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An Assessment of Reverse Engineering Capabilities among Artisanal Metal Fabricators in Selected States in Nigeria

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ABSTRACT

Due to a lack of knowhow of scientific methods of enquiry and linkages with formalized research institutions to aid machine design, many local artisans have turned to reverse engineering or copying the designs of readymade machine and machine parts. The resulting fabricated machines are however generally crude and inefficient. This study developed the reverse engineering capabilities fabricators should possess to develop efficient machines through focus group discussions and evaluated the capabilities through a survey administered on 326 fabricators. The results from the focus group discussions revealed investment, production, linkages, marketing, innovation and resources capabilities with 7, 14, 4, 10, 9, and 8 constructs respectively. The respondents rated all the capabilities (on a scale of none to very high) high except capability to advertise and determine prices (3.25), capability to reach high technology demanding foreign markets (3.15); capacity to use R & D output to improve on machine design (3.39) and capability to source for imported material (3.17) which were all rated moderate. The study attributed these limitations to lack of marketing skills, low levels of education among the fabricators and absence of linkages with foreign markets and recommends policy initiatives to alleviate these limitations.

Keywords: Reverse engineering capabilities, Agro-allied, Artisanal metal fabricators, capability, Agriculture, Nigeria

INTRODUCTION

Agriculture is crucial to the economic progress of Nigeria and Africa as a whole. In Africa, the sector employed about 30% of the population in 2020 and approximately 70% of the population engages in agricultural production at a subsistence level (Ebhota *et al.*, 2016; World Bank, 2020; Adeite, 2022). In Nigeria, the agricultural sector has faced several challenges which critically hamper the growth of the sector. These problems range from the lack of adoption of technology by smallholders, lack of maintenance of farming equipment by large-scale farmers, poor implementation of government policies, illiteracy and lack of knowledge of modern agricultural techniques by farmers. Other issues facing the sector in Nigeria are lack of transport infrastructure, market access, and non-profitability of adopted improved practices (Kate and Leigh, 2010; IFPRI, 2012; Urgessa, 2014).

Despite these challenges, smallholder agricultural practitioners have had access to certain technological inputs. In postharvest processing activities for instance, smallholders have enjoyed the use of technologies in specific unit operations. For example, the digesting and oil extraction stages of oil palm fruit processing have more or less been fully mechanised. In addition, the chipping and dewatering stages in cassava processing; milling and destoning unit operations in rice processing; and dehulling in maize processing among others have also been automated. These technological inputs have been provided by local artisanal metal fabricators who have over the years adapted and improved on their skills to fabricate these machines. Adejuwon *et al.* (2014) report the wide adoption of digesters and screw presses made by artisans in small-scale palm oil production. Adejuwon (2018) also mentions the use of band saws made by artisans in the sawn wood sector in Southwestern Nigeria. These locally fabricated machines have been useful substitutes in the absence of the wherewithal to purchase expensive imported machines.

In Nigeria, artisans manufacture tools mainly through knowledge and skills imparted through apprenticeship and learning-by-doing (Adejuwon, 2018). These machines and equipment have mainly been produced by duplicating existing machines and/or their components (Eneh, 2014; Sims and Kienzle, 2016). There are great prospects for the artisanal metal fabrication sector in Nigeria. This sector is a major provider of agricultural tools and machines to smallholders in Nigeria (Adejuwon *et al.*, 2014, Adejuwon, 2018). Prospects of this sector have been further buoyed by the surge in the influx of entrepreneurs in food processing and packaging among others. Operators in these areas are demanding locally fabricated machines to enhance their productivity (Kareem *et al.*, 2009). Adejuwon (2018) also reports that many large manufacturing industries now employ artisanal metal fabricators in their machinery and equipment maintenance teams. As at present, the formalized agro-industrial machinery manufacturing industry in Nigeria is almost non–existent compared to countries such as India, Europe, and America among others (Daum *et al.*, 2022). The smallholder agro-business industry therefore relies on the importation of agricultural machines and machine parts and local agro-allied artisanal metal fabricators for agro-industrial machinery (Ozumba *et al.*, 2019). The local artisanal metal fabrication industry is however plagued with firm and national-level institutional challenges that have resulted in the slow progress of capability building among fabricators in the industry. Research and financial institutions have little linkages and working associations with the fabricators (Kasali, 2018). This has led to challenges in access to innovative research, as well as lack of orientation and access to loan facilities. Ibirogba (2022) identified inadequate infrastructure, particularly modern metal fabrication workplaces and laboratories, as the missing connections in enhanced indigenous fabrication. The author also stated that although Nigerian artisans manufacture quite a number of indigenous machines, there still exists a wide gap in the efficiencies of some of them when compared with the imported ones. Ibirogba (2022) also went further, to report that agricultural machinery and equipment that were brought into Nigeria were not quite adjusted to the unique agricultural production and processing landscape of Nigeria. Therefore, local engineers, technicians, technologists, and fabricators may have the unique responsibility of producing agricultural machinery and implements locally. Due to a lack of knowhow of scientific methods of enquiry into machine design construction, and linkages with formalized research institutions, many local artisans have turned to reverse engineering or copying the designs of readymade machines and machine parts.

Industrialization efforts may not succeed if countries with natural resources fail to add value to their agricultural resources. Many countries have used reverse engineering strategies to develop capabilities in their Industrial Machinery Manufacturing Industries (Dahlman *et al.*, 1987). Countries such as Finland and Chile have progressed from manufacturing Original Equipment Manufacturer (OEM) parts by reverse engineering to exporting more technologically advanced machinery to the OEM home countries (Elfes *et al.*, 1998; Ramos, 2013). Reverse engineering capabilities can be said to be critical assets-human, organizational, and capital employed by engineering firms to produce by duplication, existing components, and subassembly of machinery, without the aid of documentation, drawings, or computer models (Lall, 1992). This can also be referred to as the information and talents needed to select, set-up, operate, sustain, adapt, advance, and develop systems for the duplication of efficient industrial machinery (Romijn and Albaladejo, 2004; Abereijo, *et al.*, 2007). These capabilities consist of investment, operational, linkages, marketing, innovation, and resource capabilities (Lall, 1992). Interventions to enhance these capabilities may result in the production of more efficient agro-industrial machinery. Unfortunately, not many public action efforts give precedence to developing reverse engineering capabilities of artisans for the production of industrial machinery in Nigeria.

The artisanal metal fabrication sector holds promise for mechanizing the smallholder agricultural sector with adequate public intervention. However, studies that may provide adequate information for the formulation of apt public intervention mechanisms are scarce. There is therefore the need to examine the reverse engineering capabilities needed in the sector to be able to prescribe policy measures for public intervention to strengthen artisanal engineering systems and improve the quality of locally fabricated agro-industrial machinery in Nigeria. This study intends to fill this gap in the literature by a survey of artisanal metal fabricators to examine the needed technological capabilities needed for the sector to thrive. This study therefore focuses on (i) developing an inventory of reverse engineering capabilities agro-allied artisanal metal fabricators need to possess to fabricate machine and machine components competently, and (ii) assessing the capabilities.

LITERATURE REVIEW

There are various parameters that may influence reverse engineering capabilities. These may include the following

Investment capability

This capability emphasizes capability to carry out feasibility studies on any activity to verify and identify investment needs including capital outlay, the stakeholders (such as sponsors, users, and beneficiary of the investment) and appropriate tools, techniques, and materials to be utilized in the activity (Pierre *et al*. 1992; Sobanke *et al.*, 2012). For a new project to take off, it must be critically analyzed to determine the economic viability and technical feasibility and to decide the appropriate integration of various options for effective and efficient project completion (Biggs *et al.*, 1999). With regards to artisanal fabrication, this may include capability to estimate price, resources requirement, and cost of fabrication, labor requirements, delivery schedule and plan and acquire for resources and materials to be used.

Production capability

The process of utilizing equipment and facilities with adequate knowledge of production methods is known as production capability. Production capability takes effect immediately after the completion of the two stages of investment capability (the preliminary study and project implementation), for efficiency to operate at maximum production (Akintelu, 2017). For maximum production, literature categorized the activities into three levels which include process, product, and industrial engineering (Lall, 1992; Biggs *et al.*, 1999). These activities are incorporated together to promote effective and efficient operation, maintenance, alteration, enhancement, value and inventory, workflow and arrangement of production facilities among others (Lall, 1992; Biggs *et al.*, 1999; Egbetokun, 2009). Agro-allied artisanal metal fabricators must have access to an adequate tools infrastructure to be able to produce machines and machine parts. This capability implies that they should be able to search, purchase, maintain and use these tools in the manufacture of machines.

Innovation capability

Innovation is a value or wealth creator. It is the commercialization of new ideas for an economic event. Innovations serve as the vital association between idea generation and its exploitation (Khalil, 2000). Innovation takes place when a new product, process, technique, procedure, or system is introduced and the first transaction takes place (Chang, Chen, Lin and Gao, 2012). The ability or capability employed to discover new methods or techniques of carrying out activities in a firm which includes inventing, producing, operating and supplying is referred to as innovation capability (Castellacci and Natera, 2015). Egbetokun (2009) expressed that innovation capability is an inquiry into capabilities and capacity of individuals or firms to achieve the specific purpose of exploring new ways of doing things to generate a new pattern in human resources development, Research & Development activities, information technology, adaptation to the technology, and market research (Romijn and Albaladejo, 2002). Lall (1992) maintains that innovation capability is the ability and experience appropriate for gripping, mastering and enhancing established technologies for progressing to advanced technologies. Various organizations have utilized innovation capability in the activities that cut across levels in discovering, inventing, innovating, and advancing in the available technology that surpasses previous design structures (Kim, 1997; Salisu and Bakar, 2020). Sobanke *et al.* (2012) opine that innovation capability is the ability to effect change, improve or enhance and modify current technologies, and to develop or design new and effective technologies. Innovation capability may then be the capability of the artisans to transform skills gained from copying machinery to the ability to design and fabricate new-to-the-world machines and/or new ways of fabricating machines

Linkage capability

Linkage capability focuses on firms' capability to collaborate with external organizations including customers, consultants, suppliers, distributors, academics, other firms, as well as competitors (Tidd *et al.*, 2009) with a view to providing new knowledge to the firm (Gamel *et al.*, 2011). This usually happens within and between firms (intra-firm and inter-firm); and also, with R&D institutions (domestic and international), including Technical Colleges, Polytechnics, and Universities (Olamade, 2001). Lall (1992) reports that linkage capabilities are those skills that are mandatory in spreading information, tactics, and technologies and to obtain them from suppliers of component/raw materials, customers, subcontractors, consultants, service firms, and knowledge institutions. Linkage capabilities are based on interactions among the aforementioned agents (Sobanke *et al.*, 2012). These capabilities also pave the way for information on market availability, technology assessment, technical support, research, and technical know-how (Amara *et al.*, 2008) as well as learning services, where the technological process of capability building depends. Linkage capability in the artisanal metal fabrication sector may translate into capabilities for solving fabrication, financial, supplies and customer feedback challenges. Linkages with knowledge institutions may help solve challenges with machine malfunction or failure of machine components or parts. Proper communication channels with customers may provide feedback on faults when using the machines. This may help the fabricators produce better machines in the future through incremental innovation.

Resource capability

Resource capability refers to the optimization of capabilities that may be accomplished by specific resources in a particular period of time (Nwachukwu and Chladkova, 2019). Resources include; Human resources (employees, teams, leadership), Financial resources (funding and budget), Physical resources (facilities, equipment, and infrastructure), and Intellectual resources (research and development capabilities) among others which are essential for the firm to achieve its goals and objectives and operate efficiently and effectively (Nwachukwu and Chladkova, 2019). With adequate resources, fabricators will be able to produce the machine specifications required by the design. The availability of skilled staff may help deliver machines on time while easy accessibility to financial resources may help with the purchase of materials and tools when needed.

Marketing capability

Marketing capability is the combination of knowledge, skills, techniques, behavior, and resources required for effective planning and executing marketing tactics in line with organizational objectives and goals (Duah *et al.*,

2024). It is the knowledge and talents that enables a firm to maximize the value of its resource use (Leemann and Kanbach, 2022). Wu *et al.* (2023) state that a firm's capabilities are crucial to the achievement of its goals and that its resources are converted into values as a result of internal processes, resulting into a competitive edge. Apasrawirote *et al.* (2022) reports that marketing capability is the capability to recognize the demands of customers, attain product differentiation and create greater brand equity. Minardes *et al.* (2022) affirm that when marketing capabilities are developed, imitation becomes a bottleneck for the competitors. Knowledge of customers' preferences and ability to segment markets can give fabricators a competitive edge. Product differentiation is a result of innovation capability which can lead to the production of more efficient machines in an attempt to be different from other fabricators.

The foregoing describes some of the technological capabilities to be possessed by agro-allied artisans in the manufacture of machines and machine parts. This study proceeds to assess these capabilities from the perspective of artisans in the sector.

METHODOLOGY

The study was conducted in known major artisanal metal fabrication hubs located in Abeokuta, Ibadan, and Benin cities situated in Ogun, Oyo, and Edo States respectively in Southern Nigeria. The reverse engineering capabilities were streamlined into six groups; investment, production, linkages, innovation, marketing and resources capability from literature. Information on further constructs of these capabilities was collected by focus group discussion with the executives of the association of fabricators at a cluster in Ibadan, Oyo State. This was used to develop the questionnaire for the larger pool of respondents. The Cochran (1977) formula was used to determine the pool. At 95% confidence level and 5% margin of error, 384 agro-allied artisanal metal fabricators were selected as respondents to rate the capabilities. One hundred and thirty copies of the questionnaire developed from the constructs were purposively distributed in each State capital making a total of 390. A snowball sampling technique was used to locate the fabrication hubs and artisans in the States. These capabilities were rated on appropriate five-item Likert scales. Copies of the questionnaire were hand delivered and later collected. Interviews targeted at 10% of the respondents were based on open ended questions to further reveal more information on these capabilities. Thirteen respondents for interviews were selected from each State making a total of 39 respondents. Selected representatives of the associations of artisanal fabricators at the clusters were selected as respondents for the interviews.

RESULTS

Three hundred and twenty-six usable copies of the filled questionnaire were retrieved. Saturation for the interviews was reached at the eighth interviewee. The focus group discussions revealed seven constructs based on investment capabilities, 14 on production capabilities, four on linkages with customers, ten on marketing, nine on innovation capabilities and eight based on resources capabilities. These were rated as shown in Tables 1 to 6. Table 1 shows that the highest rated required capability is capability to carry out feasibility studies, which was rated high (4.41). This suggests that the fabricators are competent in conducting feasibility studies for their machine fabrication projects and assessing their viability and profitability.

Table 1: Investment Capabilities of Agro-allied Artisanal Metal Fabricators

S/N	Capability	Mean rating
	Investment capabilities	4.12
1.	Capability to carry out feasibility study	4.41
2.	Capability to identify different types of materials available	4.12
3.	Capability to source and recognize or purchase hardened material	4.11
4.	Capability to negotiate with suppliers or marketers for supply tools	4.11
5.	Capability to analyze procurement cost and budget	4.10
6.	Capability to procure and install working tools and equipment	4.09
7.	Capability to assess new technologies and materials	3.87

Key: None= 1, low=2, average=3, high=4, vey high =5.

Also, a feasibility study is carried out in order to analyze the functional operations of a machine. This is in line with Tornincasa and Vezzetti (2005) who reported that feasibility studies are to determine the vital operational parameters of a

device in order to give the potential user a well-defined structure and information about the machine.

The second highest rated required capability is capability to source, recognize or purchase hardened materials, which was also rated high (4.11). This indicates that most of the fabricators are knowledgeable in finding and buying hardened materials for their machine fabrication projects and ensuring their quality and durability. One fabricator said;

I do compressive strength test by continuously applying load on the metal to see if it deforms or not

The third highest rated essential capability is capability to negotiate with suppliers or marketers for supplies and tools. This was also rated high (4.11). This implies that most of the fabricators are proficient and experienced in negotiating with suppliers or marketers for getting supplies and tools for their machine fabrication projects and securing their availability and affordability.

The fourth highest rated vital capability is capability to procure and install working tools and equipment, which was also rated high (4.09). This means that most of the fabricators are capable and efficient in procuring and installing working tools and equipment for their machine fabrication projects and ensuring their functionality and reliability.

The fifth highest rated requisite capability is capability to analyze procurement cost and budget, which was also rated high (4.10). This shows that most of the fabricators are skilled and effective in analyzing procurement costs and budgets for their machine fabrication projects and managing their expenses and resources. The sixth highest rated required capability is capability to identify different types of material available, which was also rated high (4.12). This reveals that most of the fabricators are able to identify the different qualities of parts to be assembled and/or fabricated. A fabricator communicated;

With my over ten years' experience on the job, I can identify and estimate the adequate types and volume of materials suitable for a particular job at hand

The lowest rated required capability is to assess new technologies and materials, which was rated average (3.87). This suggests that this may not be a regular occurrence as the emergence of new technologies and materials may not be frequent.

Table 2 depicts the mean rating of the production capability of the fabricators also on a 5-point scale. The results showed that strong production capability is needed for the manufacture of machine and machine parts. The highest rated requisite capability is the ability to be able identify and recruit skilled personnel and add features to existing machine design, which were both rated high (4.33). This suggests that most of the fabricators are knowledgeable and have adequate experience in identifying and recruiting skilled personnel for their machine fabrication projects and adding features to existing machine design to improve their performance and functionality.

The second highest rated necessary capability is ability to carry out quality assurance procedures in fabricating machines (4.21), followed by capability for troubleshooting fabrication challenges (4.17), access, analyze and integrate new types of material in machine fabrication (4.16), and carry out the construction in-house (4.16) which were all rated high.

Other required capabilities were those to improve the machine production process (4.12), collaborate with enterprises skilled in engineering/technology (4.06) as well as ability to imitate both locally fabricated machines (4.06), which were all also rated high.

The fourth highest rated essential capability are those for debugging to eliminate and/or fix machine malfunctioning parts and involvement in detailed engineering/ technology disassemble which were both rated high (4.01). One of the fabricators commented on an occasion where one of the machines fabricated did not work as envisaged:

Few years ago, I built a yam pounding machine that was returned by a customer. The electric motor used lacked the capacity to turn the blade built for the machine for pounding. However, when we changed the motor to a more powerful one the machine worked perfectly

The fifth highest rated group of capabilities is inventory control capability and capability to maximize production rate, which were rated 3.97

and 3.94 respectively. This shows that the fabricators have high proficiency in inventory control and maximizing production rate of their machine fabrication projects.

Table 2: Production Capability

S/N	Capabilities	Mean rating
	Production capabilities	4.14
1.	Capability to identify and recruit skilled personnel	4.33
2.	Capability to improve or add features to the existing machine design	4.33
3.	Ability to carry out quality assurance on machines	4.21
4.	Capability for troubleshooting fabrication challenges	4.17
5.	Rate the skills or ability of the personnel to carry out the function in-house.	4.16
6.	Capability to access, analyse and integrate new types of materials in machine fabrication	4.16
7.	capability to improve the machine production process	4.12
8.	Ability to imitate	4.06
9.	Ability to collaborate with enterprises skilled in engineering/technology	406
10.	Capability for debugging to eliminate and/or fix machine malfunctioning parts	4.06
11.	Capability to imitate advanced engineering product and process	4.01
12.	Rate your involvement in detailed engineering/ technology disassemble	4.01
13.	Inventory control capability	3.97
14.	Ability to maximize production rate and capacity	3.94

Key Note: None= 1, low=2, average=3, high=4, vey high =5.

Table 3 reveals the ratings for linkages capabilities. Linkages with the supplier should have an influence on the quality of material supplied for fabrication. The mean rating shows that the quality of the materials supplied have a high influence (4.16) on the reverse engineering capabilities of the artisans. This suggests that the quality of material supplied is a critical factor for the fabricators, and that they have to ensure that their supplier provides them with high-quality material that meets their standards and specifications. A respondent remarked that;

I frequently visit the market to source for materials for my fabricating works, and I search for high standards in term of strength, durability and suitability to the kind of machine to be fabricated.

The second most influential aspect of the linkages with suppliers is the high influence (3.97) of durability of materials. This suggests that the durability of materials is an important factor for the fabricators, and that they have to ensure that their supplier provides them with durable materials that can withstand wear and tear of machine operations. A fabricator revealed in a focus group discussion that;

"Personally, I do prefer to use durable materials because I believe my work speaks for me anywhere my machine/product is used

The third most influential aspect of the linkages with the supplier is the price/cost of material/items, which also has a high influence (3.94) on machine fabrication. This suggests that the price/cost of material/items is a significant factor for the fabricators, and that they have to ensure that their supplier provides them with affordable and competitive prices/costs that fit their budget and profitability. One fabricator mentioned in an interview that;

I purchase the materials in large quantity to have price advantage. If I buy the materials in bulk, the seller gives me a discount and this may result in reduction in prices

The fourth most influential aspect of the linkages with suppliers is the influence on functionality of items (improved/multi-function), with a high influence score (3.82). This suggests that the influence of suppliers on functionality of items is a relevant factor for the fabricators, and that they have to ensure that their supplier provides them with functional and versatile items that improve their fabrication process.

Lastly, speed of delivery of inputs has a high influence (3.66). This suggests that the speed of delivery is a high influencing factor for the fabricators, and that they have to ensure that their supplier provides them with timely and reliable delivery that meets their deadlines and schedules.

Table 3 reveals that on-time payment was rated to have a high influence (3.99). This suggests that on-

time payment is an essential factor for the fabricators, and that they expect the customers to pay them promptly and fairly for their services and products. Speed of delivery was also rated to have a high influence (3.92). This suggests that the speed of delivery is an important factor for the customers, and that they expect the fabricators to deliver their orders quickly.

Functionality of items (improved/functions) was also rated to have a high influence (3.83). This suggests that the functionality of items is a relevant factor for the customers, and that they expect the fabricators to provide them with items that can perform multiple functions and improve their production and postharvest activities. Lastly, the rating of durability of materials used in fabrication was also rated to have a high influence (4.12). This suggests that the durability of material is a crucial factor for the customers, and that they expect the fabricators to provide them with rugged and durable machines that can have a long lifespan.

The foregoing provides an insight into the aspects that affect the linkages between the fabricators and their customers, and how they perceive and evaluate their customers' needs and preferences. It also reveals some potential areas for improvement or enhancement in terms of strengthening or optimizing the linkages between the fabricators and their customers, especially those related to functionality and payment. A respondent remarked that;

When customers pay on time it facilitates prompt product delivery and results in improving the functionality of machine fabricated

Table 3: Linkages with Customers

S/N	Statement	Mean
1	On-time payment	3.99
2	Speed of delivery	3.92
3	Functionality of items (improved/functions)	3.83
4	Durability of materials	4.12

Key Note: 1 = No influence, 2 = low influence, 3 = Average influence, 4 = high influence, 5 = very high influence.

Table 4 reveals the constructs on marketing capabilities of the fabricators. The capability to create mutual trust and commitment between partners was rated strong (4.26). Majority of fabricators reported having a strong influence from this. This suggests that the fabricators value the quality and stability of their relationships with their customers, suppliers, and other stakeholders, and that they strive to establish and maintain trust and commitment with them in order to market their products successfully (Jianhua *et al.*, 2022).

The second most influential factor for the fabricators is the knowledge of customer needs and machine specifications which was also rated strong (4.25). This suggests that the fabricators are customer-oriented and responsive to their needs and preferences, have a good understanding of the specifications and requirements of their machines and machine parts, and can tailor their products to meet their customers' expectations and demands. One of the fabricators mentioned in an interview that;

One thing I understand from customers in our environment here is that they always have a strong belief in what others have used before that has served well so a majority of our customers always place orders based on known machines that colleagues have recommended that are working perfectly

Table 4: Influence on Ability to Market the Reproduced Machine

S/N	Factors	Mean rating
	Marketing capabilities	3.35
I	Capability to create mutual trust and commitment btw partners	4.26
Ii	Knowledge of customer needs and machine specification	4.25
Iii	Capability in building and maintain long term relationship with customer	4.22
Iv	Capability to interact or communicate with the customers	4.13
V	Capability to compete effectively and to deliver customer values	4.02
Vi	Capability to penetrate market and adopt technology for market purpose	3.98
Vii	Capability to segment and target market	3.82
Viii	Knowledge of competitor	3.76
Ix	Capability to advertise and price products determination	3.25
x	Capability to each high technology demanding foreign market	3.15

Key: 1 = Very weak, 2 = Weak, 3 = Moderate, 4 = Strong, 5 = very strong

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The third most influential factor for the fabricators is the capability for building and maintaining long term relationships with customers, which was also rated strong (4.22). This suggests that the fabricators have a long-term perspective and vision for their business, and can retain and satisfy their customers over time (Zeeshan, 2019).

I contact and communicate with my customers often to know the condition of machine purchased from me and this creates mutual trust and understanding between us

The least influential factor for the fabricators is the capability to reach high technology demanding foreign markets, which was rated moderate (3.15). This suggests that the fabricators have some potential and interest in reaching foreign markets that demand high technology machines, but they may not have enough resources, capabilities, or strategies to do so effectively. Most advanced technologies are in high demand in many developed countries because of the high levels of technological know-how by receiving firms. However in developing countries low and cheap technologies may be the most sought after as reported by Adejuwon (2018) who discovered that band saws made in Nigeria were in demand in low-technology demanding neighboring countries such as Ghana and Cote D'Ivoire.

The second least influential factor for the fabricators is the capability to advertise and price products determination, was also rated moderate (3.25). This suggests that the fabricators have moderate skills and knowledge in advertising and pricing their products.

The third least influential factor for the fabricators is the knowledge of competitor which was rated high (3.76). This suggests that the fabricators have some awareness and information about their competitors. This may be obvious as most of the fabricators are located in hubs and are well known to each other.

These results provide an insight into the factors that affect the marketing capabilities of the fabricators, and how they perceive and evaluate their strengths and weaknesses in marketing their products. It also reveals some potential gaps or opportunities for improvement in terms of enhancing or diversifying their marketing skills and strategies, especially those related to foreign markets, advertising, pricing, and competition. Focus group discussion among the fabricators revealed some comments;

I have good knowledge of my customers' specifications and quality and I determine prices based on location of the customer placing the order. I have some customers from neighboring countries and their price varies

Table 5 reveals that the highest rated aspect of innovation capability for the fabricators is the capability to copy cutting edge machine design which was rated high (4.31).

This suggests that the fabricators indicated that they are skilled and proficient in reproducing advanced and modern machines and machine parts designs, so that they can keep up with the latest technology and trends in their field.

Table 5: Innovation Capability

S/N	Capabilities	Mean rating
	Innovation capabilities	3.91
i.	Capability to copy cutting edge machine design	4.31
ii.	Capability to produced more innovative machine design	4.13
iii.	capacity to make changes in the physical appearance, mater components	4.06
iv.	Capability to adopt new process or method in manufacturing machinery	4.00
v.	Capability to adjust design to production needs in diverse industrial sectors	3.87
vi.	Capacity to implement new marketing method to promote product	3.86
vii.	Capability to constantly search for new ways to adopt the design produce machine for novel	3.80
viii.	Capability to open new market for new machine design	3.76
ix.	Capacity to use R & D output to improve on machine to improve on machine design	3.39

Key: 1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = very high

The second highest rated aspect of innovation capability for the fabricators is the capability to produce more innovative machine design which was also rated high (4.13). This suggests that the fabricators are creative and inventive in producing

new and original machines and machine parts so that they can generate novel and unique solutions for their customers' needs and preferences. A respondent communicated during an interview stated on a fufu (a starchy dish made from pounded cassava) mixing machine;

Recently I fabricated a fufu mixing machine, which can produce fufu for one thousand people in an hour

The third highest rated innovation capability for the fabricators is the capability to make changes in the physical appearance, materials, components, packaging purposes and capability of machines which was rated high (4.06). These results imply that fabricators should have a high capability in changing the physical appearance of machines fabricated and add other features to the machine. This implies that fabricators should be highly effective and efficient in skill and knowledge of machine production.

The fourth highest rated aspect of innovation capability for the fabricators is the capability to adopt new processes or methods in manufacturing machinery which was also rated high (4.00). This indicates that majority of the fabricators have technical knowledge of using modern equipment and gadgets in reproduction of machines. This suggests that proficiency and skill is necessary in adopting and adapting new methods and processes in fabricating or reproducing machinery that function effectively and efficiently.

The lowest rated aspect of innovation capability for the fabricators is the capacity to use R & D output to improve on machine design, which was rated moderate (3.39). This suggests that the fabricators have moderate skills in using research and development output to improve on their machine design. This may have been rated lower than other capabilities because of the low level of educational qualification of the fabricators which may affect their ability to carry out research and development in the industry (Efunwole, 2018).

The second rated lowest expected aspect of innovation capability for the fabricators is the capability to open new market for new machine design, which was rated high (3.79). The third lowest rated aspect of innovation capability for the fabricators is the capability to constantly search for new ways to produce machines from new designs which was rated high (3.80). This implies that majority of fabricators should have a moderate capability to consistently search for new ways of adopting novel machine designs.

The fourth lowest rated necessary aspect of innovation capability for the fabricators is the capability to implement new marketing methods or strategy to promote products, which was also rated high (3.86). This suggests that the fabricators are skilled in developing strategies to penetrate markets and reach their target customers. One fabricator commented that;

Most of the machines fabricated are post-harvest machines and I observe the seasons of the farm products. For example, Rice is harvested between October and December every year so I always fabricate rice Sheller machine around June and August and display in front of my shop for sale.

Capability to adjust design to production needs in diverse industrial sectors was also rated high (3.87). These results provide an insight into the aspects that may affect the innovation capabilities of the fabricators, and how they may perceive and evaluate their strengths and weaknesses in innovation. It also reveals some potential gaps or opportunities for improvement in terms of enhancing or diversifying their innovation skills and strategies, especially those related to research and development, foreign markets, advertising, and pricing.

Table 6 shows the results of resource capabilities of the fabricators. The table reveals that the highest rated aspect of resource capabilities for the fabricators is the capability for troubleshooting fabrication challenges, which was rated high (4.20). This suggests that the fabricators are competent in solving problems and overcoming difficulties in their fabrication processes, and handle any unexpected or complex situations that may arise. Adejuwon (2019) mentions that efforts to fix bugs in machines fabricated can improve the innovative capabilities of fabricators.

The second highest rated aspect of resource capacity for the fabricators is the capability to combine knowledge and skill with available resources, capability in innovation design and manufacturing application and capability to identify and analyze material components for different jobs which were all rated high (4.13). This suggests that the fabricators are efficient and

effective in using their resources, and have a good balance of knowledge and skill to optimize their fabrication activities.

The third highest rated aspect of resource capability for the fabricators is the capability to maintain product standards and meet customer specifications which was also rated high (4.09). This suggests that the fabricators are proficient in reproducing advanced and modern machines and machine parts designs, and keep up with the latest technology and trends in their field.

Table 6: Resources Capability

S/N	Statement	Mean rating
	Resources capability	3.99
i.	Capability in innovative design and manufacturing application	4.20
ii.	Capability to combine knowledge and skill with available resources	4.13
iii.	Capability in innovative design and manufacturing application	4.13
iv	Capability to identify and analyze material components for different jobs	4.13
v	Capability to maintain product standard and meet customer specification	4.09
vi	Capability to maintain cost estimates and material quality of fabrication	4.05
vii	Capability to constantly use new technology to enhance quality of products (machine) and service (repair)	4.04
viii	Capability to source for imported material	3.17

Key: 1 = Very low, 2 = Low, 3 = Moderate, 4 = High, 5 = very high

The fourth highest rated aspect of resource capability for the fabricators, the capability to maintain cost estimates and material quality of fabrication was rated high (4.05). This suggests that the fabricators have capacity in costing the required material for the job at hand and maintain quality standard required by customers.

The fifth highest rated aspect of resource capability for the fabricators is the capability to constantly use new technology to enhance quality of machine which was also rated high (4.04). This suggests that the fabricators are skilled and knowledgeable in employing new technology for the advancement of their fabrication process. The capability to source for imported material was rated moderate (3.17). This suggests that the fabricators have limited potential in sourcing for imported material.

Table 6 provides an insight into the aspects that may affect the resource capacity of the fabricators, and how they perceive and evaluate their strengths and weaknesses in using their resources. It also reveals some potential gaps or opportunities for improvement in terms of sourcing imported materials.

CONCLUSION

The study reveals that fabricators possess strong reverse engineering capabilities overall, with the exception of certain areas in marketing, innovation, and resource capabilities. Specifically, limitations were identified in the ability to advertise and determine prices, reach high-technology-demanding foreign markets, utilize R&D outputs for machine design improvements, and source imported materials. These challenges were attributed to a lack of marketing skills, lower educational levels among fabricators, and insufficient linkages with foreign markets. Demands of machine specifications and troubleshooting from high-technology demanding markets may encourage fabricators to seek to increase fabrication capabilities to meet those demands and thereby improve on machine quality. To address these limitations, the study recommends targeted policy interventions, including enhanced marketing training, improved access to foreign markets, better resource sourcing mechanisms, increased R&D investment, and financial and technical support. By implementing these measures, fabricators can overcome their current constraints and achieve greater competitiveness.

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