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The Future of Additive Manufacturing (3D Printing) in Kenya: Scenarios for 2063 Using Delphi Approach

Eric Ondimu Monayo and Godfrey Mugwimi

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THE KENYA INSTITUTE FOR PUBLIC POLICY RESEARCH AND ANALYSIS (KIPPRA)

YOUNG PROFESSIONALS (YPs) TRAINING PROGRAMME

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Kenya Institute for Public Policy
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This paper is produced under the KIPPRA Young Professionals (YPs) programme. The programme targets young scholars from the public and private sector, who undertake an intensive one-year course on public policy research and analysis, and during which they write a research paper on a selected public policy issue, with supervision from senior researchers at the Institute.

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Abstract

The rapid growth of additive manufacturing (AM) is mainly due to its evolution from primarily a prototyping tool to a useful end-product fabrication method. As much as the Government of Kenya has demonstrated its willingness to support 3D printing as an important technology in the development of the manufacturing sector, only 11.4 per cent of firms have adopted the technology. The study assessed the future of additive manufacturing in Kenya through the formulation of the most probable scenarios for 2063 using the Delphi approach.

A country transitioning to additive manufacturing by 2063 may find itself experiencing early transition, lagged transition, or late transition. Early transition to additive manufacturing would be influenced by the ability to reduce the cost of production, the ability to precisely replicate products, product customization, and enhanced product performance through additive manufacturing. The lagged transition would be occasioned by limited collaboration among firms on the production of 3D technology products and low demand for AM products. The late transition may be attributed to the absence of a regulatory framework that facilitates the sharing of industry-specific 3DP technology and the failure of additive manufacturing to reduce carbon emissions.

To achieve early transition, the government needs to support firms to invest in 3D printing technology, including reducing the cost of production through the purchase of equipment, financial support, and training of employees on AM. Further, the government to support industrial institutions to build a skilled workforce proficient in 3D printing technologies to enhance capabilities to produce products with complex geometries. To avoid a lagged transition, there is a need to enhance collaboration through the promotion, establishment, and maintenance of shared 3D printing facilities that small and medium-sized enterprises (SMEs) can access without requiring to undertake large capital investments. Further, institutionalize collaborations by anchoring partnerships in the National ICT Policy or the National Industrialization Policy. To boost demand for AM products, the government may ensure government procurement reflects the preference for 3D printed components in public projects. To avoid late transition, the government needs to promote the adoption of sustainable practices in 3D printing, which include the use of eco-friendly materials, energy-efficient processes, recycling, and waste reduction strategies.

Abbreviations and Acronyms

3DP	3D Printing Technology
4IR	4th Industrial Revolution
WITS	World Integrated Trade Solution
AM	Additive Manufacturing
KIRDI	Kenya Industrial Research and Development Institute
ICT	Information Communication Technology

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1. Introduction

The manufacturing industry is experiencing a new wave of evolution. As the advancement of technology has accelerated, so too has the adoption of innovations in different fields, and manufacturing is no exception. There are several driving forces behind these advancements, which include efficiency, cost-effectiveness, and environmental and sociological factors. Additive manufacturing (AM), also known as 3D printing technology, is one of the 4IR technologies that are revolutionizing the manufacturing sector. This technology constructs three-dimensional objects by adding layer by layer from a digital file. In the additive process, an object is created by laying down successive layers of material until the object is created (Mpofu, Mawere, and Mukosera, 2014). Each of these layers forms a thinly sliced cross-section of the object. Additive manufacturing is, therefore, the opposite of the traditional machining technique that involves the removal of materials by way of cutting out or hollowing out a block of material. It is a departure from the mass production line to a one-off customizable production.

Globally, the awareness of 3D printing is increasing due to its transformative impact on how items are manufactured in a variety of fields, including healthcare, transportation, the food industry, digital art, textiles and clothing, architecture, and construction design (Wu, Wang and Wang, 2016). Additive manufacturing was valued at US $26 billion as of 2022 up from US $6 billion in 2016. The rapid growth of this technology is mainly due to its evolution from primarily a prototyping tool to a useful end product fabrication method (Wohlers, Campbell, Diegel, Huff, and Kowen, 2020). Additionally, Gerstle et al. (2014) stated that 50 per cent of all globally manufactured goods will be printed using additive manufacturing technology by 2060 if the current investment in additive manufacturing continues. Other benefits of this technology include the creation of products that require highly complex geometries, enabling rapid prototyping, which allows companies to quickly iterate and test new designs, and the production of customized and personalized products in large quantities within a very short time among other benefits.

Despite these outstanding capabilities of AM technology for economic development, Africa is currently trailing behind some of the developed countries, such as the USA with 51 per cent adoption rate, and Germany with a 44 per cent adoption rate. The top ten economies in the Competitive Industrial Performance Index, which is a measure of the competitiveness of a country's manufactured goods globally, are by extension the leading in additive manufacturing. Germany, for instance, was ranked position one (1) followed by the USA according to the UNIDO CIP database. Cotteleer and Joyce (2014) and Wu, Myant, and Weider (2017) contend that future development of additive manufacturing is often hampered in several countries, especially those in developing countries, by high initial capital requirements for additive manufacturing machines and materials, intellectual property/privacy issues, lack of human capital, tiny production runs and scalability constraints, production standards and requirements, regulatory uncertainty in different countries, as well as a lack of choice of materials.

Under Vision 2030, Kenya aspires to be a middle-income, rapidly industrializing country and globally competitive by 2030. To achieve this, the government through the National ICT Policy has demonstrated its willingness to support 3D printing technology in the development of the manufacturing sector. To make the technology more accessible to the public, the government has encouraged all tertiary and secondary schools to acquire 3D printers and at the same time committed to providing grants to all innovation hubs and constructed labs to boost additive manufacturing capabilities. Further, the government has committed to ensure that intellectual property rights are granted to protect data objects capable of being manufactured as physical objects using 3D printing (National ICT Policy, 2019).

Among the labs constructed by the Government of Kenya to boost additive manufacturing capabilities is the University of Nairobi's Fab Lab. The lab was the first to introduce 3D printers in Kenya and since then, the technology has grown to the various sectors of the economy. For instance, Kijenzi Medtech Company uses 3D printing technology to provide medical solutions to Kenya's rural clinics. Similarly, Ultra Red Technologies Company uses 3D printing to print customized canopies for wildlife exploration vehicles which is an untapped territory in the wildlife sector in Africa among other companies. Despite the steps taken to integrate additive manufacturing in various sectors of the economy, the adoption rate is still very low, (11.4%) according to the World Bank. Further, Kenya's ranking in the Competitive Industrial Performance Index is not impressive (position 108 out of 150 countries) as per the UNIDO CIP database.

This study, therefore, intends to assess experts' opinions on the future of this technology in Kenya and develop the most probable scenarios for 2063. In addition, the study will enrich the understanding of additive manufacturing among various stakeholders, that is, academia, industry, researchers, and the government in general given that the concept has not been widely researched in Kenya. Specifically, the study aims to develop projections of the future of additive manufacturing; determine the probability of occurrence and the impact of the projections on manufacturing firms; and develop probable future scenarios.

2. Status of Additive Manufacturing in Kenya

This section presents the current policy framework, statistics on the number of firms that have adopted additive manufacturing, and the value of imports of machines for additive manufacturing. This will provide a clear picture of the rate of adoption of this technology.

2.1 Policy Framework in the Context of Additive Manufacturing

2.1.1 National ICT Policy

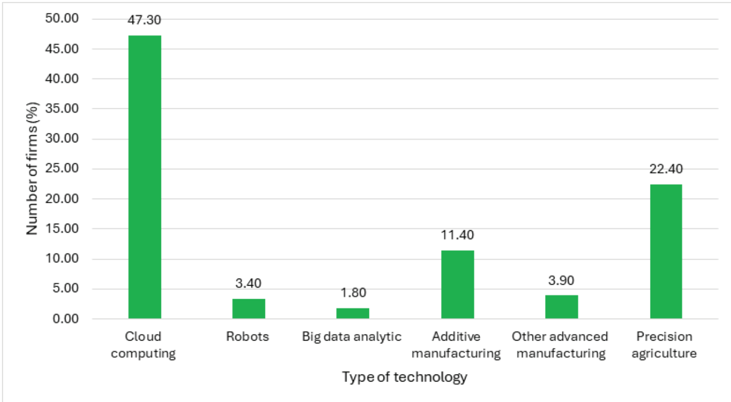
This policy aims to harness the potential of the digital economy by establishing favourable conditions for all citizens and stakeholders. The decision to revise the 2006 policy was prompted by rapid advancements in the ICT sector, global trends, and evolving public demands. The Fourth Industrial Revolution, marked by automation and extensive data exchange, is profoundly influencing the environments at macro and micro levels, and increasing global ICT consumption. Hence, this policy initiative aims to capitalize on these transformations and trends to position Kenya as a more prosperous participant in the global economy. The ICT Policy outlines the government's proactive stance on various aspects of Kenya's evolving ICT sector landscape.

The policy recognizes the technological trends in terms of mass personalization and personalized manufacturing. Personalized manufacturing represents a significant and growing advancement within the ICT and manufacturing sectors. To enhance the accessibility of this technology to the general public, the government plans to encourage all secondary and tertiary schools to adopt 3D printing capabilities. Additionally, innovation hubs and maker labs will receive grants to acquire additive manufacturing capabilities. Intellectual property protection will be extended to physibles, which are data objects capable of being manufactured into physical items using additive manufacturing methods. This policy aims to actively promote the emergence of new enterprises centred around the development of physibles.

2.1.2 Firms Using 4IR Technologies in Kenya

The World Bank estimates that about 11.4 per cent of the firms in Kenya have adopted additive manufacturing (Figure 2.1). This signifies that the manufacturing sector is slowly embracing additive manufacturing, though on a small scale.

Figure 2.1: Share of firms using 4IR technologies



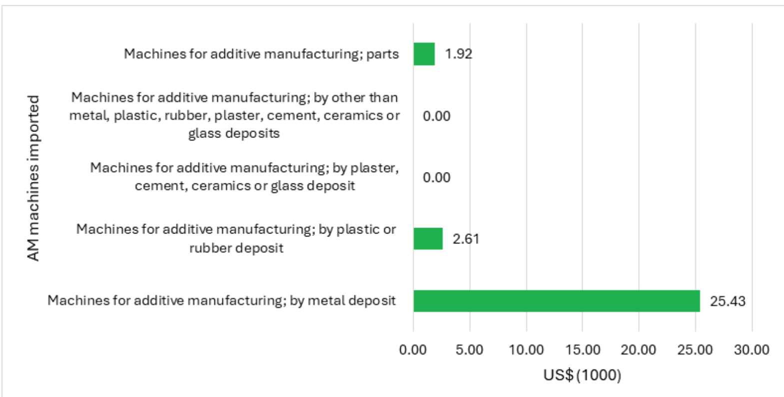
Source: World Bank (2022)

From Figure 2.1, cloud computing is the most adopted technology at 47.3 per cent, followed by precision agriculture at 22.4, per cent, additive manufacturing at 11.4 per cent, and robotic technology at 3.4 per cent. Only 1.8 per cent of the firms have adopted big data analytics.

2.1.3 Value of Additive Manufacturing Machines Imported in Kenya

In terms of imports, only US$ 30,000 worth of machines for additive manufacturing were imported as of 2022, which further signifies a low rate of adoption of this technology in Kenya (Figure 2.2).

Figure 2.2: Value of AM machines imported in Kenya as of 2022



Source: World Integrated Trade Solution (2022)

The low adoption rate as shown by the percentage of firms using AM technology and the low value of import for the additive manufacturing machines demonstrate that Kenya still lags in the adoption of this technology.

3. Literature Review

3.1 Theoretical Literature

The theories anchoring this study were linked to the objectives and discussed in detail below.

3.1.1 Theories for rigorous forecasting

Theories for rigorous forecasting encompass two main facets: domain-specific theories and general theories related to the mental way of solving problems in a quick way, reasoning biases, and the attributes of good forecasters. Domain-specific theories involve various theories relating to phenomena like economic behaviour and political dynamics that help in projecting the future of these phenomena. Forecasting also involves exploring hypothetical scenarios through ’what-if’ questions, where diverse events and their probable outcomes are systematically evaluated based on theoretical assumptions.

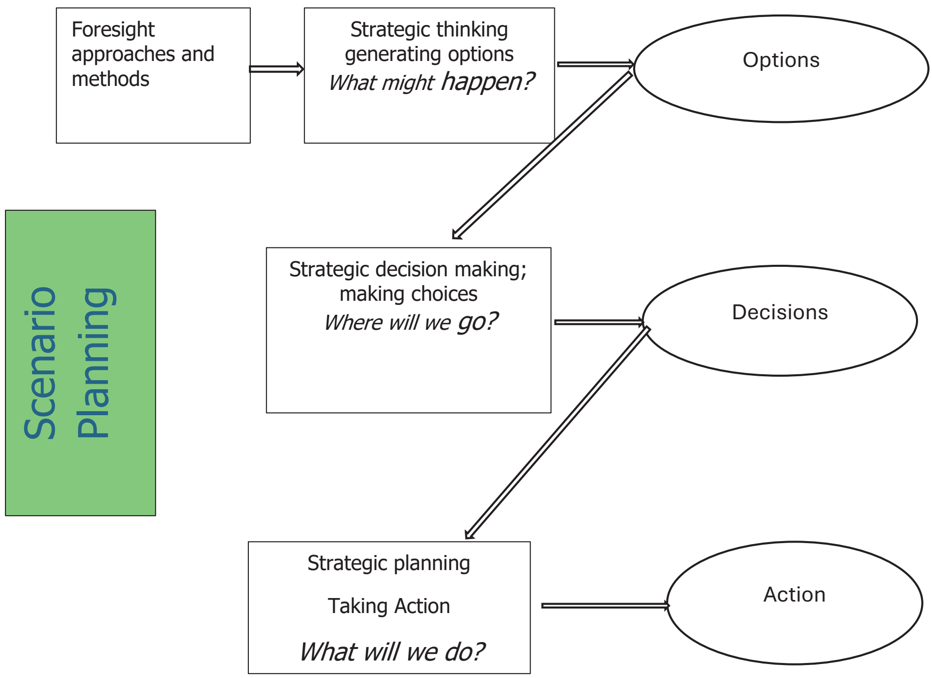
The general theories involve discussions on mental ways of solving problems in a quick way, rational biases, and the traits of successful judgmental forecasters that are drawn from sources such as systems and operations research (Winkler and Moser, 2016). The primary aim of these theoretical discussions is to strive for rational and unbiased forecasts. This body of work tends to focus more on developing methodologies for empirical research, like the Delphi method, rather than extensive theorization (Hasson and Keeney, 2011).

3.1.2 Theories for effectively representing futures

These theories aimed at effectively conceptualizing future scenarios. They encompass scenario planning, explorative futures studies, and possibilistic approaches. Emphasis has been placed on supporting the theoretical foundations of scenario planning. The theoretical frameworks informing scenario planning are largely derived from organizational studies and decision analysis. Wilkinson (2009) underscores the need to distinguish scenarios clearly from forecasts, consider the aspect of effectiveness, and incorporate new theoretical advancements.

Scenario Planning was developed by Kahn in 1967. He introduced a technique titled ’future-now thinking’. This approach intended to combine detailed analysis with imagination and come up with the reports in a way people would write them in the future. The name ’scenario’ was adopted when Hollywood determined the original name outdated. The theory is based on the premise of a participative approach to strategy that entails diverse thinking and conversations. Diverse thinking and conversations are used to change how the external environment is perceived. It seeks to anticipate some future scenarios rather than predict. Scenario planning involves strategic thinking, strategic decision making, and strategic planning (Figure 2.3).

Figure 2.3: Scenario planning process



Strategic thinking involves the exploration of signals and driving forces of the envisioned changes and is about generating options. Strategic decision making involves assessing options, examining choices, and setting a destination or direction. Strategic planning is about implementation and taking appropriate action.

3.1.1 3.1.3 Theories for making sense of anticipatory processes

These methods differ from previous approaches by focusing not on exploring potential or desired futures but on analyzing the processes and mechanisms concerning future concepts. The theory surrounding anticipatory processes seeks to understand how individuals and organizations anticipate, prepare, and respond to future developments. This theoretical framework is multidisciplinary and applied in psychology, sociology, economics, and futurology.

From a psychological perspective, anticipatory processes involve cognitive mechanisms such as imagination, prediction, and planning. Researchers explore how individuals construct mental representations of future scenarios, assess probabilities, and make decisions based on these assessments. Emotions also play a crucial role, in influencing how individuals perceive and respond to anticipated events.

Sociologists examine anticipatory processes within the context of social systems and institutions. They investigate how collective expectations, norms, and values shape anticipatory behaviour at both individual and societal levels. Social dynamics, such as collective anxiety or optimism about the future, can influence group behaviour and decision making.

Economists study anticipatory processes concerning economic phenomena such as investment, consumption, and production. For instance, Rational Expectations Theory indicates that individuals and firms form expectations about future economic variables based on all available information. These expectations guide current economic decisions and behaviour, hence influencing market outcomes.

Futurologists or foresight practitioners focus on developing methods and frameworks for systematically anticipating future trends and scenarios. This includes scenario planning, trend analysis, and speculative fiction. They explore how various drivers of change, such as technological innovation, social movements, and geopolitical shifts, interact to shape future trajectories.

Discussions around anticipatory processes also involve ethical and moral considerations. For instance, questions may arise regarding the responsibility of individuals, organizations, or governments to anticipate and mitigate potential risks or adverse consequences of future developments. Ethical foresight involves considering the long-term impacts of present decisions on future generations and the environment.

Theory for making sense of anticipatory processes, therefore, provides valuable insights into how individuals, groups, and societies navigate uncertainty and prepare for the future. By understanding the underlying mechanisms and dynamics of anticipation, researchers can develop more informed strategies for decision making, planning, and policy formulation.

3.2 Empirical Literature

According to Kulkarni, Kumar, Chate, and Dandannavar (2021), the advantages of additive manufacturing are reduction in inventory cost, lowering wastage in production, and customization of products. However, factors such as the cost of machinery, and a higher level of cost in integrating metal components have a negative impact on the adoption of this technology in small and medium-sized industries. Martens (2018) also concurs that as a result of design freedom, the use of additive manufacturing in combination with its environmental efficiency, the implications for positive social change, which include possibilities for increasing local employment, improving the environment, and enhancing healthcare for the prosperity of local and global citizens by providing potential solutions that managers could use to deploy the technology. In addition, Candi and Beltagui (2019) also indicate that adopting 3DP for innovation brings greater benefits to firms that orchestrate the functions involved in its implementation and use.

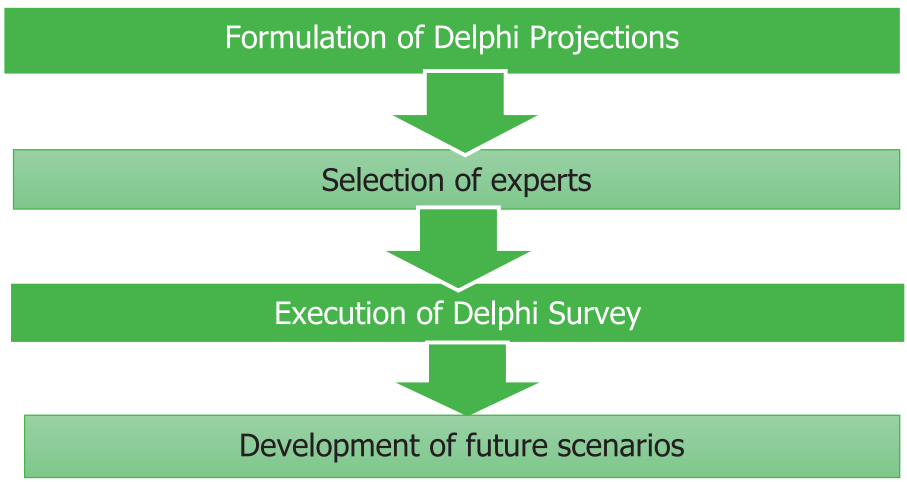
Ahsan and Rahman (2019) agree with Kulkarni, Kumar, Chate, and Dandannavar (2021) that the critical implementation challenges in additive manufacturing are predominantly technology (production) and cost related. The major challenges are related to the quality of products in terms of surface finish, standard, strength, and colour. Furthermore, the requirement of new skills in designing the products and the cost of raw materials are major challenges. On the other hand, Zhao, Yang, Shu, and Liu (2021) assert that sustainability orientation has a stronger positive effect on the acquisition of 3DP technologies in the USA firms than in Indian ones, but it has a stronger positive effect on the application of 3DP technologies in India than in the USA.

4. Methodology

4.1 The Delphi Method

In line with previous studies (Jiang, Kleer and Piller, 2017), this study adopted the Delphi method to predict the future of additive manufacturing in Kenya. The method was developed by the RAND Corporation to generate scenarios for strategic planning. It is an interactive method that relies on the expert's opinions to identify technical developments and trends. The objective is to obtain complex group opinions and develop a consensus on future developments among experts (Linstone and Turoff, 2002). Application of this method in this study involved the steps shown in Figure 4.1.

Figure 4.1: Steps in Delphi Method



Source: Authors' compilation

4.2 Formulation of Projections of the Future of Additive Manufacturing

To address the first objective of this study, a systematic literature review was conducted to identify relevant literature on additive manufacturing. The search strategy was guided by the following central question: what are the political, economic, social, technological, environmental, and legal drivers of additive manufacturing/3D printing technology adoption? The search was done from trusted online sources which included Springer, Elsevier Science Direct, Wiley Online Library, Oxford Journals, Emerald Insight, Sage, and JSTOR. The search was conducted by identification of the key terms in the central research question. The inclusion criteria was considered including the article discussing any of the six factors stated in the central research question whereas the exclusion criteria considered was; that the article does not discuss any of the six factors stated in the central research question.

The articles were searched using specific keywords such as political factors affecting the adoption of additive manufacturing, economic factors affecting the adoption of additive manufacturing, social factors affecting the adoption of additive manufacturing, technological factors affecting the adoption of additive manufacturing, environmental factors affecting the adoption of additive manufacturing and legal factors affecting the adoption of additive manufacturing.

A quality assessment of the articles was conducted to provide more detail about the inclusion and exclusion criteria. The quality assessment involved a detailed review of the articles with great emphasis on the objectives, the methodology used, and the findings. The following questions guided the quality assessment criteria:

i. Were the articles published between 2004 and 2024?
ii. Do the articles provide a clear description (political, economic, social, technological, environmental, and legal drivers) of additive manufacturing adoption?

The selected articles were utilized in collecting data that helped in answering the first objective of the study. A data extraction form containing the title, objectives, methodology, findings, and recommendations was used to collect data from the articles. The final stage involved data synthesis to determine the consistency and inconsistency of results in the different articles.

In the systematic literature review, 58 articles were found after conducting an online search in the following databases: Springer, Elsevier Science Direct, Wiley Online Library, Oxford Journals, Emerald Insight, Sage, and JSTOR. The identified articles were then subjected to the inclusion and exclusion criteria and out of the 58 articles identified, only 20 were left. The selected 20 articles also fulfilled the quality assessment criteria. From the selected 20 articles, 13 drivers of additive manufacturing were identified after carefully reviewing them.

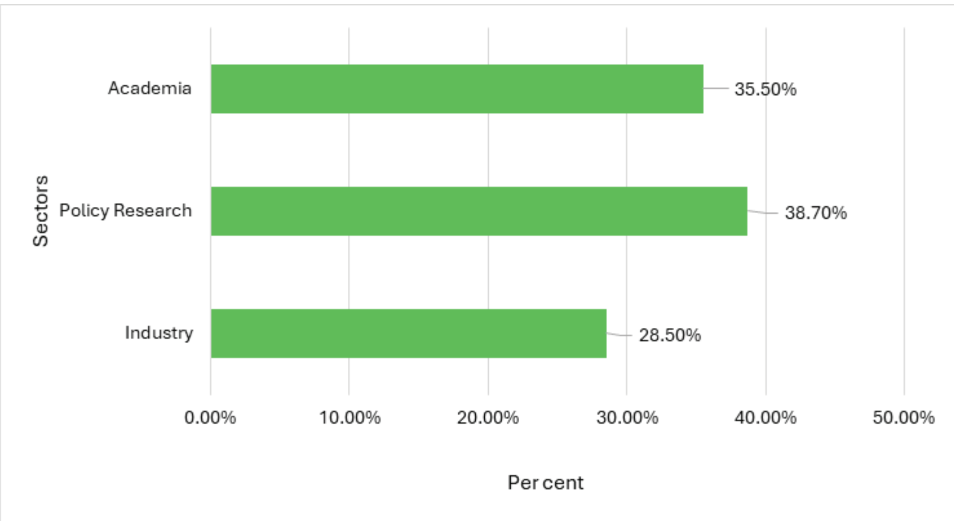
The next step involved the formulation of projections, that is, statements about the possible future of additive manufacturing from the identified drivers. A set of 14 projections were formulated and to accommodate multiple perspectives, the PESTEL analysis framework was applied as shown in Table 1 (Jiang, Kleer, and Piller, 2017). The estimated time frame for the occurrence of the projections was aligned with the African Agenda 2063, which talks of Science and Technology, Innovation-driven manufacturing/industrialization, and value addition. In addition to Kenya being a member of the African Union, Kenya's Vision 2030 is only six (6) years away from actualization, and currently, no policy on manufacturing spans beyond 2030.

4.3 Selection of Experts and Execution of Delphi Survey

The panel experts were identified depending on their relevance, interest in the study, and capabilities. As such, experts were obtained from three fields namely academia comprising lecturers from the faculty of engineering, industry comprising manufacturing firms using additive manufacturing technology, and policy research comprising research professionals from research and policy institutions. The presence of a heterogeneous panel in this study was intended to obtain more accurate estimates as more diverse views serve to reduce the polarization of responses (Hussler, Muller, and Rondé, 2011). According to Jiang, Kleer, and Piller (2017), experts may be identified through database search, networking approach, and professional social networks. The survey targeted 35 experts from the three selected fields, which is in line with other Delphi studies (Gordon and Helmer-Hirschberg, 1964).

An online questionnaire was developed and sent to 35 experts. The experts were asked to estimate the probability of occurrence of the 14 projections and their firm impact. The probability of occurrence was measured in percentages where 25 per cent = Very Low, 50 per cent= Low, 75 per cent= High, and 100 per cent= Very High. Firm impact was measured on a Likert scale (ranging from 1='very low' to 5='very high' impact). 31 experts out of the targeted 35 experts participated in the survey, which translates to 88.57 per cent response rate. The highest number of respondents were policy researchers (38.7%), followed by experts in academia (35.5%) and the remaining 28.5% were industry experts (Figure 4.2).

Figure 4.2: Response rate



4.4 Development of Future Scenarios

Delphi results were analyzed where interquartile range, means of probability of occurrence, and means of firm impact were obtained to determine whether a consensus was reached for every projection and to select the projections that would form the most probable future scenario. While the interquartile range was used to determine whether consensus was reached for each projection, the probability of occurrence and the firm impact was used to determine the projections with the highest level of certainty that would be used to determine the most probable future scenario.

In line with previous Delphi studies, an interquartile range (IQR) of two (2) or less indicates that consensus was reached among experts while an interquartile range of above two (2) indicates that consensus was not reached. Aside from the interquartile range, projections with firm impact equal to or higher than 3.0 imply that the projections were relevant to the purpose of the study (Jiang, Kleer, and Piller, 2017). Further to that, projections with an expected probability of occurrence above 50 per cent indicate that consensus was reached among the experts, which is in line with other Delphi studies (Von der Gracht and Darkow, 2010; Jiang, Kleer, and Piller, 2017).

5. Results and Discussion

This section presents the results of the study. Section 5.1 presents findings on objective one, Section 5.2 presents findings on objective two, and Section 5.3 presents findings on objective three.

5.1 Projections on the Future of Additive Manufacturing

The first objective of the study was to develop projections for the future of additive manufacturing. Table 5.1 presents findings obtained after carefully reviewing 20 research papers to obtain drivers of additive manufacturing, which informed the development of the Delphi projections for 2063.

Table 5.1: Projections on the Future of Additive Manufacturing

Framework	Drivers of additive manufacturing	Sources	Delphi projections
Political	Opportunities for local and international collaborations	D'Oca, Ferrante, Ferrer, Pernetti, Gralka, Sebastian and op't Veld (2018)	A significant number of local and international firms will collaborate in the production of AM products A significant number of Micro, small, and medium enterprises will share industry-specific 3DP technology to achieve higher machine utilization, learning effects, and quality assessments
	Government investment in 3DP projects	Li, Hojati, Wu, Piasente, Ashrafi, Duarte and Radlinska (2020)	Kenya will be the leading country in Eastern Africa in 3DP manufactured products
Economic	Reduced costs of production	Esposito, Casagrande, Menna, Asprone and Auricchio (2021) Guimaraes et al., 2021; Hossain et al., 2020; Kulkarni, Kumar, Chate and Dandannavar (2021)	The cost of production will be significantly reduced due to the use of additive manufacturing technology

	Competitive advantage	Muylle (2019)	Competitive advantage will shift from manufacturing and supply chain capabilities to customer access and designer networks
	Production time	Muylle (2019)	Production time will significantly reduce due to the use of additive manufacturing
	Demand for AM products	Shahrubudin and Ramlan (2019);Martens, Fan and Dwyer(2020);Kulkarni, Kumar,Chate and Dandannavar (2021)	The demand for AM products will be significantly higher compared to products manufactured through traditional methods
	Ability to produce complex designs	Niaki, Torabi and Nonino (2019); Ahsan and Rahman (2019)	Manufacturers will be able to produce products that require complex geometries that could not be produced through traditional methods
Social	Shift in consumer behaviour and demand	Subramani (2004)	Consumers will use design databases to purchase or download freely accessible product designs for additive manufacturing printing purposes
Technological	Precise replication of products	Gibson et al. (2010)	Additive manufacturing will be able to precisely replicate products
	Customizing products for specific applications	Kurfess and Cass (2014)	It will be possible to produce customized products as per consumer needs through additive manufacturing
	Performance increases by improving product function and reducing weight	Gausemeier et al. (2011)	Product performance will be enhanced through improved product function and reduced weight

Environmental factors	Creating safer environments that reduce health and safety risks	Buchanan and Gardner (2019); Ning et al. (2021)	The carbon emissions from production will be significantly reduced by additive manufacturing
Legal factors	Regulatory and legal issues	Shahrubudin and Ramlan (2019); Kamble,Belhadi, Gupta, Islam, Verma and Solima (2023)	An important regulatory measure will be the regulation of additive manufacturing file-sharing platforms

5.2 Probability of Occurrence of the Projections and their Estimated Firm Impact

The second objective of this study was to determine the probability of occurrence and the firm impact of the Projections. Table 5.2 shows the results of the Delphi survey indicating the interquartile range, probability of occurrence, standard deviation, and the firm impact for each projection. In particular, the results depict consensus development through Delphi. The study participants were able to reach a consensus in all 14 projections after the first round. The fact that all 14 projections fulfilled the interquartile range criterion shows that the topic of additive manufacturing is finally gaining awareness among different stakeholders. Aside from consensus among stakeholders, all 14 projections had a firm impact equal to or higher than 3.0, which implies that the projections were relevant to the purpose of the study (Jiang, Kleer, and Piller, 2017). Further to that, all the projections had an expected probability of occurrence above 50 per cent, which is in line with other Delphi studies (Jiang, Kleer, and Piller, 2017; Ogden et al., 2005).

Table 5.2: Probability of occurrence and the firm impact of the Delphi projections

Projections for 2063	Interquartile range	Probability of occurrence (%)	Std. deviation (%)	Firm impact
1. Collaboration in the production of 3D printing technology products	2	72.50	19.08	3.82

2. Sharing industry-specific 3DP technology to achieve higher machine utilization, learning effects, and quality assessments	2	63.33	15.64	3.35
3. Kenya will be the leading country in East Africain 3DP manufactured products	1	65.83	22.98	3.26
4. 3DP will reduce the cost of production	1	77.50	20.14	3.84
5. Competitive advantage will shift from manufacturing and supply chain capabilities to customer access and designer networks	1	73.33	20.90	3.87
6. Production time will significantly reduce due to the use of additive manufacturing.	1	80.00	17.92	4.06

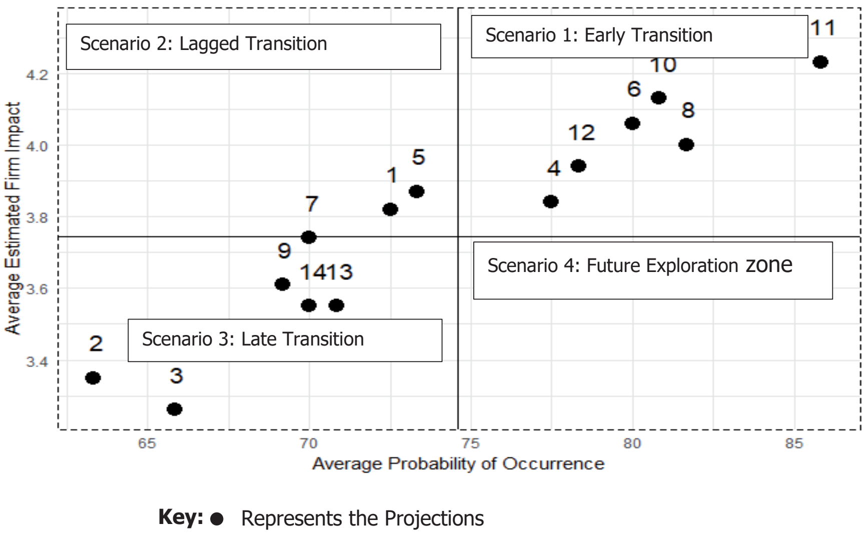
7. The demand for AM products will be high	1	70.00	19.46	3.74
8. 3DP will be useful in the production of products that require complex geometries	1	81.67	19.57	4.00
9. Use of design databases to purchase or download freely accessible product designs for AM	1	69.17	20.83	3.61
10. 3DP will enable precise replication of AM products	1	80.83	19.33	4.13
11. 3DP will enable customization of products as per consumer needs	1	85.83	16.88	4.23
12. 3DP adoption will enhance product performance	1	78.33	15.93	3.94
13. 3DP use will reduce carbon emissions	1	70.83	24.78	3.55
14. Regulation of AM file sharing	1	70.00	23.64	3.55

Source: Authors' computation

5.3 Probable Future Scenarios of Additive Manufacturing

The third objective of this study was to develop probable futures of additive manufacturing. Results on average estimates for the probability of occurrence and firm impact were plotted in Figure 5.1 for all 14 projections to develop the scenarios cluster.

Figure 5.1:Scenarios cluster



Source: Authors Compilation

5.3.1 Scenario 1: Early transition

The scenario is characterized by six projections (projections 4,6,8,10,11 and 12) with a high probability of occurrence (above 75%) and high firm impact (above 3.7). These projections have a high influence on firms' decisions to adopt additive manufacturing in the future. As such, if these projections are realized, they will serve as an impetus for the manufacturing firm to adopt additive manufacturing by 2063. Projection 4, for instance, asserts that additive manufacturing is expected to significantly reduce the cost of production through a faster and cheaper design process. Fast prototyping is one of the main uses of additive manufacturing and prototypes that are currently expensive to develop will likely be produced cheaply in the future as research on 3D printing materials intensifies. With reduced costs, even small and medium enterprises will be able to pursue product development in the future. Secondly, projection 6 predicts that firms will significantly reduce the time taken to manufacture products because the technology enables quick prototyping. Instead of waiting for weeks or months for prototypes to be machined or molded, engineers and designers will be capable of producing prototypes in a matter of hours or days. This will speed up the product development cycle significantly.

Third, this scenario is also characterized by projection 8, which predicts that 3DP will be useful in producing products requiring complex geometries. Traditional manufacturing methods often struggle with complex geometries, leading to time-consuming processes like machining or assembly. Advancements in materials compatible with 3D printing will likely lead to improved properties such as strength, flexibility, and heat resistance. These materials will produce even more complex and functional parts across a wider range of applications. As printing speed increases, the time required to produce complex geometries will decrease, making 3D printing more competitive with traditional manufacturing methods for high-volume production. In addition, this scenario is also characterized by projection 10 which asserts that 3DP will enable precise replication of products. This development will be driven by advancements in printing techniques such as selective laser sintering (SLS), stereolithography (SLA), or binder jetting, which enable finer details and smoother surfaces, resulting in higher-quality prints. The advancement in 3D printing materials will allow the production of more precise and functional parts with greater consistency.

Another characteristic of this scenario is projection 11, which asserts that 3DP will enable the customization of products as per consumer needs. Additive manufacturing will open exciting possibilities for product customization to meet individual consumer needs and preferences. This technology can create unique designs for individual consumers. As such, it will be possible to tailor products based on specific requirements such as size and functionality. It will be possible for companies to insert customers' names and initials and other personalized elements directly on the product, hence creating more meaningful and engaging experiences for the consumer. Traditional manufacturing methods often rely on the mass production of standardized products. In contrast, 3D printing will enable mass customization. This means that companies will efficiently produce large quantities of customized products, each tailored to meet the unique preferences of individual consumers.

Lastly, this scenario is also characterized by projection 12, which asserts that product performance will be enhanced through improved product function and reduced weight. Continued research and development in materials science will lead to the manufacturing of new lightweight materials with superior mechanical properties. These materials will be specifically tailored for 3D printing processes, enabling the production of parts with enhanced performance characteristics such as strength, stiffness, and durability. Future 3D printers will be capable of printing with multiple materials simultaneously or sequentially, allowing for the fabrication of hybrid structures with optimized properties. By combining materials with different properties, engineers can create parts that are lightweight yet strong, flexible yet rigid, and thermally conductive yet electrically insulating.

5.3.2 Scenario 2: Lagged transition

This scenario is composed of projections with high firm impact (above 3.7) but a low probability of occurrence (below 75%). Projections 1,5 and 7 fall under this category. The low probability of occurrence will lead to a lagged transition into additive manufacturing by 2063. These projections will have a moderate influence on a firm's decision to adopt additive manufacturing in the future. According to Projection 1, a considerable number of local and international firms will collaborate in the production of additive manufactured products. The collaboration could be in sharing resources and expertise to lower costs associated with research, development, and production of additive manufactured products. Collaboration is also expected to lead to faster innovation by combining different perspectives, skills, and technologies, leading to more advanced and market-ready products. Partnering with other firms is also expected to open access to new markets and customer bases that might not have been accessed independently. Collaborations could also spread the financial and operational risks associated with new manufacturing technologies, making it less daunting for individual firms to invest in 3D printing. In addition, working together can help establish industry standards and best practices, which can facilitate wider adoption and integration of 3D printed products in various sectors. Lastly, joint efforts can help firms navigate complex regulatory environments more effectively by pooling resources and knowledge to meet compliance requirements.

Another characteristic of this scenario is projection 5 which asserts that competitive advantage will shift from manufacturing and supply chain capabilities to customer access and designer networks. 3D printing allows for highly customized and personalized products, which can be tailored to individual customer needs and preferences. Firms that excel in understanding and accessing customer needs can leverage 3D printing to offer unique, made-to-order products, providing a significant competitive edge. In addition, this technology supports localized and decentralized production, reducing the reliance on large-scale manufacturing facilities and complex supply chains. It is also important to note that competitive advantage will increasingly come from the ability to collaborate with a wide network of designers who can create innovative and appealing products. Companies that build and maintain robust designer networks will continuously introduce fresh, creative designs, keeping them ahead in the market. Lastly, the ability to quickly design, prototype, and produce new products using this technology shortens the time to market. Firms with strong designer networks can rapidly innovate and introduce new products faster than competitors relying on traditional manufacturing methods.

This scenario is also characterized by projection 7, which predicts that the demand for additive-manufactured products will be significantly higher compared to products manufactured through traditional methods. This technology allows for high levels of customization and personalization. Consumers can have products tailored to their specific needs, preferences, and measurements, which is difficult and costly to achieve with traditional manufacturing methods. Secondly, technology excels in producing complex geometries and intricate designs that are challenging or impossible to achieve with traditional manufacturing methods. For applications requiring highly customized or unique shapes, 3D printing offers superior capabilities.

5.3.3 Scenario 3: Late transition

This scenario is characterized by projections with a low probability of occurrence (below 75%) and low firm impact (less than 3.7). Projections 2,3,9, 13, and 14 fall in this category and according to the experts, these projections have a low influence on the firms' decision to transition to additive manufacturing technology by 2063. Projection 2 for instance predicts that a significant number of micro, small, and medium enterprises will share industry-specific 3DP technology to achieve higher machine utilization, learning effects, and quality assessments. This can lead to collective learning effects where each participant benefits from the insights and experiences of others, accelerating the pace of innovation within the industry. Sharing industry-specific technology can collectively assess and improve the quality of products, which ultimately benefits all participants by enhancing the reputation and reliability of 3DP products in the market. Collaborative efforts to share technology can also facilitate market expansion. This benefits all participants by increasing demand and creating new business opportunities.

Secondly, this scenario is also characterized by projection 3 which predicts that Kenya will be the leading country in Eastern Africa in 3DP manufactured products. This implies that a significant number of firms in various sectors will adopt this technology and there will be high consumer preference for additive manufactured products to drive production. Another characteristic of this scenario is projection 9, which states that consumers will use design databases to purchase or download freely accessible product designs for additive manufacturing printing purposes. There are numerous online marketplaces specifically dedicated to 3D printable designs. Consumers can browse these platforms to find a wide range of designs for various products, ranging from household items to decorative objects to functional prototypes. Examples of such platforms include Thingiverse, MyMiniFactory, and Cults. On top of that, many designers and organizations contribute to open-source repositories where they freely share their 3D printable designs. These repositories often host a vast collection of designs covering diverse categories. Consumers can access these repositories to download designs for personal use or to contribute their designs to the community. In some instances, manufacturers and brands offer downloadable 3D printable designs of their products on their websites. This allows consumers to customize or replicate products according to their preferences or specific needs. For example, a furniture company might provide downloadable designs for its furniture pieces, enabling consumers to customize dimensions or features before printing.

Another characteristic of this scenario is projection 13, which predicts that the technology will significantly reduce carbon emissions from production. The use of sustainable and recyclable materials in 3D printing is on the rise. Biodegradable polymers, recycled plastics, and other eco-friendly materials can be used in 3D printing, reducing the reliance on non-renewable resources and minimizing the environmental impact of production. The last feature of this scenario is projection 14, which states that an important regulatory measure will be the regulation of additive manufacturing file-sharing platforms. Platforms will be required to comply with local and international laws and regulations regarding product safety, consumer protection, and other relevant areas through regular audits and reporting to regulatory bodies. In addition, they will also be required to implement robust cybersecurity measures to protect them from hacking, data breaches, and other malicious activities that could compromise user data or file integrity. Another important consideration would be the establishment of guidelines and moderation policies to prevent the sharing of files that could be used for illegal or unethical purposes, such as creating counterfeit goods or offensive items.

5.3.4 Scenario 4: Future exploration zone

Projections characterizing this scenario have a high probability of occurrence (above 75%) but a low firm impact (less than 3.7). However, none of the 14 projections fell under this category. This may be explained by several factors including limitations of the study in terms of the number of projections, and biases among others.

6. Conclusion and Recommendations

6.1 Conclusion

This study aimed to determine the future of additive manufacturing in Kenya using the Delphi approach. Through an extensive analysis, a set of 14 projections was developed from the identified drivers of additive manufacturing. Analysis of the probability of occurrence and firm impact of the projections revealed that the country's early transition to additive manufacturing by 2063 will be highly influenced by reduced cost of production and time; the ability of the technology to produce products with complex geometries; precise replication of AM products; the ability of the technology to customize products as per consumer needs; and enhanced product performance.

Additionally, the lagged transition into additive manufacturing may be caused by a lack of industry c collaborations in the production of AM products; a lack of shift in competitive advantage from manufacturing and supply chain capabilities to customer access and designer networks; and low demand for AM products.

Finally, the county may experience a late transition due to its inability to position itself as the leader in AM-manufactured products in East Africa; the inability of the technology to reduce carbon emissions; and the lack of regulation on AM file sharing.

6.2 Recommendations

Scenario 1: The country's early transition

Some of the interventions that will promote early transition into additive manufacturing include:

Cost of production

The government may consider providing direct financial support to firms to enable them to invest in 3D printing technology, including purchasing equipment and training employees. In addition, the government may consider providing tax breaks or credits for investments in 3D printing technology and related innovations.

Capability of firms to produce products with complex geometries

The government may consider increasing funding for research and development in 3D printing technologies to build a skilled workforce proficient in 3D printing technologies. More funding may also be provided for innovation hubs and labs focused on 3D printing to foster knowledge sharing and technological advancement. In addition, the government may promote skills development through educational institutions by integrating 3D printing into engineering, design, and manufacturing curriculums. Currently, very few institutions of learning are offering 3D printing lessons despite the National ICT Policy advocating for all secondary and tertiary institutions to acquire 3D capabilities.

Scenario 2: The country lagging in transition

To ensure a fast transition into the use of additive manufacturing by 2063, there is a need for:

Increased collaboration among firms to produce 3D-printed products

This can be achieved through the promotion, establishment, and maintenance of shared 3D printing facilities that small and medium-sized enterprises (SMEs) can access without the need for large capital investments. Firms may also create more technology parks or industrial clusters that bring together 3D printing firms, suppliers, and related industries to foster collaboration and innovation. In addition, a framework for collaborations between government research institutions, universities, and private firms to advance 3D printing technologies and applications may be developed and anchored in the National ICT Policy or the National Industrialization Policy.

Promote demand for AM products

To hasten the transition into the adoption of additive manufacturing, there is a need to create demand for additive-manufactured products through the use of government procurement to create demand for 3D printed products by setting targets or preferences for 3D-printed components in public projects. Firms may also launch marketing and educational campaigns to inform businesses and consumers about the benefits and potential of 3D printed products, such as customization, cost-efficiency, and sustainability. In addition, media may assist in showcasing case studies and success stories of companies and industries that have successfully adopted 3D printing, highlighting the tangible benefits they experienced.

Scenario 3: The country experiencing late transition

For a smooth and fast transition into the adoption of additive manufacturing in Kenya by 2063, the government could consider:

Positioning Kenya as a destination hub for additive manufacturing

This could be achieved by providing support to firms in accessing international markets by promoting 3D printed products in foreign markets and providing export assistance. Similarly, the government may work with industry bodies to develop and implement standards for 3D printing materials, processes, and products to ensure quality and safety.

Reduction of carbon emission

Efforts to reduce carbon emissions by firms may include the adoption of sustainable practices in 3D printing, which include the use of eco-friendly materials, energy-efficient processes, recycling, and waste reduction strategies. The government may also provide incentives for firms to adopt sustainable 3D printing technologies and practices, as well as promote awareness and education on the environmental benefits of 3D printing.

Framework for AM file sharing

Firms need to invest in robust digital infrastructure to support the high data demands of 3D printing, including high-speed internet and secure data storage solutions. In addition, the government may develop a comprehensive framework or regulations to govern AM file sharing.

References

Ahsan, K., and Rahman, S. (2019), Implementation challenges of three-dimensional printing (3DP) in medical device manufacturing supply chains. In Symposium on Logistics (p.2).

Besklubova, S., Skibniewski, M. J., and Zhang, X. (2021), "Factors affecting 3D printing technology adaptation in construction". Journal of Construction Engineering and Management, 147 (5): 04021026.

Boddenberg, F., Schwarz, J. O., and Schmies, P. (2024)," Scenario planning in the digital transformation of the fashion industry: Starting point for the adjustment of business processes from a colour management perspective". Journal of Futures Studies, 28 (3): 49-63.

Bogue, Robert. (2013), 3D Printing: The dawn of a new era in manufacturing?

Candi, M., and Beltagui, A. (2019)," Effective use of 3D printing in the innovation process". Technovation, 80: 63-73.

Cirera, X. (2015), Catching Up to the Technological Frontier? Understanding Firm-level Innovation and Growth in Kenya.

Cirera, X., Comin, D., Cruz, M., Lee, K. M., Martinez, P., and Martins-Neto, A. (2022), Firm-level Adoption of Technologies in Kenya.

Cotteleer, M., and Joyce, J. (2014), "3D opportunity: Additive manufacturing paths to performance, innovation, and growth". Deloitte Review, 14(1): 3-19.

Coughlin, P. E., and Ikiara, G. K. (Eds.) (1988), Industrialization in Kenya: In search of a strategy. East African Publishers.

D'Oca, S., Ferrante, A., Ferrer, C., Pernetti, R., Gralka, A., Sebastian, R., and op 't Veld, P. (2018), "Technical, financial, and social barriers and challenges in deep building renovation: Integration of lessons learned from the H2020 cluster projects". Buildings, 8 (12): 174.

Dodziuk, H. (2016), "Applications of 3D printing in healthcare". Kardiochirurgia i Torakochirurgia Polska/Polish Journal of Thoracic and Cardiovascular Surgery, 13(3): 283-293.

Dzogbewu, T. C., Fianko, S. K., Amoah, N., Jnr, S. A., and de Beer, D. (2022), "Additive manufacturing in South Africa: Critical success factors". Heliyon, 8 (11).

Esposito, L., Casagrande, L., Menna, C., Asprone, D., and Auricchio, F. (2021). "Early-age creep behaviour of 3D printable mortars: Experimental characterisation and analytical modelling". Materials and Structures, 54: 1-16.

Gerstle, T. L., Ibrahim, A. M., Kim, P. S., Lee, B. T., and Lin, S. J. (2014), "A plastic surgery application in evolution: Three-dimensional printing". Plastic and reconstructive surgery, 133(2): 446-451.

Cotteleer, M., and Joyce, J. (2014), "3D opportunity: Additive manufacturing paths to performance, innovation, and growth". Deloitte Review, 14(1): 3-19.

Wu, B., Myant, C., and Weider, S. (2017), The value of additive manufacturing: Future opportunities. Imperial College London, Briefing Paper, (2).

Hasson, F., and Keeney, S. (2011), "Enhancing rigour in the Delphi technique research". Technological forecasting and social change, 78(9): 1695-1704.

Hussler, C., Muller, P., and Rondé, P. (2011), "Is diversity in Delphi panelist groups useful? Evidence from a French forecasting exercise on the future of nuclear energy". Technological Forecasting and Social Change, 78(9): 1642-1653.

Kamble, S., Belhadi, A., Gupta, S., Islam, N., Verma, V. K., and Solima, L. (2023), Analyzing the barriers to building a 3-D printing enabled local medical supply chain ecosystem. IEEE Transactions on Engineering Management.

Klenam, D. E. P., Bamisaye, O. S., Williams, I. E., van der Merwe, J. W., and Bodunrin, M. O. (2022), "Global perspective and African outlook on additive manufacturing research– an overview". Manufacturing Review, 9: 35.

Kulkarni, P., Kumar, A., Chate, G., and Dandannavar, P. (2021), "Elements of additive manufacturing technology adoption in small and medium-sized companies". Innovation and Management Review, 18 (4): 400-416.

Li, Z., Hojati, M., Wu, Z., Piasente, J., Ashrafi, N., Duarte, J. P., and Radlińska, A. (2020), "Fresh and hardened properties of extrusion-based 3D-printed cementitious materials: A review". Sustainability, 12 (14): 5628.

Lipton, J. I., Cutler, M., Nigl, F., Cohen, D., and Lipson, H. (2015), "Additive manufacturing for the food industry". Trends in food science and technology, 43(1): 114-123.

Marak, Z. R., Tiwari, A., and Tiwari, S. (2019), „Adoption of 3D printing technology: An innovation diffusion theory perspective". International Journal of Innovation, 7 (1): 87-103.

Martens, R. (2018), Strategies for Adopting Additive Manufacturing Technology into Business Models (Doctoral dissertation, Walden University).

Martens, R., Fan, S. K., and Dwyer, R. J. (2020), "Successful approaches for implementing additive manufacturing. World Journal of Entrepreneurship, Management and Sustainable Development, 16 (2): 131-148.

Miladinov, S. (2018), Adoption of 3D printing technology and its impact on business.

Mpofu, T. P., Mawere, C., and Mukosera, M. (2014), The impact and application of 3D printing technology.

Muylle, L. (2019), Technology readiness and adoption of 3D printing in the construction industry. Ghent University, Ghent.

Ng, J. S., and Hashimoto, M. (2021), "3D-PAD: Paper-based analytical devices with integrated three-dimensional features". Biosensors, 11 (3): 84.

Niaki, M. K., Torabi, S. A., and Nonino, F. (2019), "Why manufacturers adopt additive manufacturing technologies: The role of sustainability". Journal of cleaner production, 222: 381-392.

Nollet, L. J. E. (2017), Factors influencing the adoption decision of metal additive manufacturing technologies (Master's thesis, University of Twente).

Sardesai, S., Stute, M., and Kamphues, J. (2021), A methodology for future scenario planning. Next Generation Supply Chains: A Roadmap for Research and Innovation, 35-59.

Shahrubudin, N., and Ramlan, R. (2019), "An overview of critical success factors for implementing 3D printing technology in manufacturing firms". Journal of Applied Engineering Science, 17 (3): 379-385.

Shahrubudin, N., and Ramlan, R. (2019), "An overview of critical success factors for implementing 3D printing technology in manufacturing firms". Journal of Applied Engineering Science, 17 (3): 379-385.

Shahrubudin, N., Lee, T. C., and Ramlan, R. J. P. M. (2019), "An overview on 3D printing technology: Technological, materials, and applications". Procedia Manufacturing, 35, 1286-1296.

Shahrubudin. N., Koshy, P., Alipal, J., Kadir,M.H.A., Lee, T.C. (2020), Challenges of 3D printing technology for manufacturing biomedical products: A case study of Malaysian manufacturing firms. National Library of Medicine.

Spahiu, T., Canaj, E., and Shehi, E. (2020), "3D printing for clothing production". Journal of Engineered Fibers and Fabrics, 15: 1558925020948216.

Spicek, N., Besklubova, S., and Skibniewski, M. J. (2023), "Benchmarking critical success factors in construction projects utilizing 3D printing technology". *International Journal of Applied Science and Engineering*, *20* (4): 1-18.

Turoff, M., and Linstone, H. A. (2002). The Delphi method techniques and applications.

Ukobitz, D. V. (2020)," Organizational adoption of 3D printing technology: A semi systematic literature review". Journal of Manufacturing Technology Management, 32 (9): 48-74.

Winkler, J., and Moser, R. (2016),” Biases in future-oriented Delphi studies: A cognitive perspective”. Technological forecasting and social change, 105: 63-76.

Wohlers, T., Campbell, R. I., Diegel, O., Huff, R., and Kowen, J. (2020), Wohlers Report 2020 3D Printing and Additive Manufacturing State of the Industry.

Wu, P., Wang, J., and Wang, X. (2016), "A critical review of the use of 3D printing in the construction industry". Automation in Construction, 68: 21-31.

Wu, B., Myant, C., and Weider, S. (2017), The value of additive manufacturing: Future opportunities. Imperial College London, Briefing Paper, (2).

Zhao, M., Yang, J., Shu, C., and Liu, J. (2021), “Sustainability orientation, the adoption of 3D printing technologies, and new product performance: A cross-institutional study of American and Indian firms”. Technovation, 101: 102197.

Appendix 1: DELPHI Questionnaire

S/ NO.	Projections for 2063	Probability of occurrence	Impact on manufacturing firms
1.	In 2063, a significant number of local and international companies will collaborate in the production of 3D technology products.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
2.	In 2063, a significant number of micro, small, and medium enterprises will share industry-specific 3DP technology to achieve higher machine utilization, learning effects, and quality assessments.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
3.	In 2063, Kenya will be the leading country in Eastern Africa in 3DP manufactured products.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
4.	In 2063, the cost of production will be significantly reduced due to the use of additive manufacturing technology	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
5.	In 2063, competitive advantage will shift from manufacturing and supply chain capabilities to customer access and designer networks.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
5.	In 2063, production time will significantly reduce due to the use of additive manufacturing.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]

6.	In 2063, the demand for AM products will be significantly higher compared to products manufactured through traditional methods.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
7.	In 2063, manufacturers will be able to produce products that require complex geometries that could not be produced through traditional methods.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
8.	In 2063, consumers will use design databases to purchase or download freely accessible product designs for additive manufacturing printing purposes.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
9.	In 2063, additive manufacturing will be able to precisely replicate products.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
10.	In 2063, it will be possible to produce customized products as per consumer needs through additive manufacturing.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
11.	In 2063, product performance will be enhanced through improved product function and reduced weight.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]Very high [ ]
12.	In 2063, the carbon emissions from manufacturing will be significantly reduced by additive manufacturing.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]
13.	In 2063, an important regulatory measure will be the regulation of additive manufacturing file-sharing platforms.	25 [ ] 50 [ ] 75 [ ] 100 [ ]	Very low [ ] Low [ ] Moderate [ ] High [ ] Very high [ ]

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