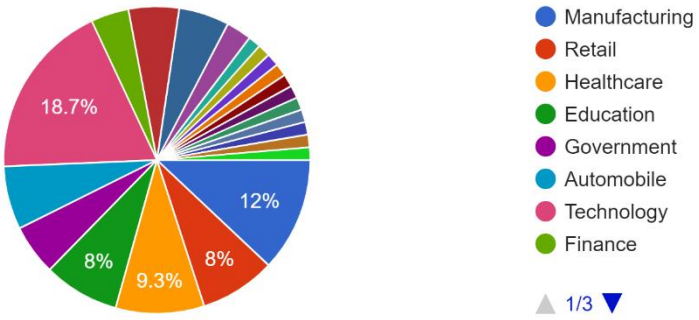

Fig. 6

As shown in the chart the 12% from manufacturing, 8% from retail, 9.3% from healthcare, 8% from education, 5.3% of government, 6.7% of automobile, 18.7% from technology and remaining from various professions out of these above-mentioned industries like architecture, servicing, legal, defence and banking.

Experience:

This information shows their knowledge level in their industry:

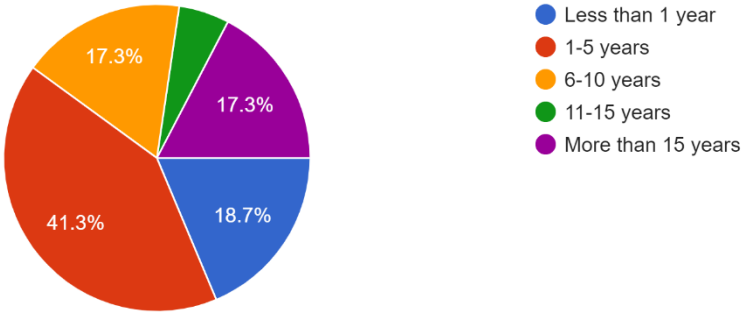

Fig. 7

41.3% from the 1-5 years of experience, 17.3% from the 6-10 years of experience, 18.7% from the less than 1 of experience and 17.3% respondents has the experience of more than 15 years.

Previous Use of the Technology:

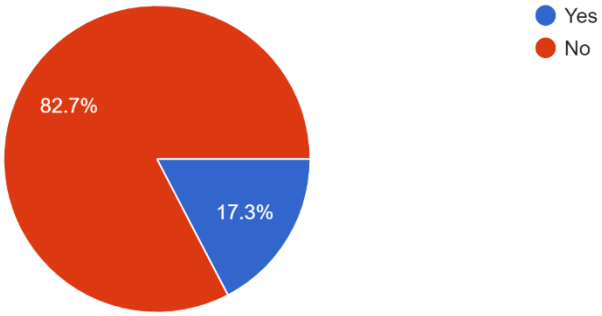

Fig. 8

Majority of the respondents 82.7% does not have the experience of using 3D printing technology while the remaining of 17.3% had the experience in their own industry.

Affecting Factors: Behavioural Intention

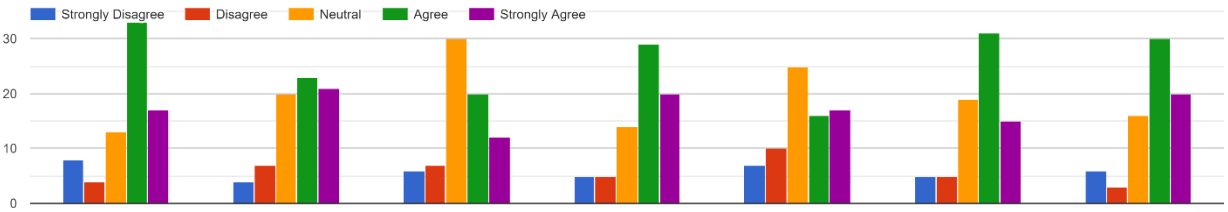

Fig. 9

Under this factor, the survey results indicate that respondents believe adopting 3D technology positively impacts their work quality and requires less effort compared to traditional methods. The decision to adopt is independent of peers and industry trends. Respondents see significant benefits in incorporating 3D technology into their work, and while organizational support is neutral, they believe it fulfils their need for creativity and self-expression. Overall, respondents agree that 3D technology provides substantial advantages over traditional methods.

Adoption:

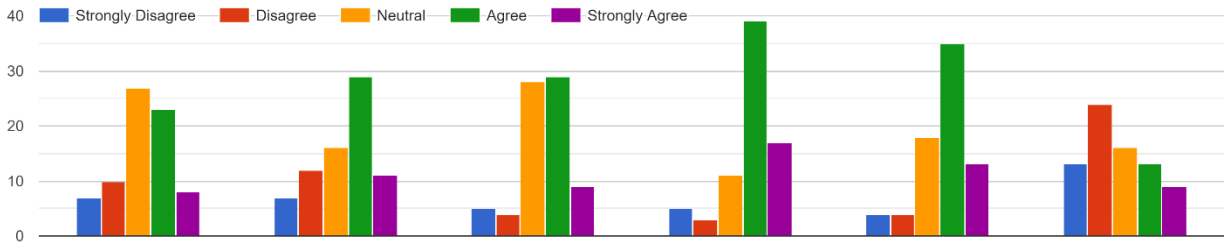

Fig. 10

In this factor, the survey findings indicate a neutral response regarding the compatibility of 3D technology with respondents' manufacturing processes. Respondents strongly agree that setting up and operating 3D technology is significantly more efficient than traditional methods. Mixed opinions exist on the impact of 3D technology on brand reputation and market positioning, while respondents express a high willingness to experiment with it on a small scale before full adoption.

Awareness:

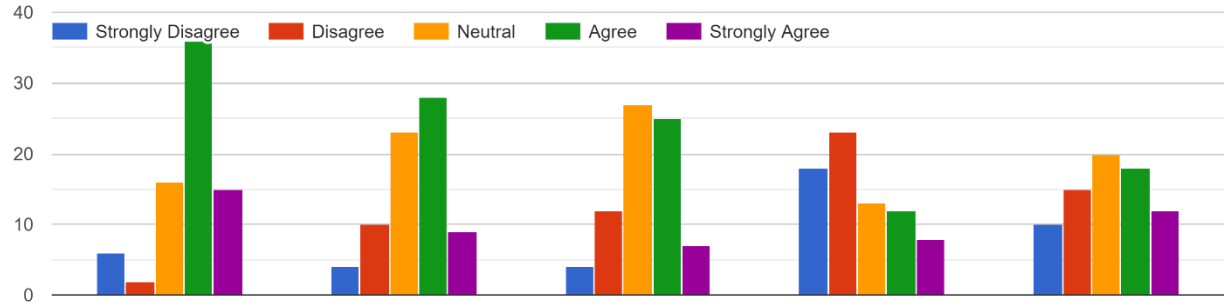

Fig. 11

This factor aimed to assess the respondents' awareness of 3D technology. Respondents agree that 3D printing technology offers significant advantages over traditional methods. While most respondents find the user interface and software user-friendly, some have a neutral stance. There is a mixed response regarding the level of support, experience, and collaboration with 3D printing technology in their workplace or industry.

Sustainability:

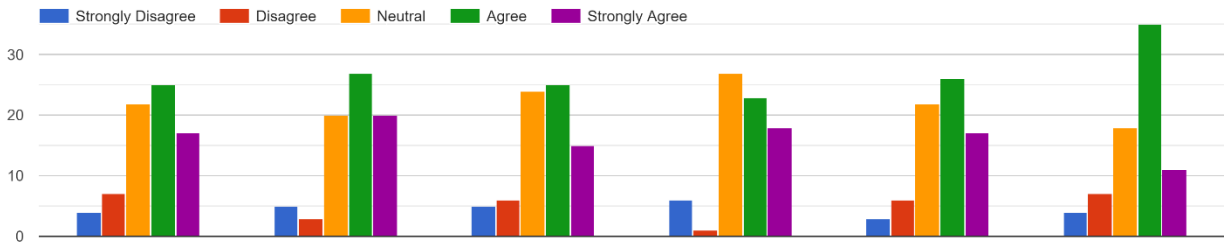

Fig. 12

This factor aimed to assess the sustainability of 3D printing technology in the long run. Respondents generally agree that 3D printing technology offers environmental benefits and significant societal advantages. They also acknowledge the potential economic impact and superior technical capabilities of 3D printing. Moreover, survey participants acknowledge the cultural ramifications associated with 3D printing technology and acknowledge the impact of regulations and policies on the acceptance and utilization of this technology.

Decision Tree Analysis:

In this study, a decision tree hierarchical model was employed to analyse and comprehend the decision-making process of respondents regarding the adoption of the technology. A decision tree is an algorithm utilized for decision-making, characterized by a structure resembling a flowchart. Internal nodes of the tree represent features, branches represent decision rules, and leaf nodes represent outcomes.

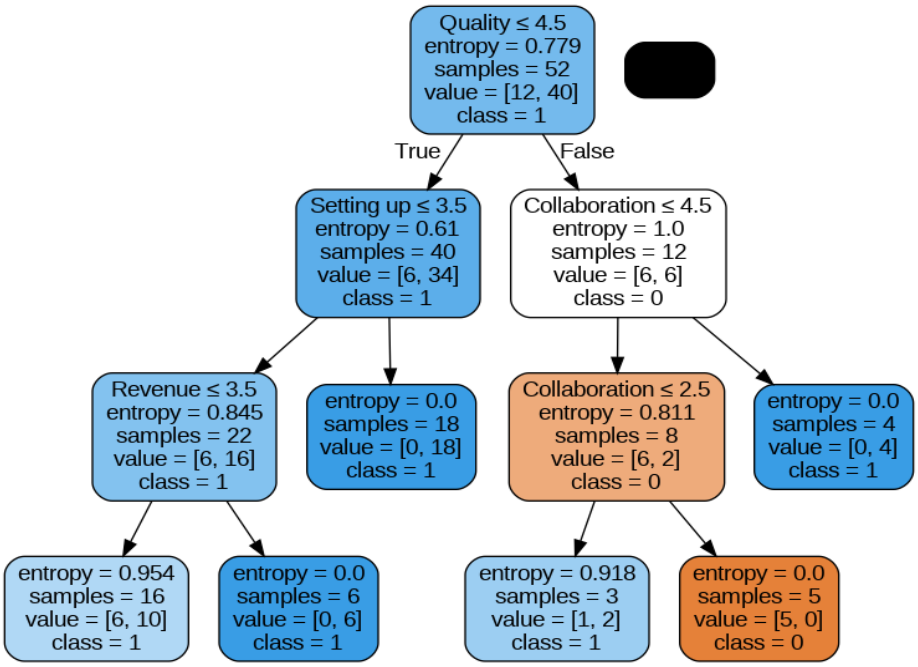

Fig. 13 Decision Tree Outcome

The decision tree model analysed the adoption of 3D technology based on key factors. Respondents who believed that 3D technology would have a substantial impact on the quality of their work were more likely to be aware of and adopt it. Those who perceived that setting up and operating 3D printing required less time and effort were also more inclined to adopt it. Additionally, respondents who recognized the potential economic impact, such as cost savings and revenue growth, were more likely to adopt the technology. The study revealed that awareness and knowledge of 3D technology were predominantly possessed by employed respondents. It improved the quality of their work, required comparable effort to traditional methods, and fulfilled their need for creativity. However, support from their organization was not necessarily present. Compatibility with their manufacturing processes was uncertain due to limited awareness. Respondents were willing to experiment on a small scale before full adoption and considered their organization's goals and objectives in the decision-making process. Training and education related to 3D printing were minimal. Benefits of 3D printing technology, such as faster prototyping, design

flexibility, and waste reduction, were recognized. The user interface and software were perceived as user-friendly. Encouragement and support for 3D printing varied within the industry. Respondents had limited experience and opportunities for collaboration with others using 3D technology.

The study also found that 3D technology offered environmental benefits, provided significant societal advantages, and had a potentially superior technical capability. Cultural implications, such as aesthetics and user experience, were considered. The decision to adopt and use 3D printing technology was influenced by regulations and policies.

CONCLUSIONS

The study on the adoption of 3D printing technology yielded significant findings that can contribute to its broader utilization and maximize its benefits for industries and society. Firstly, employed respondents displayed higher knowledge and awareness of the technology, highlighting the importance of industry awareness and trends in adoption. Secondly, the study emphasized the compatibility, efficiency, and advantages of 3D printing over traditional methods, despite the lack of organizational support and training. Respondents exhibited a willingness to explore and collaborate, indicating potential for further adoption. Lastly, the study underscored the significant environmental, economic, and cultural implications of 3D printing, emphasizing the need for policy considerations during decision-making processes.

To facilitate the broader adoption and utilization of 3D printing technology, several suggestions can be implemented. Firstly, enhancing knowledge and awareness through educational programs, workshops, and awareness campaigns, in collaboration with industry experts, can effectively disseminate information. Secondly, fostering industry collaboration through forums, conferences, and networking events, facilitated by industry associations, can encourage knowledge exchange and experiences sharing. Thirdly, providing organizational support, such as allocating resources, creating dedicated spaces, and establishing training programs, can encourage employee adoption. Fourthly, collaboration with universities, research institutions, and 3D printing experts can promote knowledge exchange, joint research projects, and shared resources. Engaging governments and regulatory bodies is crucial to developing policies addressing regulatory frameworks, intellectual property rights, sustainability, and safety considerations. Moreover, raising public awareness and acceptance through outreach programs, exhibitions, and collaborations with educational institutions and media channels can showcase real-world applications and address concerns. Lastly, continuous research and evaluation of 3D printing technology, monitoring advancements, studying economic and environmental impacts, and assessing integration into industries, can inform decision-making and develop best practices.

By implementing these suggestions, the adoption and utilization of 3D printing technology can be fostered, promoting knowledge, collaboration, and policy development to maximize its benefits across various sectors.

ACKNOWLEDGMENT

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REFERENCES

1. Haleem, A., & Javaid, M. (2019). Enablers, Barriers, and Critical Success Factors for Effective Adoption of Color-Jet 3D Printing Technology. Journal of Industrial Integration and Management, 07(04), 599–625. https://doi.org/10.1142/s242486221950009x
2. Holzmann, P., Schwarz, E. J., & Audretsch, D. B. (2018, September 14). Understanding the determinants of novel technology adoption among teachers: the case of 3D printing - The Journal of Technology Transfer. SpringerLink. https://doi.org/10.1007/s10961-018-9693-1
3. Lasi, H., Fettke, P., Kemper, H. G., Feld, T., & Hoffmann, M. (2014). Industry 4.0. Business & Information Systems Engineering, 6(4), 239–242. https://doi.org/10.1007/s12599-014-0334-4.
4. Mehta, Y., & Rajan, A. J. (2017). Manufacturing Sectors in India: Outlook and Challenges. Procedia Engineering, 174, 90–104. https://doi.org/10.1016/j.proeng.2017.01.173
5. Oke, A., Atofarati, J., & Bello, S. (2022). Awareness of 3D Printing for Sustainable Construction in an Emerging Economy | Construction Economics and Building. Awareness of 3D Printing for Sustainable Construction in an Emerging Economy | Construction Economics and Building.https://doi.org/10.5130/AJCEB.v22i2.8015
6. Opawole, Akintayo & Olojede, Betty & Kajimo-Shakantu, Kahilu. (2022). Assessment of the adoption of 3D printing technology for construction delivery: A case study of Lagos State, Nigeria. Journal of Sustainable Construction Materials and Technologies. 184-197. 10.47481/jscmt.1182607.
7. Oztemel, E., & Gursev, S. (2018). Literature review of Industry 4.0 and related technologies - Journal of Intelligent Manufacturing. SpringerLink. https://doi.org/10.1007/s10845-018-1433-8
8. Shahrubudin, Nurhalida & Te Chuan, Lee & Ramlan, Rohaizan. (2019). An Overview on 3D Printing Technology: Technological, Materials, and Applications. 35. 1286-1296. 10.1016/j.promfg.2019.06.089.
9. Steenhuis, H. J., & Pretorius, L. (2016, September 5). Consumer additive manufacturing or 3D printing adoption: an exploratory study. Journal of Manufacturing Technology Management, 27(7), 990–1012. https://doi.org/10.1108/jmtm-01-2016-0002
10. Tsaramirsis, G., Kantaros, A., Al-Darraji, I., Piromalis, D., Apostolopoulos, C., Pavlopoulou, A., Alrammal, M., Ismail, Z., Buhari, S. M., Stojmenovic, M., Tamimi, H., Randhawa, P., Patel, A., & Khan, F. Q. (2022). A Modern Approach towards an Industry 4.0 Model: From Driving Technologies to Management. Journal of Sensors, 2022, 1–18. https://doi.org/10.1155/2022/5023011

11. Ukobitz, D. V. (2020). Organizational adoption of 3D printing technology: a semisystematic literature review. Journal of Manufacturing Technology Management, 32(9), 48–74. https://doi.org/10.1108/jmtm-03-2020-0087

12. Ukobitz, D.V. (2021), "Organizational adoption of 3D printing technology: a semisystematic literature review", Journal of Manufacturing Technology Management, Vol. 32 No. 9, pp. 48-74. https://doi.org/10.1108/JMTM-03-2020-0087

13. Varajão, J., Carvalho, J. Á., Silva, T., & Pereira, J. (2022, January 20). Lack of awareness of its adoption and use theories by IT/is project managers: Poor relevance, unfocused research or deficient education? MDPI. https://doi.org/10.3390/info13020048