UNIVERSITY OF NAIROBI

<u>SCHOOL OF THE ARTS AND DESIGN</u>

PRODUCT DESIGN SPECIFICATION FOR ARTISANAL ALUMINIUM COOKWARE: A CASE STUDY OF LANDHIES ROAD PRODUCERS

RESEARCH PROJECT THESIS

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DECLARATION

I **Samuel M.K. Nkuubi** do declare that this research project thesis is my original work and has not been submitted for a degree in any other university. The ownership of any intellectual property rights which may be described in this project is vested in the university of Nairobi School of The Arts and Design and may not be made available for use by a third party without written permission of the university which will prescribe the terms and conditions of such agreements.

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DEDICATION

To my wife and children for the unwavering support and encouragement for the duration of my study.

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ABSTRACT

The paper is a research project report based on a study on product design specification for artisanal aluminium cookware. The study makes emphasis on a case study of foundry and fabrication workshops along the Kamukunji metal work cluster along Landhies road in Nairobi County. Product design specification PDS is one of the core activities in ‘total design’, a method developed by Stuart Pugh to integrate the voice of a consumer in product design decisions. Product design specification is one of the methods employed in tracking the growth of a product using various constraining parameters. The constraining factors include design, product geometry, ergonomics, aesthetics, safety, product environment and product performance issues. The objectives of the study is based on the rational that production of aluminium cookware is done using rudimentary methods that lack controls to ensure quality product designs. Literature for the study was gathered through document analysis from published online journals and books. The sample size for the study was determined as 40 respondents from a target population of 300 registered informal workshop artisans. The instruments that were used in data collection include questionnaire survey, observational forms and checklists and photography. Reconnaissance study was conducted and the preliminary observations determined the structure of questionnaires to be administered. The study was exploratory sequential design that commenced with quantitative analysis expounded by a qualitative follow-up .Qualitative analysis was conducted by using themes derived from the research questions. Results from demographic data on gender distribution, skills acquisition and artisan specialization was presented on a table and analyzed graphically. The study established that product design specification is to a large extent not consciously considered in production of cookware. Design knowledge is mainly recorded in templates and prototypes and is not found in a written project design. This phenomenon compounded by level of artisan’s skill reduces the chances of capturing novel ideas that may have commercial significance thus preventing acquisition of patents. The study recommends an adaptation of environmentally responsible manufacturing to enable cookware products to meet international manufacturing standards.

Key words; Product design specification, Aluminium cookware, Informal cluster, Total design. Tacit knowledge

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LIST OF ABREVIATIONS

ERM: Environmentally Responsible Manufacturing

ISO: International Standards Organization

PDS: Product Design Specification

PDP: Product Development Process

1.0. CHAPTER ONE

1.1. Background to the study

In 1984 the Kamukunji Jua Kali association was established by its founders as a forum that would cater for the workers in the informal cluster. This association was the first of its kind and prevailed in catering for the needs of artisans within the cluster to date. Kenya's government acknowledged the existence of this informal cluster through a visit by the second president of the republic Daniel Moi in 1986 (Bull, Daniels, Kinyanjui, & Hazeltine, 2016). The president provided working shades along Landhies road in Nairobi County to protect the artisans from the hot sun. These events manifested into the official registration of the association in 1992. (Kamukunji Jua Kali Association 2013).

According to Bull et al., (2016), the informal workshop owners who learn their trade in metal working through apprenticeship face a myriad of challenges. The deficiencies in their trade are heavily entrenched in the approach to training which is non-formal. The products they make are usually approximations of existing or imported products such as aluminium cooking pots and potato chips cutters lids and spoons and pans.

Donaldson (2006); Akuno & Kidenda (2015), conducted studies on the informal metal fabrication workshops in Kenya. The two studies posited that unreliable record keeping presents a difficulty to track any further improvements or stylizations that are developed by members of the cluster. Wangare (2015) observed that the methods for preservation of knowledge in the informal workshops encourages loss of innovative ideas through artisans who leave the workshop due to various reasons. This results in depriving artisans of continuous upgrading that could be aided by learning from previous challenges or constraints. The artisans also loose the opportunity to implement the enduring best practices.

Ogola (2007): Mbuya, Odera, & Ng'ang'a (2003), observed that artisans at Kamukunji who majorly produce cookware rely heavily on out-sourced services for casting aluminium. The majority of artisans are not equipped with facilities that can determine the quality of aluminium used in casting items such as pots and cooking spoons. Awareness on environmentally friendly manufacturing methods is essential in the production of cookware. The increasing consciousness by industries on scarce material inputs and the resulting effect on the environment has developed awareness on the effects of gradual and indiscriminate consumption of materials. According to Gaustad, Olivetti, & Kirchain (2010), one method that can be employed to reduce material consumption in product design is recycling and repurposing. Attaining a satisfactory level for recycling requires an overhaul of systems used in handling materials. One unique approach is to develop unique alloy designs that have a capacity for an increased amount of scrap. Experimentation and thorough quality assessment are the only paths that can ensure new concepts for alloy designs are admissible in the manufacturing of items. This process can be expensive and time consuming. In the informal foundries in Kenya this is the case as demonstrated in a study by Wang'ombe et al., (2012), where quality of melt in aluminium furnaces is not standardized for any specific use in manufacture.

According to Osborn (2009), Artisans in the foundry workshops such as those in Nigeria prefer aluminium to iron as a material for cookware. Aluminium is corrosion resistant and can be melted without any reduction of mass. When compared to iron and steel it is melted at lower temperature. The metal can easily be recycled by using technology that is rudimentary and with comparatively cheaper sources of energy. Lee et al., (2013) observed in a study on designing an aluminium furnace in Zambia, that the common method of production of aluminium cookware used by artisans is sand casting. This is also the case in Kenya (Mbuya et al., 2003). The sand mould casting method of production requires considerable training by apprenticeship before an artisan achieves perfection with the skill (Siyanbola et al., 2012).

Seno et al., (2015), posited that die casting is a faster method of casting that entails pressing aluminium melt into metallic moulds when extremely hot, and with speed, and force. Overall, die casting achieves accurate dimensions and superior finish on surfaces, and forms produced are more durable and cannot be matched to methods like sand mould casting.

When producing aluminium cookware it is important to consider users of the product in the overall product development. According to Hansen & Andreasen (2004), the appropriate way of including the demands of customers in the design of a product is through product design specification (PDS).Products in which customer requirements are not embodied in the overall design are not profitable.

Østerås, Murthy, & Rausand (2005), established that advancements in knowledge and an increase in consumer expectations have resulted in the introduction of new products at an increasing pace in the market. Products such as cookware are becoming more sophisticated and have a shorter lifecycle. For artisans to endure in a dynamic setting where marketplaces are becoming universal and with increased competitiveness, they have to make improved and reasonably priced products. This phenomenon stresses the need for expert management and improvement of novel ideas for products. The main task is to efficiently reduce possibilities of failure in products such that an acceptable standard of reliability may be attained within a reasonable period of time and financial constrains (Østerås et al., 2005).

The main concern of this study is to establish if product design specification is consideration in the production of aluminium cookware by artisans at the Kamukunji cluster. The current study therefore attempts to ask pertinent questions regarding a detailed product specification guideline that will address the quality control practices at the foundry and fabrication workshops.

1.2. Problem statement

The potential challenges encountered in the production of cookware are related to the application of product design specification parameters. Methods of production or restyling of existing designs of cookware are not recorded and the best enduring practices remain as tacit knowledge. The artisans rely on old drawings and photographs that require experience to interpret, thus subjecting new and untrained entrants into workshops to long periods of apprenticeship under master artisans. (Obeng, Adjaloo & Amrago, 2013).

Informal foundry shops do not subject their aluminium cookware to usability testing Artisans are not conversant with the hazards related to the use of artisanal products. The workshops operate in a rudimentary manner and the idea of good quality is the acceptance of simple and passable functionality of a product (Donaldson, 2006). The human interface in the production of wares is not considered to be important. Workshop conditions are not ergonomically sound. Artisans hardly consider the design input by consumers in terms of affective characteristics.

Aluminium scrap as the main raw material for casting pots, spoons and potato chips cutter heads is sorted by eye selection which does not ensure quality melt. The sand casting process in use does not lend itself to repeatability when making identical forms or parts of cookware. Defects such as pores and cracks are exposed during machining and finishing processes. This increases the number of rejects thus making production costly .Production methods in the informal workshops experience lack of environmentally sustainable methods of production such as energy efficiency and advancement in green machining and finishing methods (Debnath, Reddy, & Yi, 2014). Artisans are not conversant with the hazards related to the use of artisanal aluminium cookware such as leaching which exposes users to harmful metals such as lead.

The absence of product design specification in the production of artisanal cookware limits the workshop owners from reaching a wide customer base. Much of the products are sold locally and are hardly acceptable in the international market. The absence of PDS in the growth of a design from the conceptual stage to production denies artisans a chance to capture or track innovative and creative production practices.

1.3. Purpose of the study

To propose product design specification for the production of artisanal aluminium cookware made by informal workshops.

1.4. Research questions.

1. Do the artisanal aluminium cookware exhibit design deficiencies?
2. What are the hazards associated with production of aluminium cookware?
3. Do the informal workshops have appropriate strategies in the production of cookware?
4. What are the standard product specifications for aluminum designs of cookware?

1.5. Research objectives

1. To establish the design deficiencies in artisanal aluminium cookware.
2. To assess the hazards associated with production of artisanal aluminium cookware.
3. To determine appropriate strategies in the production of artisanal aluminium cookware.
4. To propose standard product specifications for the design of aluminium cookware.

1.6. Rationale

The study intends to develop a mind shift of design issues from the traditional recycling paradigm to understanding the effects of recycling materials for product design specification.

1.7. Justification

The study will help workers in the informal production of cooking utilities to establish standard prerequisites that inform product design specifications. This phenomenon will ensure ease in acquisition of patents for innovations in the design of artisanal products. The result will encourage innovation that meets the need of both the local and international consumers.

1.8. Significance of the study

The study addresses the deficiency in knowledge experienced by artisans on advantages of product design specifications. The artisans mainly acquire their skills through apprenticeship as opposed to formal training. The study will enable the documentation of tacit knowledge inherent in informal workshop experts into coded information that can be accessed by new entrants in the informal industry.

1.9. Scope and Limitations of the study

The research only focuses on artisanal aluminium cookware thus limiting the study to informal foundry and fabrication industries at the Kamukunji cluster (Ref Appendices Figure 64), and those from input suppliers from Kariobangi (Ref Map Appendices Figure 66). The researcher is also exposed to health hazards experienced by the respondents at their workshops. This phenomenon will require prior meeting arrangements with the expected respondents. Access to the Kamukunji artisans is guided by permission from the welfare association whose policy stipulates that a registration fee must be paid to validate any research work (Ref Appendices Figure 67). The language spoken is Swahili which needs translation to analyze results. Budgetary constraints also played a major role in determining the number of cases that could increase data for the study (Ref Appendices Table 27). The study uses a combination of open ended questions to gather demographic data and matrix questionnaires based on the likert type scale, for data on the research questions. This approach results in restricting respondents to specific patterns of answering questions. The researcher chose this method owing to perceived lack of comprehension of the phenomenon under study by majority of the respondents.

1.10. Definition of concepts

The product design specification (PDS)

A paper sheet that captures the information acquired in the process of design or concept development for a chosen product. The design specification captures the fine points that will be needed for the product development to be successful. The product design specification creates a platform for undertaking all technical production steps. It guarantees that all the dynamics of production are clearly laid down and all interested parties provide their input (Pugh, 1991).

Product development process (PDP)

The techniques and systems enterprises or businesses employ in designing novel products and convey them to customers. Improvements and innovation in technology, the dynamics of conveying product designs to customers and the need for competitiveness demand for frequent production of new concepts (Hsiao & Chou, 2004).

Environmentally responsible manufacturing (ERM)

'A scheme that incorporates product and process design issues with issues of manufacturing production planning and control in such a manner as to identify, quantify, assess and manage the flow of environmental waste with the goal of reducing and ultimately lessening its impact on the environment while also trying to maximize resource efficiency (Robert B. Handfield, Melnyk, Calantone, & Curkovic, 2001)**.**

Cluster

A group of enterprises located in a single defined region or locale. The attributes of a cluster include groups of firms that are interdependent on the diffusion of knowledge for innovations and have close proximity to markets (Oyelaran-Oyeyinka, B. & McComick, 2007).

Jua kali

A direct translation of hot sun in Swahili. The phrase refers to non-formal businesses that rely on manual skills in manufacturing products. The phrase also includes apprentices, traders who work in an informal manner (Bull et al., 2016).

Artisanal aluminium cookware

Cookware made by craftsmen located in informal foundry workshops by the use of hand craft technique (Weidenhamer et al., 2014).

2.0. CHAPTER TWO

2.1. LITERATURE REVIEW

2.2. Design constrains

Knowledge preservation is key to determining the growth of design in the informal sector. Wangare (2015), in an examination of discernible knowledge management practices in Kenya established that new knowledge in the informal workshops is attained through reverse engineering and trial and error. The artisans make studies of both locally made and imported products which they dismantle and reassemble (Donaldson, 2006). Trial and error is avoided by the artisans because of resources such as material and time input that is costly. The main challenge not identified by the authors is how the deviations or restyling of imported designs is recorded and the impact of this documentation.

According to Wangare (2015), the informal sector artisans manifest their ideas majorly through sketching with limited effort in model making. However the study established that artisans barely kept any written records of some of the best and enduring practices. Only a small group of artisans retained dummies of what they intended to make. The informal workshops owners relied heavily on photography as the main medium for record keeping. Similarly, little effort is made at protection of intellectual property. Sharing of ideas, copying and imitation are so institutionalized that attempts to conceal and protect ideas bear little fruits. Moreover, their mode of production and operation impedes any attempt at concealment of ideas.

Donaldson (2006), conducted a study on the designing of products in countries whose industries are majorly informal like Kenya. The study established that no logical design procedures were adhered to. Initial stages in designing of products were not afforded any standards within the enterprises. Final choices of designs were not recorded or stored for future reference. Managers of the informal industries indicated that what is stored in their heads it terms of the structure and design process is enough. Therefore design templates and drawings could be done away with. The concentration of products from lager firms and the artisanal workshops were fabrications of existing designs. The craftsmen avoided challenges in creating new product concept.

Akuno & Kidenda (2015) ; Donaldson (2006), observed that the idea of original design in the informal clusters is developing close configurations of existing products through fabrication under limiting conditions. Few drawings existed to inform the structural design of a product. The drawings were not new nor were they consistent or true to the physical product they represented. Prototypes which are as a standard practice required for usability testing did not exist. The basic testing was only done to ensure the product is simply functional without considering other factors. The need for a rigorous design process was not given consideration because of the overall cost implications. The types of products made heavily relied on self-taught training and experience. For example, artisanal product designs were only made because of pure know how and that customers purchased them (Akuno & Kidenda, 2015); (Donaldson2006).

According to a study on informal metal working sector in Nairobi, Kenya by Bull et al., (2016), ideas for artisanal products hardly originate in the informal clusters. The workshop owners in the cluster pick ideas from products seen in local markets and trade fairs, suggestions from customers, manufactured items brought by clients for restoration or any other source. The innovation that commonly occurs is the development of techniques and processes that allow those in the cluster to create products that function as closely as the original. The product mix includes items whose origins predate ideas for intellectual protection such as cooking pots, aluminium ladles and potato chips cutters.

2.3. Information sources for design

According to Restrepo & Christiaans (2004) , suitable schemes are required to guide the designer during the first considerations made in the process of design. Individuals engaged in design must interact with sources of information. There is need for a more definite understanding of what inspires the need to access information. Information is important in the construction of a design problem which provides the designer knowledge on what information systems are needed to actualize specific tasks in the design process. The concerns that yield from the design process need to be presented as constrains and requirements. According to some designers Information use is sometimes motivated by the existence of design issues and requirements. For other designers the access to information is the trigger for generating design issues and requirements. The relevance and accessibility to information ultimately determines how it is used (Restrepo & Christiaans, 2004).

Expert designers are seen to solve design problems by the use of unconventional methods. They do not concentrate on problem formulation because this does not lead automatically to a successful product. Problem scoping is the most adequate process which collects information with emphasis on a directional approach and working only with priorities. Processes of structuring and formulating the problem are frequently identified as key features of design expertise. Generating a wide range of alternative solution concepts is an aspect of design behaviour which is recommended by theorists and educationists but appears not to be normal practice for expert designers (Dorst & Cross, 2001).The informal workshop artisans can be treated as expert designers because of the tacit knowledge in production of cookware. They seldom follow the normal design path to production .The artisans instead work through reverse engineering and iteration to achieve items that function as closely as the imitated versions.

2.3. Aesthetics

According to Blijlevens et al., (2012), the presence of particular attributes in the design of a product such as tonality of hue or form can result in thought processes and sentiments that affect the assessment of visual appeal. Zhai, Khoo, & Zhong (2009), observed that products that exhibit aesthetic merit immediately gain meaning and purpose in the improvement of their overall design. The products should also appeal to buyers both in terms of structural characteristics and also the human emotions and behavior. Concepts or ideas for products that are able to adapt to human emotions in specifications for the design of a product are ideal instruments for advancements in the design of a product. According to Zhai et al., (2009), what is important in the integration of human emotions in the design of products is the adoption of 'Kansei knowledge'. A procedure which entails 'mapping between elements of product design and affections attributed to human beings'. Aesthetics is only perceived in the physical attributes of cookware at the foundry workshops in Kamukunji .The consideration of human emotions in the overall cookware design is of secondary importance.

2.4. Geometry Specification and verification standards

Srinivasan (2008), observed that product geometry specification in industry is dominated by determining the area or volume occupied by a product, the amount of variation that is allowed in measurement or any other characteristic of a product, and standards for finishing product surfaces. The foundation of these standards existed before the age of information. These standards are important and unavoidable regardless of whether designs are drafted manually by the draughtsman or electronically by computer aided design software. The reason for this argument is that the design specifications are supposed to be easily interpreted by individuals participating in the design process, production and maintenance of the products. These standards will still be important even in situations where we have a single system for computer aided design. Designer and any other person engaging in the stages of products lifecycle should be able to make inferences or decipher the product design specifications (Srinivasan, 2008).This study indicates that design features of any product should be easy to interpret. The knowledge on a particular design such as that of casting aluminium cookware should not be accessible only to the experienced artisan.

In a study by (Radford, Harari, Northway, & Kroop, n.d.)Radford, Harari, Northway, & Kroop, (2015) in Zambia on causes of defects on aluminium pots when they are dropped posited two reasons for this occurrence. On one hand there is a probability that the pot designs were initially meant to use iron instead of aluminium for casting. Secondly defects associated with the casting process were found to play a minimal role in the shattering of the legs on the base of aluminium pots. These defects included air bubbles in the melt and surface finish. The study established that one method that can reduce the rate of failure in the casting process is improved the dimensioning of the pot stands. Recycling aluminium did not lead to impurities that resulted in the defects. This phenomenon also affect the quality of cookware dimensionality in the informal workshops.

2.5. Environmental constrains

The insights from authors about challenges in developing a safe working environment as a factor in production has been made explicit. According to a study on Regulating the operations of the informal cluster undertakings in Nairobi for sustainability development goals by Ouma (2010), planning policy mediations will develop organized use of scarce space and secure areas for locating informal enterprises. This will also develop the aesthetic quality for the chosen business locale. The initiative to solve the lack of sufficient space for informal firms will provide a conducive environment for business. The study has focused on securing limited urban space for artisans but details on the ideal safe working environment for artisanal workshops have not been clearly stated.

2.6. Environmentally responsible manufacturing

Handfield,et al.,(2001), posited that any global manufacturing company must pay attention to environmental performance. One of the forces leading to this occurrence include the reduction of costs through waste management and disposal. Many governments are also increasing protocols and the potential for positive and negative publicity. Thirdly customers are developing an increasing preference for goods that use environmentally responsive designs and processes. There is also the dawn of ISO14000 which places great importance on international principles for compliance to a sustainable environmental. (Rounds & Cooper, 2002) Advocate for the inclusion of environmental and health concerns in the manufacturing of products. (Ref appendices table 29), is an example of a taxonomy that captures manufacturing stages and environmental constraints that need consideration. The major concerns are the levels to which the design of products affects material consumption. The taxonomy also pays attention to sustainable manufacturing methods. The taxonomy develops parameters for efficient use of materials and waste disposal from manufacturing processes. The local foundry shops at Kamukunji need to outline the challenges in manufacturing and develop methods of manufacturing that include environmental and health issues.

2.7. Health Hazards

Weidenhamer et al., (2017), investigated the leaching characteristics of low-priced aluminium cooking pots acquired from ten countries in Asia Central America and Africa, the cookware made by local artisans were in the past not recognized as means of exposure to lead and other metals. The study carried out an experiment by performing simulated cooking whose result was the leaching of 1 to 1426 micrograms of lead per every portion from fifteen items bought from eight countries. Some of the portions exhibited the presence of cadmium and arsenic at levels that were potentially not safe for human consumption.

The projected exposure to aluminium on every served portion overrides the recommended maximum intake for forty of the forty two aluminium items that were tested.

A D Semwal et al., (2006) ; Neelam, Bamji, & Kaladhar (2000), in a study on leaching of aluminium utensils developed a new insight to safety precautions in the use of aluminium utensils. The results of the experiment in the study demonstrated that cooking in pots made of aluminum significantly adds to the total daily intake of aluminium through foods that have a considerable level of acidity. Rice and wheat contributed less aluminium as compared to legumes and pulses. Observations from the study deduced that the leaching of aluminium is also contributed by the level of acidity in the spices and raw food. Spices are a common ingredient in the cooking process. Other factors include the period of time the cooking pot is exposed to heat and the alkalinity of the food. The study recommended that anodized cookware is the most appropriate to use because it is not affected by acidic foods. Artisans from the cluster at Kamukunji may need to engage users of artisanal cookware in determining the appropriate types of food that can be prepared by using artisanal cooking pots.

Following a previous study by Weidenhamer et al.,(2014), of cookware from a single African country, Cameroon, artisanal aluminum cookware that is made from scrap metal released significant quantities of lead. Twenty-nine samples of aluminum cookware and utensils manufactured by local artisans in Cameroon were selected and analyzed for their potential to release lead during cooking. The Source for scrap materials for this cookware included such as construction materials engine parts, radiators, and cans. The lead content of this cookware is relatively low (b1000 ppmby X-ray fluorescence), however considerable quantities of lead, as well as cadmium and aluminium were released from a reasonable number of specimens using dilute acetic acid extractions at boiling and ambient temperatures. Potential exposures to lead per serving were approximated to be as high as 260 μg. This quantities can lead to severe health hazard. The study concluded that, aluminum and cadmium can migrate from this aluminum cookware during cooking and enter food at levels beyond recommended public health guidelines. This results support the need to regulate lead content of materials used in the production of pots. Artisanal aluminum cookware may be a major contributor to lead poisoning in most of the developing countries (Weidenhamer et al., 2014b).Informal workshop artisans may lack the capacity to conduct efficiency and usability performance tests on products before disbursement to consumers.

2.8. Training

According to a study by Ogola (2015), on knowledge in metal working, the type of training of an artisan is not a direct function of the standards of products that are manufactured by artisans in the informal sector. The study revealed that desired product quality is not accomplished all the time by all paths of training. Delivery of products on schedule is not achieved always by the respondents in the study regardless of their level of training. Therefore, the key areas of product development in the metal fabrication sector that will ensure quality products in desired magnitudes and on a desired schedule are product design, material and choice of equipment , production scheduling and quality assurance. Hence these areas should inform the path of technology diffusion to the informal sector (Ogola, 2007).

2.9. Aluminium scrap selection

Quality in foundry workshops is aided by appropriate control of inputs, and sound equipment, processes used and standards to which the parameters defining the processes can be controlled. Following a study on aluminium foundries conducted by Elahetia (2013) in Nairobi, all the workshops used aluminium scrap metal as their basic raw material. The selection of the scrap metal was conducted manually with no consideration for empirical approaches in the overall selection. The foundry shops were deficient in equipment such as a spectrometer or any other equipment that has the capabilities of classifying the qualities of materials with regard to elemental structure. Out of the foundries in the study two performed the sorting of aluminium qualities by visual inspection. The scrap aluminium was classified based on their previous use. For example car engine parts such as pistons and cylinder heads were heaped in one stack. Alloy wheels and car parts with a similar composition of aluminium were placed in a separate heap. Despite this separation of metal qualities, the melting process combined all the different compositions of metal in one furnace (Ref Figure 1). The process of sorting out the different aluminium qualities was only done to facilitate cleaning and determining their weight (Elahetia, 2013). According to Mbuya et al., (2003), the quality of castings produced locally is inferior to the varieties acquired through importation. The majority of the foundries in Kenya rely on pure luck to make quality castings.

Figure 1: A cupola filled with scrap aluminium from vehicle parts
Source: https://benistoves.wordpress.com/

Mbuya et al., (2003), established that the informal sheds of Kariobangi in Nairobi , scrap selection was determined by the size of individual pieces .The artisans could also categorize the scrap as ‘hard’ or ‘soft’ aluminium. ‘Hard’ aluminium constituted parts of engines such as pistons and sump guards. The soft variety of aluminium was derived from items made from wrought aluminium such as paneling for windows and furniture. Although the ‘Hard’ aluminium variety was the most appropriate for casting, ‘soft’ aluminium was added to the melt when the consistency of the hard variety resulted in undesirable hardness. For the two categorizations of aluminium a reliable chemical structure is mandatory. The absence of best practices in the recycling of aluminium foundries explains some of the defects experienced during the casting process. This information is crucial in creating an appreciation of the fundamental challenges associated with lack of controls in the type of scrap used on cookware production (Mbuya et al., 2003).

The major source of aluminium used for casting in other African countries such as Nigeria includes worn out utensils and other disposed products. These aluminium is recycled by melting scrap in locally assembled furnaces that are earthen. Crucibles for holding the melt are also made locally. The main source of fuel is acquired from biomass. The melt from the furnace is poured into molds made from soil or clay to take the shape of a desired product such as cooking pots of different capacities. The artisans have also integrated custom made products whose shapes are dictated by their customers. The artisans in the cluster indicated that customers contribute ideas that contribute to innovation through their commissions for unique products. As a result of deficiencies attributed to the choice of raw material some containers made of recycled aluminium may not withstand frequent use and are vulnerable to breakages (Siyanbola et al., 2012).

2.10. Casting aluminium pots

In a study by Macgaffey & Macgaffey (2015), in Ghana a chosen design of aluminium or 'cauldron' acts as a model used to prepare the sand mould for casting. The finest earth derived from termite hill is encased in a frame constructed with wood. The shape of the pot usually consists of a moderately sized waist and a wide opening mouth (Ref Figure 2). The complicated nature of the pot's shape demands for several molds. Because the pot has a waist and a flared mouth, the frame is made in three parts and the chosen model is cut hallway in a lateral or vertical fashion. After the artisans completely fill the mold with soil, a delicate process of opening the mold is done. The model is then removed and interior surfaces are smoothened and dusted with a chalk like powder then the frame for the mould is assembled for a second time. The aluminium melt is poured into channels located at the top of the mold. The casting process requires skilled labour and cooperation from artisans performing the steps in casting (Osborn, 2009). After the melt cools and hardens in the mould, the wooden frame is disassembled then the mold is broken revealing the cast pot (Ref. Figure 3). The cast form is further smoothened by filling any rough edges and breaking off protruding channel shafts. The largest aluminium pot can have a capacity of thirty-five litres (Ref. Figure 2). The entire team of artisans can cast four to five pieces in a single day. The two authors indicate that the knowledge of casting is tacit and only the expert and apprentices can access this skill.

Figure 2: Women carrying large capacity cauldron
Source: https://benistoves.wordpress.com/

Figure 3: Cast pot broken away from sand mold

Source: https://benistoves.wordpress.com/

2.11. Foundry production capacity

Following a survey by Wang'ombe et al.,(2012), conducted with an aim of assessing the level of quality control and determining the categories of foundry industries in Kenya. Forty five foundries that use aluminium as the main material were placed under study. These foundries were using aluminium scrap as a raw material. Three classification of foundries were arrive at and were termed as large scale, medium scale small scale and *jua kali* foundries. From the foundries under study 9.1 percent of the local foundries were classified as jua kali. The attributes of *jua kali* industries include the use of temporary sheds. The furnaces are locally fabricated and use oil as fuel. The melting did not employ a crucible making the melt vulnerable to contaminants. The workshops had a capacity of six workers and safety mechanisms and environmental conservation were not prioritized. Casting technology was acquired informally by apprenticeship of workers was through apprenticeship. Molten metal was not treated by application additives, degassers or fluxes were not applied in the melt and. Sand mould casting was the preferred technique and did not achieve accuracy when manufacturing many identical forms.

2.12. Ergonomics

According to Sagot, Gouin, & Gomes (2003), challenges that are associated with lack of good design on any product that does not consider man as a unit for measuring safety needs and reliability performance, include manufacturing of products with inferior quality. The ergonomist being an important player in the design of a product works with designers to ensure that the human interface is considered in design decisions. The ergonomist advises the designer on the characteristics of the product user so as to design products that are adapted to the ways individuals operate .The ergonomist also considers the output of a design in terms of affective nature of the human an in matters pertaining to safety (Sagot et al., 2003). The products made in the informal foundries should consider safety issues so as to allow for an environment where products are efficiently manufactured to reduce overall cost.

According to Beevis & Slade, (2003), the primary concern for ergonomic principles is to ensure an improvement of the performance of man or of man - machine systems. There is great need for determining and measuring this improvements in terms of financial benefit. Determining the value of an ergonomist in a design team only from a financial point of view is not necessary. Other specialist in a product development team such those concerned with energy, material requirements and dynamic performance of a product should be educated on the input of a ergonomist to avoid the self-justifying attitude on financial implications (Beevis & Slade, 2003). This scenario is replicated even in informal workshops where only passable functionality is an indicator of a successful product.

2.13. Theoretical framework

The study is based on the premise that giving ‘total design’, to production processes and quality of materials improves product viability and effectiveness. According to Stuart Pugh (1991), a product design specification is an indispensable means of control that permits the manifestation of a design of a successful product concept. The writing of a product design specification must be comprehensive and sufficiently easy to interpret. The kind of evaluation that is done at the end of a design process should match with the product design specification. An ineffective design specification results in an unsatisfactory product that will not meet the needs of the market place. However having a properly constituted product design specification does not necessarily accomplish a satisfactory product but enables attainment of set goals for the design. PDS is one of the five core activities under 'total design'. Total design includes four other activities such as identifying the needs of the consumer, designing of concepts, and design detail, manufacturing and identifying the performance of a product in the market.

According to Otto and Wood (2001), the periods that preceded the industrial revolution were characterized by artisans being in close proximity to their consumers. The products were also not sophisticated and the producer handled the needs of the customer directly. This means that the producer could address the needs of the customer directly. With the advent of specialization by producers, separation from the consumer sufficiently increased. The observation was that this specialization in particular disciplines have led to decision making that does not coincide with the needs of the customer. In the Kamukunji cluster workshops artisans are in close proximity to the consumers who buy cookware directly from traders within the cluster. The workshop owners therefore have more opportunity to articulate the needs of the consumer in product design specifications.

According to Stuart Pugh (1991), if a proficient or skilled craftsman is to design a product without an all-inclusive product design specification, the designer will inevitably try to solve any unforeseen considerations on an individual basis. When this considerations vary with the actual needs of the consumer then the skilled artisan will be designing an impractical product.

2.14. Conceptual framework

The research is framed on the relationship between product design specification and its impact on the quality of artisanal aluminium cookware produced in artisanal industries (Ref Figure 4) the production process for artisanal products should be designed to fit global consumer market.

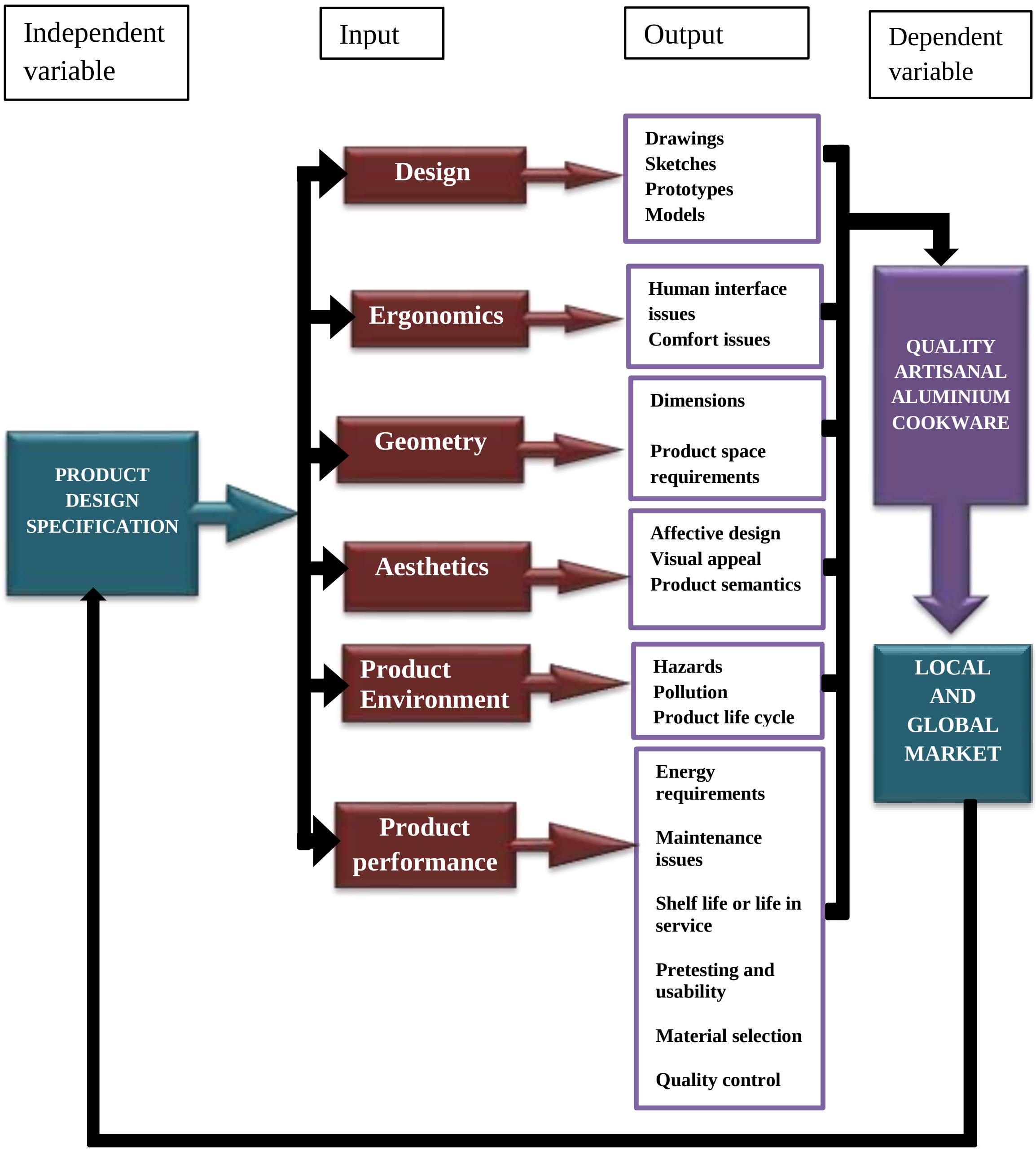


Figure 4: Conceptual framework for product design specification
Source: Developed from Stuart Pugh (1991)

3.0. CHAPTER THREE

3.1. METHODOLOGY

3.2. Research type

The research project employs a mixed methods design chosen for the descriptive survey study. The data will be collected using questionnaire survey as the main instrument. Particular cases demand observational forms, checklist and photography when assessing qualities of artisanal cookware products. The choice of the research design was preceded by a reconnaissance visit to the Kamukunji Jua kali Association office and selected workshops. The hierarchy of the Kamukunji Jua kali Welfare Association provides information on the history of the association. The remaining respondents include workshop owners with experience in foundry and fabrication of aluminium products.

3.3. Population

The target population for the study is 300 registered Jua Kali artisans at the Kamukunji cluster. These include Key informants who form the hierarchy of the Kamukunji Jua kali welfare association. The key informants were chosen because of the wealth of information in their long service. Due to impracticability of covering the entire target of accessible population, the sample units chosen mainly included artisans dealing purely in aluminium cookware manufacturing.

3.4. Sample size

The sample size for this study will be administered by the level of conviction that the nature of the data collected is representative of the attributes of the total population.

The model, na = (n x 100)/re%, supported by Saunder, Lewis and Thornhill (2007), cited in (Obare, 2015)was applied in the estimation of the actual sample size for the study in question, where;

n - The actual sample size

na - The lowest estimated sample size

re% - The estimated rate of response conveyed as a percentage.

na = {(1/10 x 300) x 100}/75 40 respondents

3.5. Sampling procedure

3.5.0. Snowball sampling

The research intends to find initial subjects with desired attributes. In the case of the research workshop owners dealing with aluminium cookware. This workshop owners will guide in finding other subjects with similar attributes to achieve the required cases (Mugenda and Mugenda 1999).

3.6. Data analysis

The study is an exploratory sequential design that is characterized by an initial quantitative analysis which is expounded by employing a qualitative follow up (Meissner, Creswell, Klassen, Plano, & Smith, 2011). After the questionnaires and checklists have been administered the data will be coded and analyzed qualitatively for non-empirical analysis because the research is dealing with a case study. The study intends to find information on awareness of product design specifications to establish useful insights that inform recommendations and inferences. Photographs from the case study will be analyzed by using QDA Miner, a mixed-methods qualitative data analysis software. Demographic data on the sample population will be assigned numbers and analyzed quantitatively.

3.7. Logical frame works

The (Ref Table 1) below presents the methodology that would be employed with regard to the data needs which are informed by the research questions and objectives. The table also underscores the expected output and outcomes of the study

Table 1: Logical framework

Research question	Research objectives	Data needs	Outputs	Methodology Research tools	Outcome
Do the artisanal aluminium cookware exhibit design deficiencies?	To establish the design deficiencies in artisanal aluminium cookware.	Drawings Project design	Specification of designs based on drawings and project designs	Interviews with key informants document analysis	Collection of product history and development procedures
What are the hazards associated with production of aluminium cookware?	To assess the hazards associated with production of artisanal aluminium cookware.	Toxicological information. Workshop safety procedures. Cleaning and sanitation approaches. Environmental impact assessment.	Specification of materials and production methods according to potential hazards.	Structured Interviews With workshop owners. Document analysis. Desktop research.	Identification of hazardous sources of raw materials. Internationally accepted standards of production. Environmentally responsible manufacturing processes.
Do the informal workshops have appropriate strategies in the production of cookware?	To propose standard product specifications for the design of aluminium cookware	Quality assurance Procedures. Usability testing Methods of sorting scrap material.	Level of facilitation material Scanning equipment	Interviews Observation Photography Document analysis. Desktop research	Categorization of informal workshop
What are the standard product design specifications for aluminum designs of cookware?	To propose standard product specifications for the design of aluminium cookware.	Geometry Calibration methods Product performance Aesthetics Ergonomics.	Methods of rating a product. Approaches to production. A scheme for environmentally responsible manufacturing methods	Interviews Observation forms and checklists Photography Document analysis	Strict separation methods following material properties and intended use. Categorizing production methods and environmental impact

4.0. CHAPTER FOUR

4.1. ANALYSIS PRESENTATION AND INTERPRETATION OF FINDINGS

4.2. Introduction

This section of the study is an examination and explanation of findings of the study in question. The methodology used in the study guided and determined the nature of the findings. The data collected through questionnaire survey, observation forms and checklists is analyzed quantitatively followed by a qualitative analysis. The questionnaires are informed by the research study objectives .The responses have been presented according to themes guided by research questions. The research set out to establish the four objectives of the study as outlined in chapter one of the research report. From the target population of 300 a sample size of 40 respondents was achieved. The interviews were administered on 27 respondents out of the expected sample size of 40 respondents. The 27 respondents represent 67.5% of the sample size which was adequate for analysis and drawing inferences.

4.2. Information on case study

The key informants included three members of the leadership hierarchy of the Kamukunji Jua Kali welfare Association (Ref Appendices Table 28) and a veteran artisan who provided vital information on contact addresses for input suppliers at the informal cluster. Kariobangi light industries, Industrial Area in Nairobi County were identified as the main locations for casting aluminium pots while fabrication of sheet aluminium cookware was conducted at the sheds bordering Landhies road (Ref Map Appendices Figure 63 and 65). The vice chairperson who serves as the treasurer of the Kamukunji Jua kali association presented insights to the mode of operation and workings within the cluster. All the three members of the association's hierarchy indicated that much of training on fabrication was conducted at the National Jua Kali Demonstration Centre in Kariobangi Nairobi County (Ref Map Appendices Figure 65).

4.3. Demographic characteristics

(Ref Table 2) presents the profile of respondents with regard to specialization, gender and range of products manufactured or used by customers. The aluminium products manufactured by casting shops range from car engine parts, measuring equipment and aluminium cookware, components of food processing machines such as meat mincers ,potato chips cutters, and decorative fixtures.

Table 2: Respondent profile

Respondent specialization	**Population**	**Gender**		**Aluminium Product Range**
		male	female	
Sand casting	5	5	0	Cooking spoons ,weighing scales, meat mincers, cooking pots, chips cutter heads and levers, shallow frying pans, cooking basins, scoops, servers, maize shredders, fruit juice squeezer
Die casting	4	3	1	Frying plate, gate finials and floral decorations, Flat disc frying pans, vehicle engine parts, gas cylinder grill, juice squeezer
Sheet fabrication	7	5	2	Institutional boiling troughs, cooking basins, deep frying troughs, scoops and servers, milk cans, quantity measures, institutional Plates and serving troughs.
Cookware distributers	6	2	4	Cast cooking pots, spoons ,scoops frying pans, maize shredders, shallow frying pans,
Food sellers	3	1	2	Sheet aluminium boiling troughs and pots, cast aluminium pot, scoops and ladles.
Household users	2	0	2	Aluminium frying disc pan, sheet aluminium boiling pot, scoops and ladles, gas cylinder grill.

The 16 respondents representing 60% of the interviewed population in the aluminium casting workshops and sheet aluminium fabrication shops were unable to clearly define the capacity of their workshops as being small, medium or large. All the respondents indicated that their workshops are jua kali meaning that they are located in temporary sheds and methods of production are basic or rudimentary. The graphical presentation (Ref Figure 5), is a pie chart showing the percentage representation of the population of respondents in the overall study.

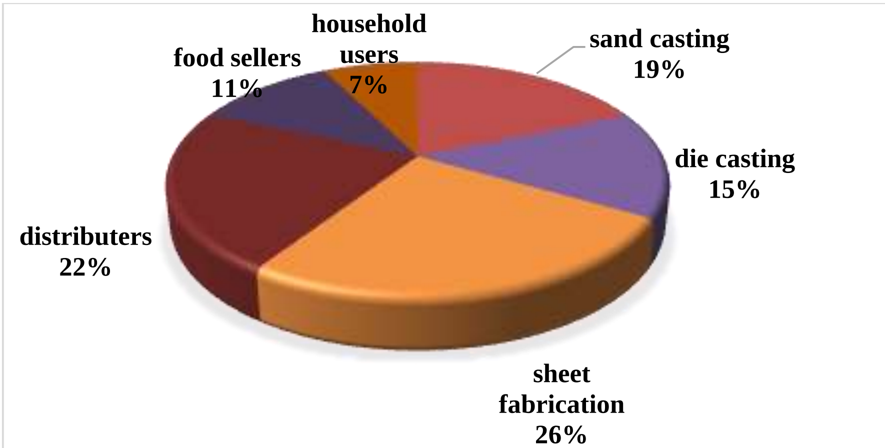
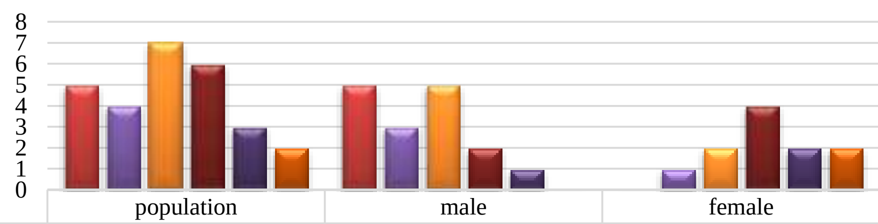


Figure 5 : Percentage population of respondents



	population	male	female
sand casting	5	5	0
die casting	4	3	1
sheet fabrication	7	5	2
distributers	6	2	4
food sellers	3	1	2
household users	2	0	2

sand casting die casting sheet fabrication distributers food sellers household users

Figure 6: Population and gender distribution of respondent

Table 3: Respondent's skills acquisition route

Respondent Characteristics	Population	Workshop position		Skill acquisition route	
		Owner	Assistant	formal	apprenticeship
Sand casting	5	4	1	0	5
Die casting	4	3	1	0	4
Sheet fabrication	7	4	3	2	5
Cookware distributers	6	3	3	1	5
Food sellers	3	1	2	0	3
Household users	2	none	none	none	none

From the demographic characteristics of the respondents (Ref Table 3 and Figure 6) it is clear that the common route for training was apprenticeship where an artisan works under a master craftsman until the required skill is achieved. From the 9 respondents in the sand and die casting workshop, one workshop owner was an entrepreneur with previous training in accounting. The entrepreneur employed skilled artisans to perform sand casting and had no formal training in the trade. Two workshop owners from the sheet fabrication received basic training on fabrication from National Jua kali Demonstration and Training Centre Kariobangi (Ref appendices Figure 65). Some of the previous employment engagements cited by respondents include driving masonry, restaurant jobs, automotive industry and accounting.

4.4. Do the artisanal aluminium cookware exhibit design deficiencies

The workshop members in the aluminium casting and aluminium sheet fabrication represent 60% of the respondents interviewed. All artisans in the workshops provided no tangible evidence of the use of freehand drawing or technical drawing in the design for the cookware items manufactured. Cookware distributors who represent 22% of the respondents also cited no need for having drawings for cookware designs. One of the distributors running a sheet aluminium sheet metal spinning machine observed that the milling machine has molds from which specific sizes of plates can be pressed on to shape plates and trays. According to the distributor all that is required to make the plates and trays was an appropriate mandrel and thus no need for sketches. All the cookware distributors indicated that workshop owners had templates for production of aluminium sheet fabricated cookware and models of cookware for the casting process.

Three respondents in sand casting workshops agreed that there is need for having drawings for the cookware they make. The reasons for this is that when training apprentices it takes a long period of time to demonstrate the basic steps in production. From observation done through photography the only evidence of a design scheme were templates which acted as guides for fabricating pots from sheet metal. The artisans provided no means of determining the measurements on the template in a quantifiable way. The templates were made from either galvanized and aluminium sheet metal. Galvanized sheet metal was most preferred because of remaining flexible and non-corrosive for many years. All the sheet fabrication artisans indicated that Aluminium templates do not last long as the metal is malleable and can easily be deformed by small amounts of stress. (Ref Figure 7.).

Figure 7: Comparison of aluminium and galvanized steel template

Source: Author

(Ref Figure 8) presents the response rate in terms of methods employed in the generation of ideas for cookware.

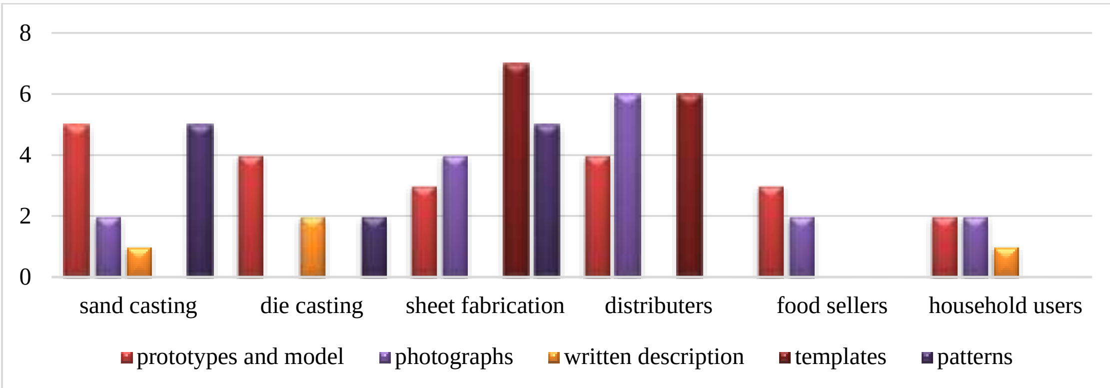


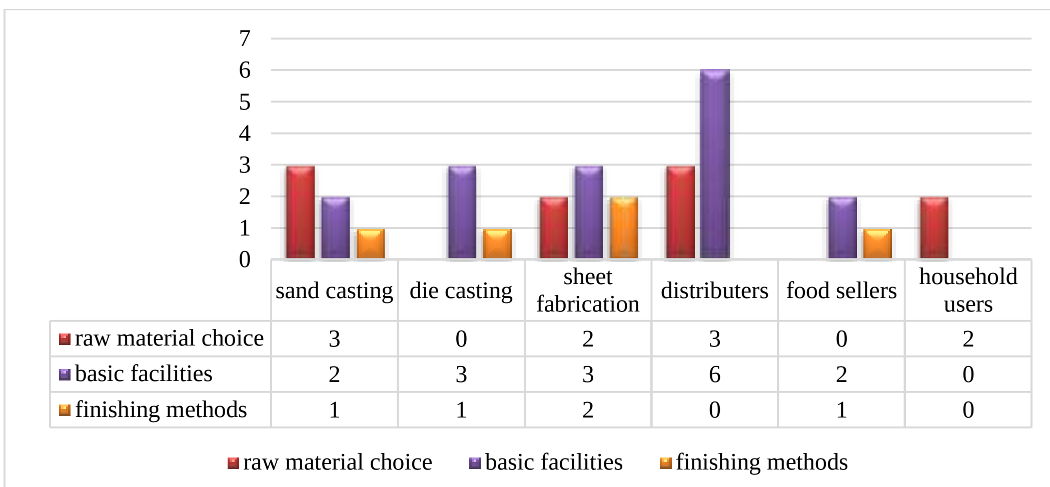
Figure 8: Respondent opinion on methods of recording design ideas

The sand casting artisans who represent 19 % of the respondents indicated that there was no urgent need for the preservation of the best practices in a written form or document. The main reason behind this attitude was that competitors may copy their ideas because in written form it can be shared easily. Foundry shops performing the casting process only had prototypes from which molds were prepared. The protoypes or models were stored in a manner that exposed them to elements that cause corrosion (Ref Figure 9.).

Figure 9: Models used for making casts
Source: Author

Die casting artisans who represent 15% of the interviewed respondents relied upon pre-existing dies that have produced successful products. The die casting workshop owners acknowledged the fact that developing a die for casting aluminium takes a long period of time,expertise and approppriate workshop facilities . None of the workshops had the capacity to design and make dies from hardened tool steel. Sand casting process relies on accurate molds made from fine sand compacted in wooden or metalic frames (Ref Figure 10.). According to the sand casting respondents representing 19% of the interviewed sample, the quality of sand and knowledge of compacting the sand into perfect mold is the main requirement for successful casts.

Figure 10: Sand casting molds and die casting moulds.Source: Author



	sand casting	die casting	sheet fabrication	distributers	food sellers	household users
raw material choice	3	0	2	3	0	2
basic facilities	2	3	3	6	2	0
finishing methods	1	1	2	0	1	0

Figure 11: Respondent opinion on causes of cookware defects. Source :author

The respondents gave their observations on the likely causes of defects on cookware products.From (Ref Figure 11), 16 respondents of the interviewed population, indicated that the lack of sophisticated facilities and use of rudimentary methods of production are the major causes of defects on products. Five respondents indicated that finishing methods like filing or buffing were only responsible for exposing underlying defects. Some of the defects identified through observation of photographs include,open pores and tearing (Ref Figure 12),and uneven casts resulting in irregular forms, flaking of surfaces, and fissures (Ref Figure 13).Some of the examined cookware had parmanent stains from car battery acid used in the polishing process (Ref Figure 14).

Figure 12: Maize shredder with cracked surface and boiling pot lid showing and fissures

Source: Author

Figure 13: Cookware showing pores and repaired tearings

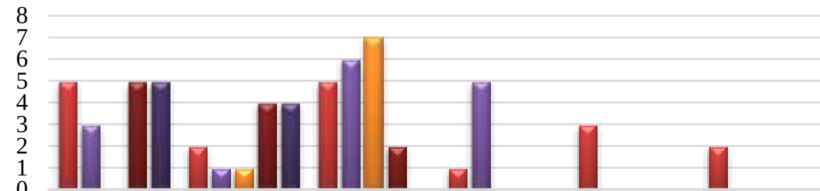
Source: Author

Figure 14: Permanent streaks of acid stain marks on cookware

Source: Author

4.5. Hazards associated with production of aluminium cookware

(Ref Figure 15) is a graphical analysis of the rate of response to the question on hazards that result from cookware production at the aluminium casting workshops and sheet fabrication shops.



	sand casting	die casting	sheet fabrication	distributers	food sellers	household users
dust and fumes	5	2	5	1	3	2
weather elements	3	1	6	5	0	0
noise pollution	0	1	7	0	0	0
extreme heat	5	4	2	0	0	0
explosions	5	4	0	0	0	0

dust and fumes   weather elements   noise pollution   extreme heat   explosions

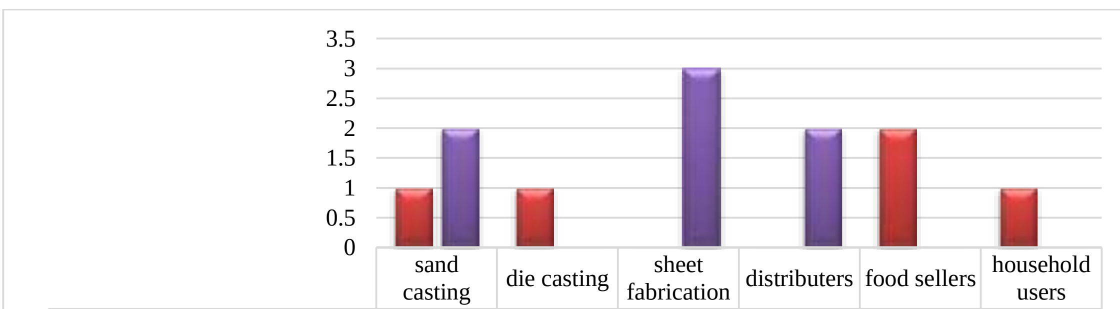
Figure 15: Responses to hazards that result from cookware production

The highest source of hazards was dust and fumes as observed by 18 respondents. Artisans in The sand casting and die casting workshops that used paraffin blow torches and charcoal furnaces catalyzed used engine oil injection. Workers in close proximity to the furnaces observed that they were exposed to explosions resulting from melt impurities (Ref Figure 16). Aluminium sheet fabricators identified noise pollution as the main hazard due the repeated hammering procedures when forging metal. All the 4 respondents in the die casting workshops observed that the conditions in the foundry shop exposed them to extreme heat.

No workshop had safety precautions outlined on a chart within the foundry and sheet fabrication premises. All artisans in the study reported to be familiar with challenges associated with working in a foundry workshop. The foundry workshops owners were more conversant with the hazards that result from the production of cookware than the distributors who sell the products directly to users. One out of the 9 casting workshops surveyed from Kariobangi indicated that lack of proper scrap selection exposes the artisans to other metals such as lead and zinc. The melting process used to separate aluminium from zinc exposes the workers to zinc oxide. The artisans work with very little protection and thus are vulnerable to fumes, dust flares and extreme heat from the furnaces for long hours. corrosive cleaning agents and sharp edges(Ref Appendices Fig 68, 69, 70, and 71).

Figure 16: Flares from a charcoal furnace

Source: Author



	sand casting	die casting	sheet fabrication	distributers	food sellers	household users
corrosion of cookware	1	1	0	0	2	1
migration of chemicals to food	2	0	3	2	0	0

Figure 17: Respondent opinion on the type hazards aluminium cookware users are exposed to

The respondents in the study were quizzed on knowledge on the hazards customers or users of artisanal cookware are exposed to. The range of hazards included corrosion of cookware and migration of chemicals from cookware to foods (Ref Figure 17). From the results few artisans and users were conversant with the dangers posed by artisanal aluminium cookware. Some of the models used for creating sand casting moulds were exposed to corroding chemicals due to inappropriate storage (Ref Figure 18).


Figure 18: Cookware model used in making sand casting moulds showing corrosion marks

Source: Author

One respondent at the aluminium sheet fabrication workshop indicated that some of the choice material for sheet metal fabrication are suitable for vehicle body work and not making cooking drums, frying pans and troughs. The artisan demonstrated the quality of textured aluminium sheet metal by making a rubbing on it revealing a deep metallic grey pigment (Ref Figure 19). According to the respondent this type of metal can wear down easily. The grey rubbing presents the chance that substances can migrate into food during cooking and also any food stored in aluminium cookware. The artisan indicated the material selection is one of the major reasons for low quality production of the cookware. Recycled aluminium needs annealing so that it is easily rolled into various configurations of cookware. According to the artisan annealing weakens the strength of the recycled aluminium metal


Figure 19: Rubbing from textured aluminium sheet metal used in making shallow frying pans

Source: Author

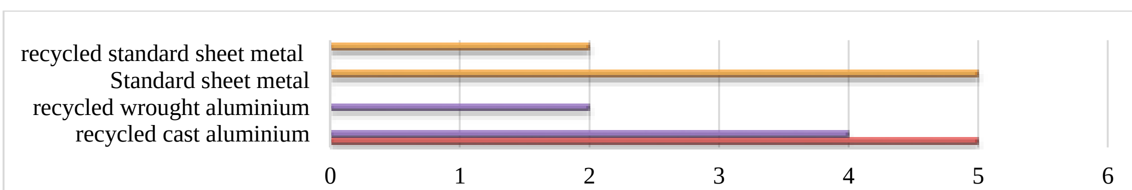
Majority of the respondents in the study are not conversant with the hazards that result from using cookware made from aluminium. From the respondents interviewed only the sand casting and fabrication workshop owners and their artisans could identify deficiencies in the materials used in making cookware. All workshop owners indicated that as much as they are conversant with the risks posed by low quality material inputs, the users are not provided with such information.

Figure 20: Cooking basin made from recycled milk can

Source: Author

4.6. Appropriate strategies in the production of cookware.

4.6.1. Material selection



	recycled cast aluminium	recycled wrought aluminium	Standard sheet metal	recycled standard sheet metal
sheet fabrication	0	0	5	2
die casting	4	2	0	0
sand casting	5	0	0	0

Figure 21: Respondent choice material for cookware production

During the selection of materials the only classification known to the workshop owners for aluminium metal was soft and hard. 60% of the respondents composed of artisans from the aluminium casting and sheet fabrication workshops did not conduct critical analysis of scrap metal to ascertain quality. Vehicle cylinder heads, and pistons were used for casting items like weighing scale stands and supports and also gas cylinder grills. All the 5 Respondents in the casting workshops were not able to distinguish between wrought metal and cast metal as the standard classifications for aluminium. The terminology used by artisans for wrought aluminium was soft. This classification of soft aluminium was derived from aluminium electric cables and off-cuts from sheet metal and aluminium alloy vehicle wheel rims. The term hard aluminium was used in place of cast metal such as that derived from engine cylinder heads and blocks (Ref Figure 22).

Figure 22: Images showing a cast engine block and a billet of melt aluminium

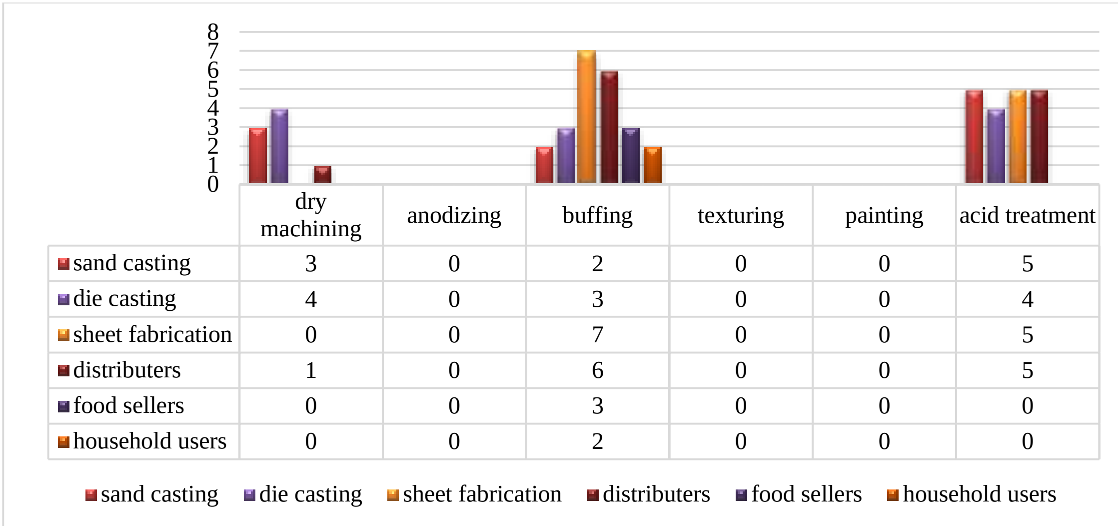
Source: Author

All the respondents in the sand casting representing 19% workshop preferred hard aluminium because of its wide applicability in making machine components and cookware. One aluminium sand casting workshop owner observed that lack of controls allows for any aluminium metal source to enter the furnaces for recycling. One major challenge noted by all respondents in the casting workshops in material selection is metal separation methods that do not ensure attainment of pure melt. The sand casting experts expressed the difficulty in determining the timing required to separate other metals such as zinc that is found in some types of aluminium alloys. The casting shops lacked appropriate methods of disposing the zinc metal. The waste metal was dumped together with other waste materials and no effort is made in separation.

Aluminium sheet fabrication artisans who represent 26% of the respondents surveyed used standard sheet metal and recycled aluminium sheet metal in production. The recycled metal was derived from defective old milk cans and industrial tanks and drums. The artisans observed that recycled sheet metal required annealing on a furnace to soften the metal for forging processes. The annealing process changes the colour of the metal to a pale cream colour (Ref Figure 23). The artisans use car battery acid to clean the oxidized surfaces of cookware made from aluminium scrap to achieve a shiny finish similar to standard sheet aluminium.

Figure 23: Comparison of recycled sheet aluminium and standard sheet aluminium.

Source: Autho**r**

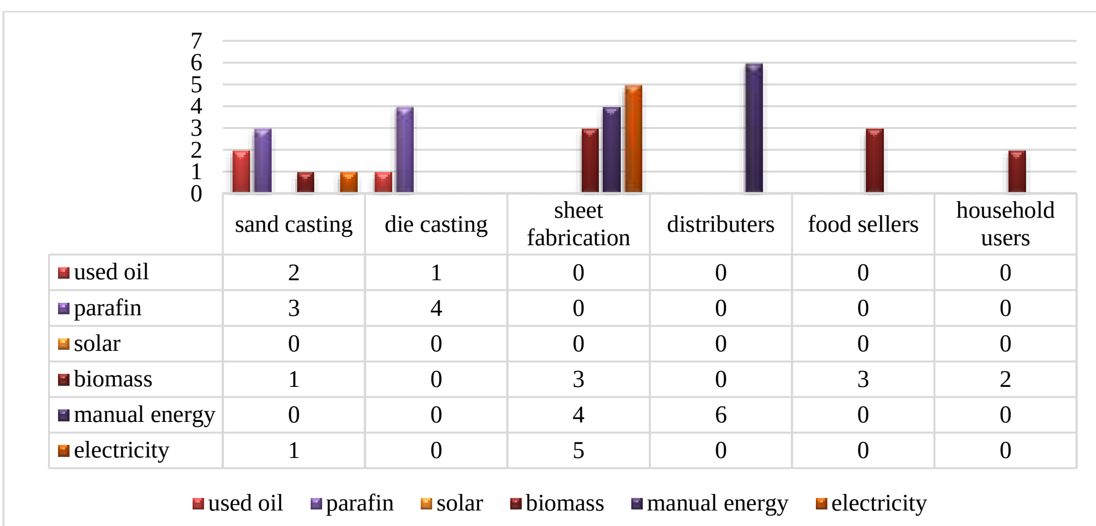


	dry machining	anodizing	buffing	texturing	painting	acid treatment
sand casting	3	0	2	0	0	5
die casting	4	0	3	0	0	4
sheet fabrication	0	0	7	0	0	5
distributers	1	0	6	0	0	5
food sellers	0	0	3	0	0	0
household users	0	0	2	0	0	0

Figure 24: Respondents choice of cookware finishing methods

All respondents in the case study area indicated that the workshops do not have the capacity to produce anodized cookware. The respondents in the sheet fabrication workshop observed that the preferred cookware finish achieved in the workshops was buffing and acid treatment. The acid treatment provides a permanent sheen on the cookware. The sand casting workshops used dry machining and acid treatment in the finishing process.

4.6.2. Energy sources in use for production



	sand casting	die casting	sheet fabrication	distributers	food sellers	household users
used oil	2	1	0	0	0	0
parafin	3	4	0	0	0	0
solar	0	0	0	0	0	0
biomass	1	0	3	0	3	2
manual energy	0	0	4	6	0	0
electricity	1	0	5	0	0	0

Figure 25: Respondent choice of energy sources for cookware production

Artisans in foundry shops dealing with die casting used paraffin blow torches which were portable and efficient in melting aluminium scrap. Four respondents representing 15 % of the surveyed population in the die casting workshop observed that paraffin blow torches can be catalyzed by a hand pump which can be repaired with basic technology by the artisan (Ref Figure 26).

Figure 26: Images showing pressurized paraffin blow torch used as a furnace catalyst

Source: Author

Three aluminium sheet fabricators used charcoal furnaces catalyzed with blowers powered by electricity or a hand-crank (Ref Figure 27 and 28).

Figure 27: Open charcoal furnaces

Source: Author

Figure 28: Furnace blowers powered by electric motor and hand cranking

Source: Author

4.6.3. Product geometry

Data on the application of product geometry such as dimensioning and product space was collected by observation through photography. The aluminium cookware manufactured by die casting included flat frying disc pans. The die casting method requires accuracy in achieving proper or desired dimensions. The artisans have to machine the die casts and this reveals further defects such as bubble pores and irregular cast (Ref Figure 29). All sand cast cookware input suppliers from Kariobangi representing 34% of the surveyed population identified the challenge of not having equipment for checking the appropriate temperature for aluminium melt. The artisans cited the challenge of achieving repeatability of designs from casting models with the desired accuracy (Ref Figure 30 and 31). They indicated that one of the aluminium product that has been successfully replicated by die casting without the need for intense machining is the gas cylinder cooking grill known as *Meko* in Swahili.

Figure 29: Flat disc frying pan with inconsistent surface

Source: Author

Models used in the sand casting shops were analyzed fom photography taken in the case study area. The models remain unchanged in design and therefore inconsistencies in the resulting cast are not corrected (Ref Figure 30 and 31) compares a model used in preparing a sand mold and the resulting cast

Figure 30: Casting model with detail of flaws in geometry

Source: Author

Figure 31: Resulting cast from defective models showing rough cookware handles

Source: Author

(Ref Figure 32) exhibits one of the successful casts that responded well to methods of machining. No pores were exposed after machining. Some of the cast flat frying plates are afforded a shiny finish by using tungsten carbide cutter heads by gradual milling processes. The milling process does not ensure a smooth and even finish that is characteristic of chapatti frying plates. The shininess of the aluminium is achieved after applying car battery acid then exposing the pan in the sun. The more refined smooth finish is achieved by the users after a considerable period of use and cleaning with steel wool.

Figure 32: Successful die cast flat disc frying pans

Source: Author

Some of the cast flat frying plates are afforded a shiny finish by using tungsten carbide cutter heads. The milling process does not ensure a smooth and even finish that is characteristic of frying discs made from plate steel. The shininess of the aluminium is achieved after applying car battery acid then exposing the pan in the sun. The more refined smooth finish is achieved by the users after a considerable period of use and cleaning with steel wool.

The aluminium cooking pot that has a similar design form to the traditional clay pot presents considerable challenges in the sand casting process. The casting artisan has to make a two part molds for the lower pot shape because of it having a wide opening. The three parts have to be seamed together with melt aluminium. A third mould has to be made for the covering lid. The complexity in developing the molds and accuracy in seaming and ensuring a fitting lid combined with the artist experience or skill affects the quality boiling pot dimensions (Ref Figure 33).

Figure 33: Sections of aluminium cooking pot

Source: Author

following observations conducted through photography one of the cookware items that artisans have been successful in achieving approppriate dimensions and repeatability were the aluminium plates and trays. From the respondents interviewed only one distributer had a metal spinning machine which uses mandrels with molds of different dimensions. Flat aluminium disc is pressed onto the mandrel to form shallow trays or plates ref fig.The edge of the plate is spun and trimed around a wire ring to provide sturdy finish (Ref Figure 34). The process of metal spinning employs localy fabricated tools for pressing and triming edges to an even finish.

Figure 34: Plates and tray derived from sheet metal spinning

Source: Author

The aluminium kettle is constructed by assembling folded sheet metal and a cast spout. The major deficiency in dimensionality is ensuring perfect registration of the lid on the opening of the kettle design (Ref Figure 35)

Figure 35: Aluminium kettle with inconsistent lid dimensions and joining of the spout

Source: Author

4.6.4. Ergonomics

From an observation checklist used in the data collection ergonomics was considered majorly on the cooking pots fabricated from sheet aluminium. The hammering methods heavily determine the surface finish quality of the observed products in the study. Cast aluminium pots presented a considerable challenge in achieving proper shapes for the handling sections and on the lid. Inconsistent melt and unreliable mold resulted in objects that have eliminated ergonomic qualities. The figure below presents sections of the handles from sampled cast cooking pots (Ref Figure 36).


Figure 36: Cooking pot lid with rough handle

Source: Author

The sand casting workshop artisans observed that Cold sand and the timing of pouring the melt leads to inconsistencies and flows in the resulting cast. (Ref Figure 37) exhibits one of the sheet aluminium boiling pots that had a roughly hammered edge of the lid and was on sale.


Figure 37: Boiling pot with twisted edges on the lid

Source: Author

4.6.5. Aesthetics

All respondents indicated that customers are provided with an opportunity to suggest designs of cookware. The die casting artisans explained that the choice of design is limited to the workshop facilities and skill capacities of artisans. Observations captured by photography reveal inconsistencies in achieving circular decorative ridges on the cover and body of the aluminium cooking pot.

Figure 38: Inconsistent decorative ridges on the spherical boiling pot girth and lid

Source: Author

The sand casting artisans have made some articles with brand names and decorative elements as part of the model design. This aesthetic quality was observed through analysis of photographs from the case study area. The main challenge is ensuring accurate repeatability of the decorative elements. (Ref Figure 39 and 40) highlights some of the flaws in casting decorative and brand name elements on cooking trough lids and spoon handles.

Figure 39: Flaws on branding elements and floral designs

Source: Author

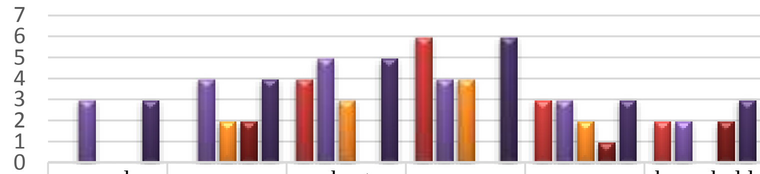
Figure 40: Sand cast spoons and servers with decorated bands on handles

Source: Author

4.7. Standard product specifications for aluminum designs of cookware

4.7.1. Usability testing

Respondents were asked to determine the parameters of usability testing as presented on the checklist administered to cookware distributers, customers and workshops (Ref Appendix 7.8. Questionnaire) to capture this phenomenon in the case study area. The chosen parameters for testing cookware usability included the type of food appropriate for cookware, the energy to be used on cookware, the product retirement or disposal stage, the type of maintenance to be applied by customers and cookware capacities.



	sand casting	die casting	sheet fabrication	distributers	food sellers	household users
specific food type for cookware	0	0	4	6	3	2
energy source for cookware	3	4	5	4	3	2
maintainance needed	0	2	3	4	2	0
disposal stage	0	2	0	0	1	2
cookware capacity	3	4	5	6	3	3

specific food type for cookware · energy source for cookware · maintainance needed · disposal stage · cookware capacity

Figure 41: Respondent knowledge on parameters for cookware usability

Cookware distributors who represent 22% of the respondents were more conversant with the type of cookware that are appropriate for different types of food and the capacities. However the six respondents could not determine the disposal stage for cookware. The sand casting artisans observed that once products are manufactured the maintenance needed is in the public domain.

4.7.2. Product performance

Observation conducted through photography in the case study present the main challenges in the application of appropriate production processes. The qualitative data analysis program QDA Miner Lite was used to code themes categorized under the product design specifications from the photographic images (Ref Figure 42 ,45,48,50,53, and 56). A selection of images of workshop environment and aluminium cookware on display at the case study area were selected. Analyzing the chosen images by coding variables provided an estimate of the level to which standard methods of production are adhered to in the sheet fabrication and casting workshops. The product design specifications outlined in the conceptual framework are treated as the parameters for quality control in production of cookware.

Figure 42: Coding frames on sand casting workshop image from QDA Miner Lite

Source: Author

Table 4: Results for distribution of key words

Category	Code	Count	% Codes	Cases	% Cases
Ergonomics	Human interface issues	9	26.50%	2	100.00%
Ergonomics	Safety issues	4	11.80%	2	100.00%
Product Environment	Energy efficiency	2	5.90%	1	50.00%
Product Environment	Pollution	7	20.60%	2	100.00%
Product Environment	Waste management	3	8.80%	2	100.00%
Product Environment	Hazards	5	14.70%	2	100.00%
Product Performance	Quality control	1	2.90%	1	50.00%
Product Performance	Energy requirements	2	5.90%	2	100.00%
Product Performance	Maintenance issues	1	2.90%	1	50.00%

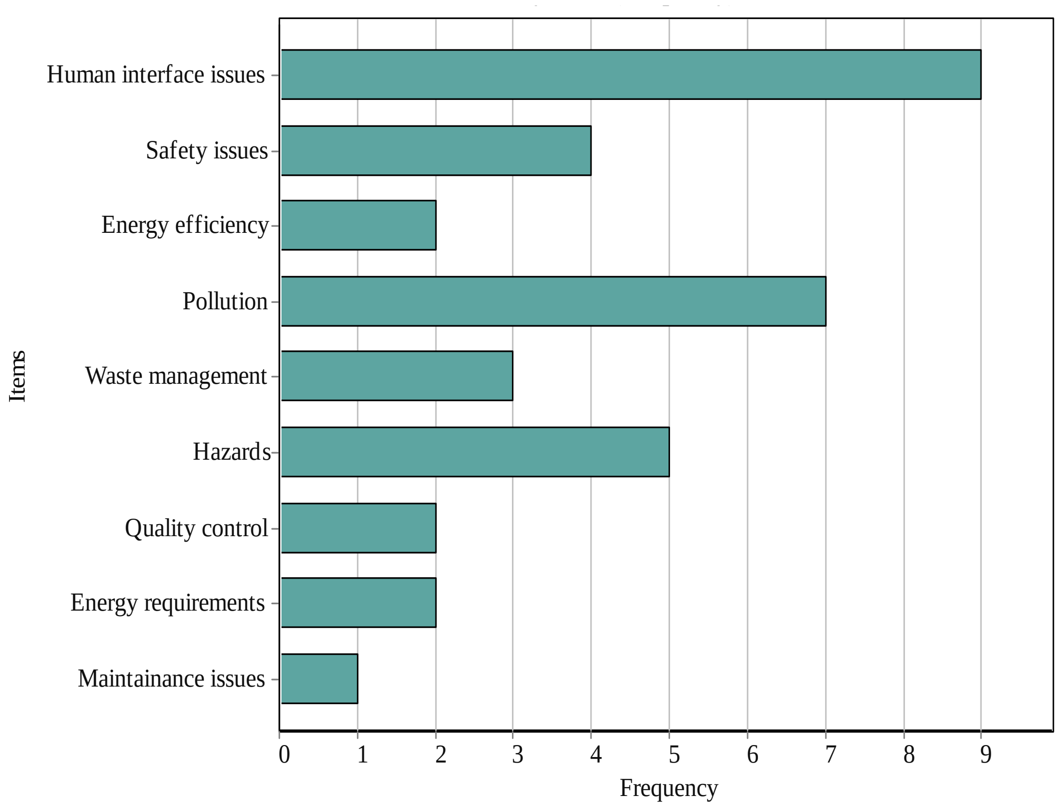


Figure 43: Distribution of key words

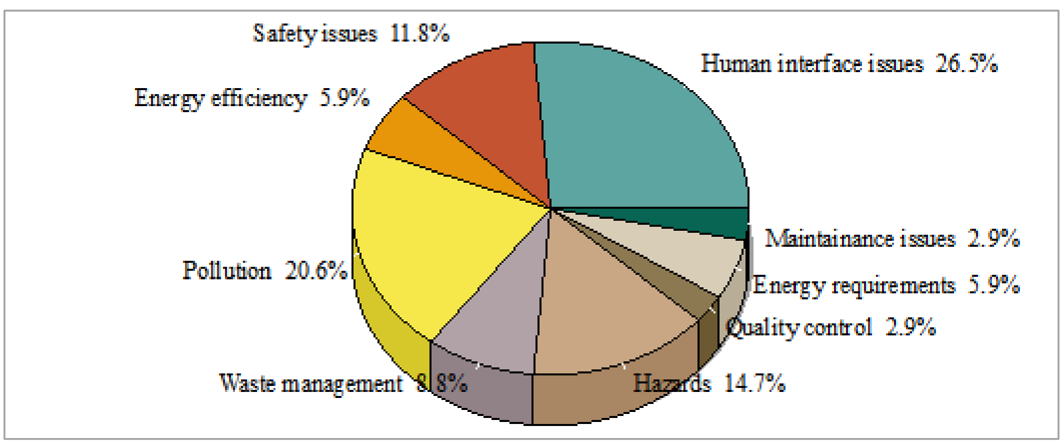


Figure 44: Percentage distribution of key words

From the analysis of coding results (Ref Table 4) from the photograph (Ref Figure 42) and presented graphically on (Ref figure43 and 44), human interface issues recorded 26.5% as the highest frequency of coded cases. Pollution which is categorized under product environment recorded 20.6%. of the coded cases. Quality control categorized under product performance presented the lowest count of 2.9%. The results from the coding indicate that sand casting workshops were deficient in including ergonomics and approppriate production environment as a specification in cookware production.

Figure 45: Coding frames for sheet fabrication workshop image from QDA Miner Lite

Source: Author

Table 5: Results for distribution of key words

Category	Code	Count	% Codes	Cases	% Cases
Ergonomics	Human interface issues	6	28.60%	1	100.00%
Ergonomics	Comfort issues	1	4.80%	1	100.00%
Product Environment	Energy efficiency	1	4.80%	1	100.00%
Product Environment	Pollution	2	9.50%	1	100.00%
Product Environment	Hazards	2	9.50%	1	100.00%
Product Environment	Contaminants	4	19.00%	1	100.00%
Geometry	Product space	2	9.50%	1	100.00%
Geometry	Product dimensions	1	4.80%	1	100.00%
Product Performance	Energy Requirements				
Product Performance	Material selection	2	9.50%	1	100.00%

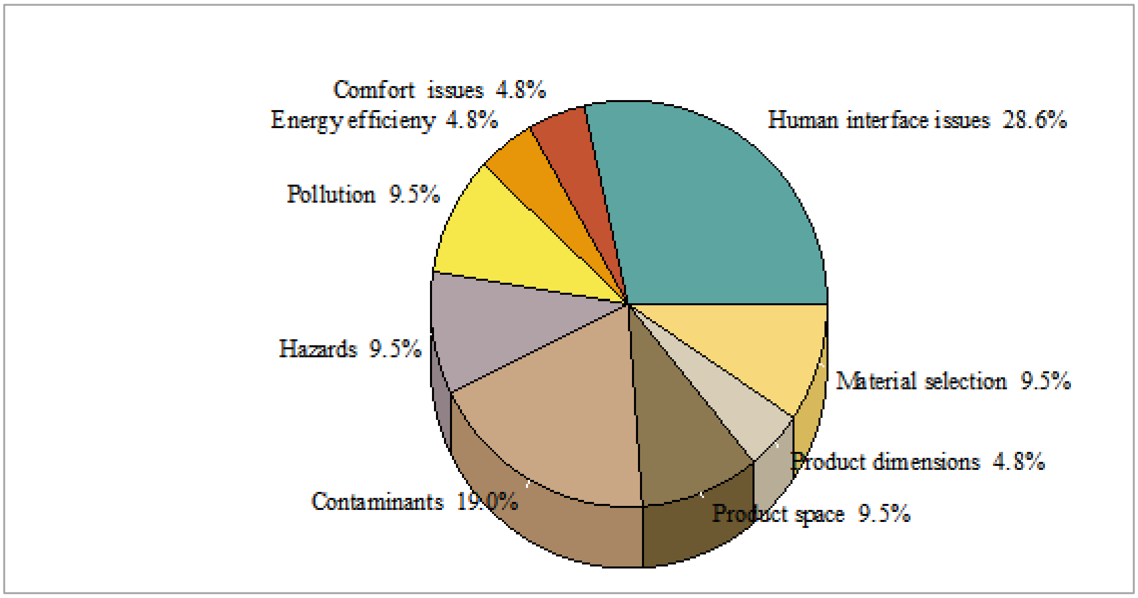


Figure 46: Percentage distribution of key words

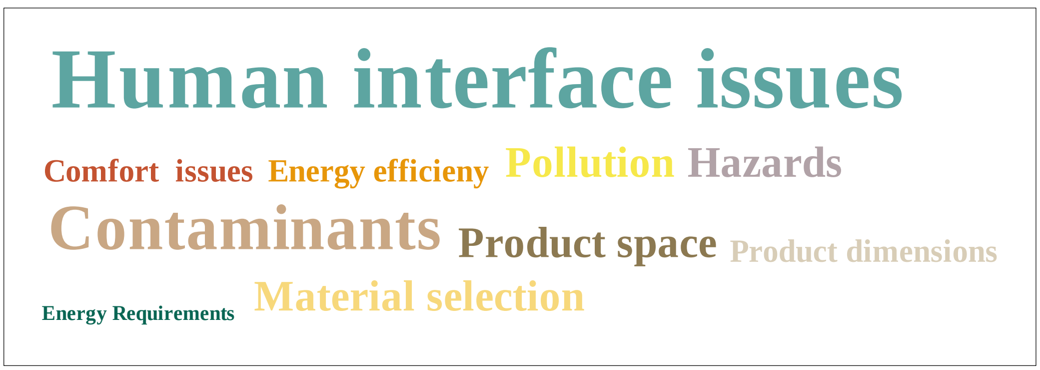


Figure 47: Word cloud for coding frequency

From the examination of the photograph (Ref Figure 45) with analysis of results (Ref Table 5) and presentation on the word cloud (Ref Figure 47) and pie chart (Ref Figure 47), Human interface issues categorized under ergonomics recorded 28.6% of the codes counted. Contaminants which is categorized under product environment achieved 19.0% of the coding frequency. Energy requirements scored the lowest percentage because the production process employed manual means. The inferences made from the coded themes indicate that the products in the particular sheet fabrication workshop are exposed to contaminants that result from small working spaces and inappropriate facilities.

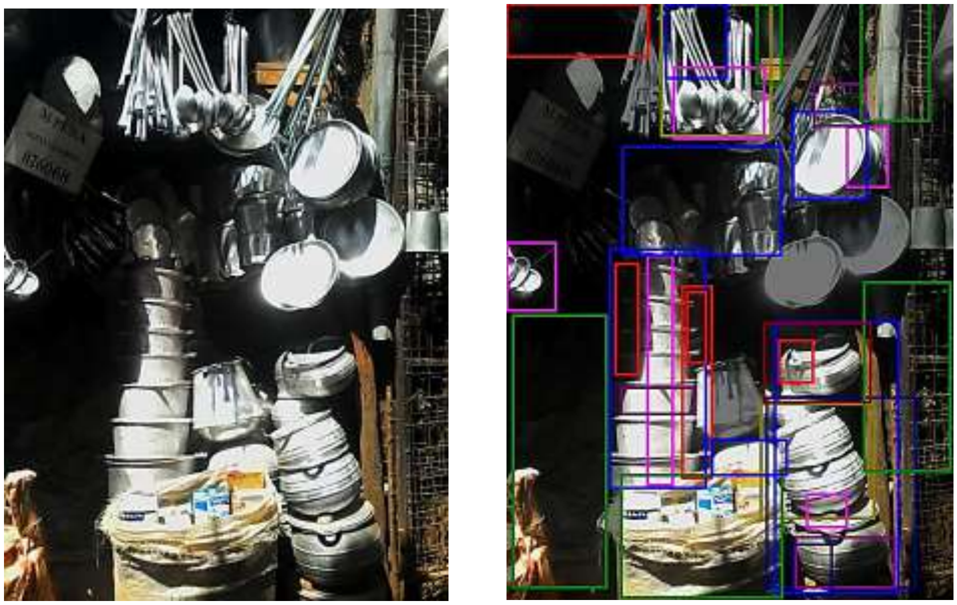


Figure 48: Coding frames for cast aluminium cookware image

Source: Author

Table 6: Results for distribution of key words

Category	Code	Count	% Codes	Cases	% Cases
Ergonomics	Safety issues	2	7.10%	1	100.00%
Ergonomics	Human interface issues	2	7.10%	1	100.00%
Geometry	Product dimensions	2	7.10%	1	100.00%
Geometry	Product space	1	3.60%	1	100.00%
Geometry	Repeatability	4	14.30%	1	100.00%
Aesthetics	Traditional design	2	7.10%	1	100.00%
Aesthetics	Product appeal	6	21.40%	1	100.00%
Product Performance	Maintenance issues	2	7.10%	1	100.00%
Product Performance	Quality control	1	3.60%	1	100.00%
Product Environment	Pollution	3	10.70%	1	100.00%
Product Environment	Exposure to elements	2	7.10%	1	100.00%
Design	Templates				
Design	Models	1	3.60%	1	100.00%

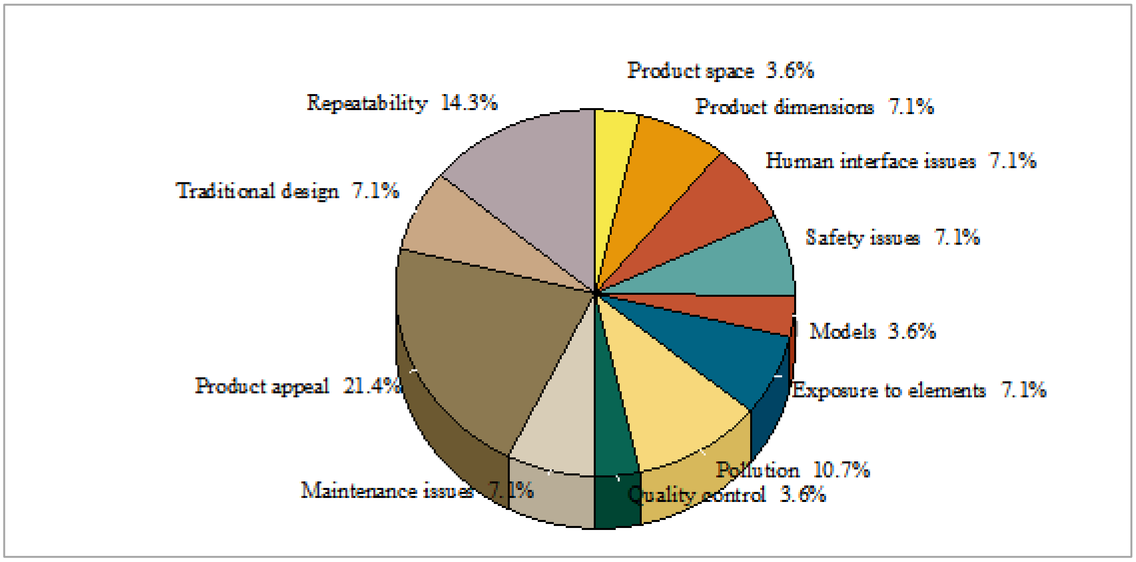


Figure 49: Percentage distribution of key words

The analysis of the coding frequency on the photograph (Ref Table 6) and (Ref Fig 48 and 49) indicated that product appeal was given more attention by traders displaying sand cast aluminium cookware. Product appeal achieved a count of 21.4% as compared to traditional design with a count of 7.1% under aesthetics. The application of human interface issues on aluminium cookware achieved 7.1% of the codes counted. The low percentage means that ergonomics needed more consideration in cookware production. Quality control categorized under product performance had 3.6% of the counted codes. This result indicated that quality control was not applied exhaustively in the production of cookware.

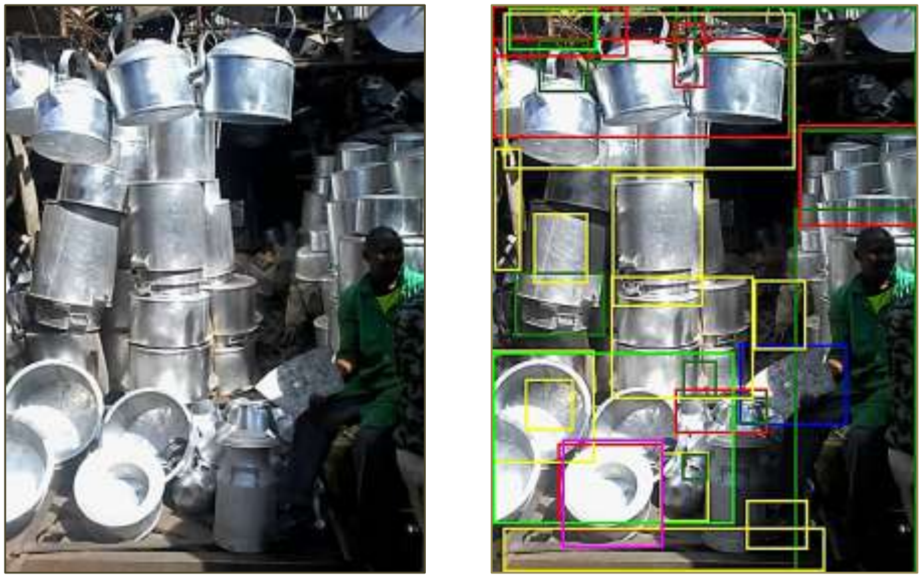


Figure 50: Coding frames for sheet aluminium cookware on display on QDA Miner Lite

Source: Author

Table 7: Results for distribution of key words

Category	Code	Count	% Codes	Cases	% Cases
Geometry	Product capacity	1	3.40%	1	100.00%
Geometry	Product space	1	3.40%	1	100.00%
Geometry	Repeatability	3	10.30%	1	100.00%
Geometry	Product dimensions	1	3.40%	1	100.00%
Aesthetics	Visual appeal	1	3.40%	1	100.00%
Aesthetics	Product semantics				
Aesthetics	Affective design	2	6.90%	1	100.00%
Design	Templates	1	3.40%	1	100.00%
Design	Patterns	-	-	-	-
Product Performance	Maintenance issues	2	6.90%	1	100.00%
Product Performance	Quality control	1	3.40%	1	100.00%
Product Performance	Material selection	1	3.40%	1	100.00%
Product environment	Pollution	4	13.80%	1	100.00%
Product environment	Product safety	2	6.90%	1	100.00%
Ergonomics	Human interface issues	7	24.10%	1	100.00%
Ergonomics	Safety issues	2	6.90%	1	100.00%

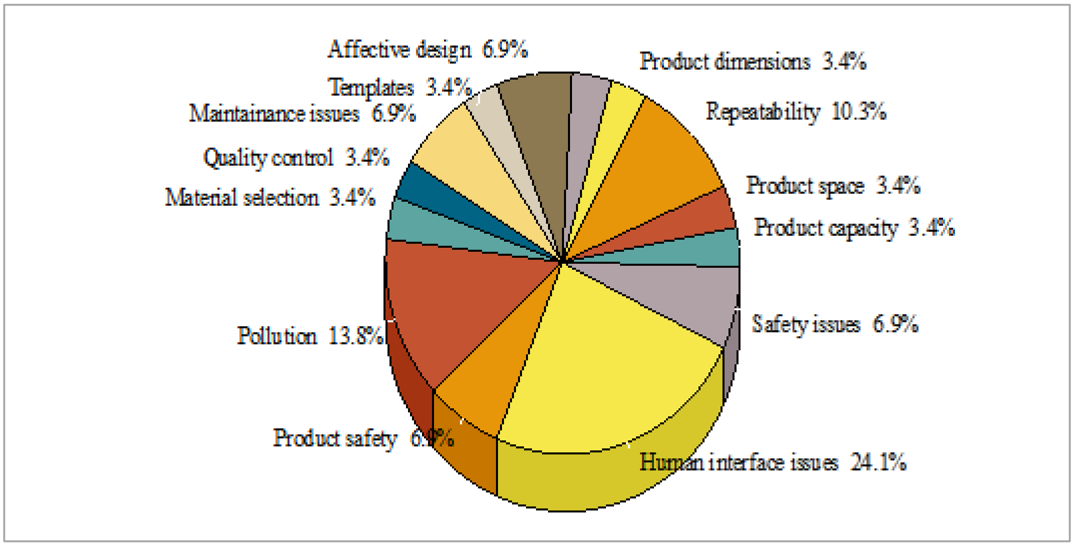


Figure 51: Percentage distribution of key words

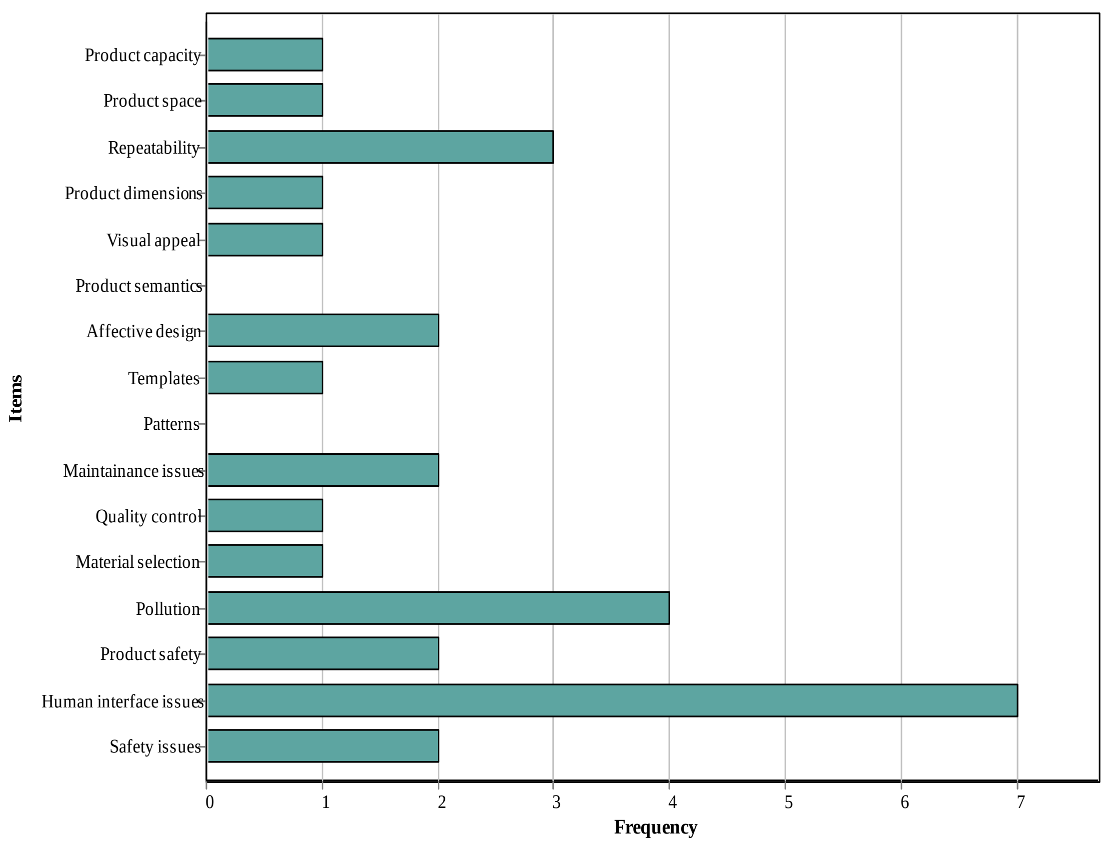


Figure 52: Distribution of key words

From the analysis of coding results on the photograph (Ref Figure 50) on (Ref Table 7) and graphical presentation on (Ref Figure 51 and 52) repeatability as a code categorized under product geometry achieved 10.3% in comparison to the other parameters under product geometry. This observation indicated that the major challenge in geometry for sheet fabricated cookware is making identical cookware of the same dimensional space. Human interface issue also scored a high count of 24.1%indicating that features of cookware such as handle and carrying capacity need to be improved

Figure 53: Coding frames for models used in sand casting on QDA Miner Lite

Source: Author

Table 8: Results for distribution of key words

Category	Code	Count	% Codes	Cases	% Cases
Geometry	Product dimensions	2	9.50%	1	100.00%
Geometry	Product space	1	4.80%	1	100.00%
Product environment	Pollution	6	28.60%	1	100.00%
Product environment	Hazards	3	14.30%	1	100.00%
Aesthetics	Product shape	1	4.80%	1	100.00%
Aesthetics	Cultural object	1	4.80%	1	100.00%
Ergonomics	Human interface	4	19.00%	1	100.00%
Ergonomics	Safety issues	2	9.50%	1	100.00%
Design	Prototype				
Design	Model	1	4.80%	1	100.00%

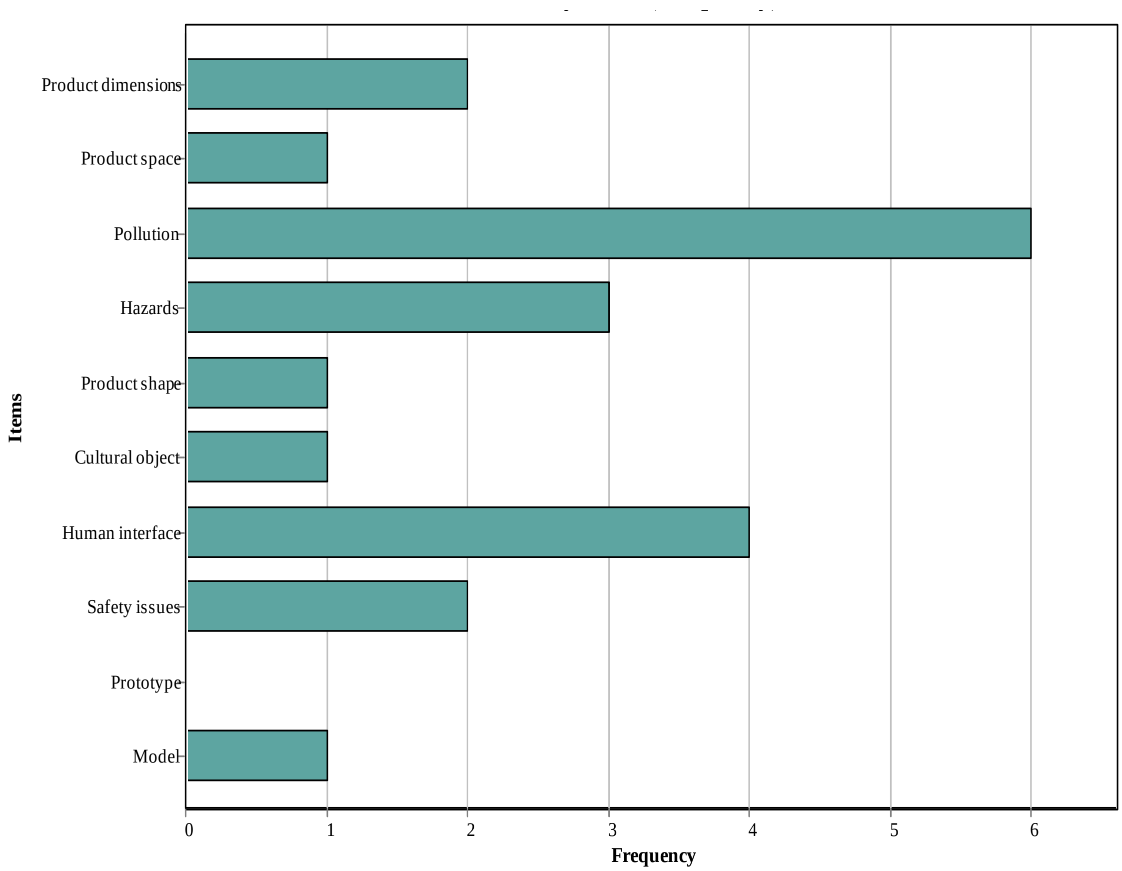


Figure 54: Distribution of key words

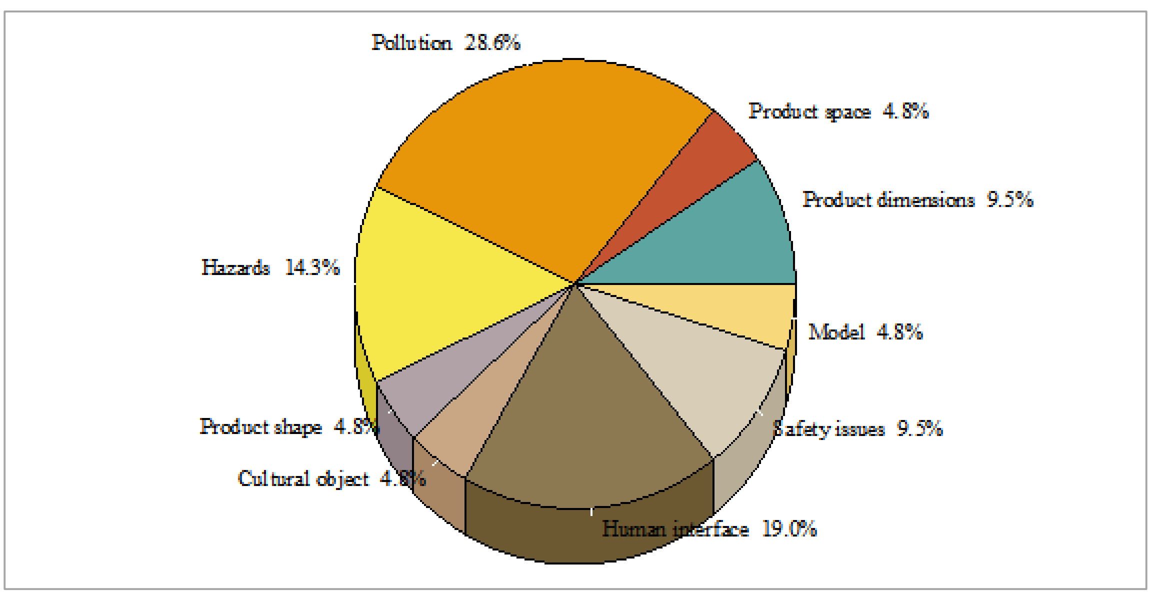


Figure 55: Percentage distribution of key words

From the coding results analysis (Ref Table 8), derived from the photograph (Ref Figure 53) and the graphical presentation (Fig 54 and 55), hazards and pollution recorded 14.3% and 28.6% counts respectively. This indicates that the models of aluminium cookware were vulnerable to elements that affected the overall quality of cookware. Product shape and cultural object which all achieved a frequency of 4.8% means that aesthetics was not treated as the main goal for production but an end result of a well-conceived cookware design.

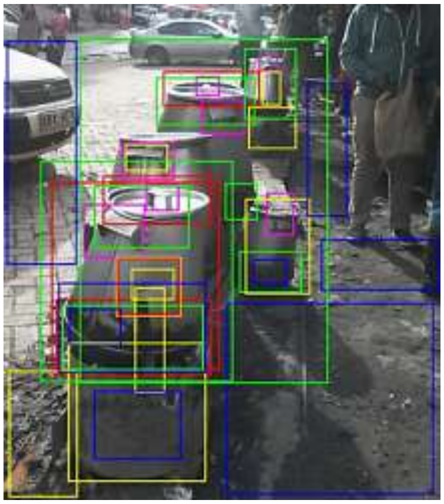


Figure 56: Coding frames on sheet aluminium cookware from users

Source: Author

Table 9: Results for distribution of key words

Category	Code	Count	% Codes	Cases	% Cases
Geometry	Product dimensions	2	5.60%	1	100.00%
Geometry	Product space	2	5.60%	1	100.00%
Product Performance	Usability testing	3	8.30%	1	100.00%
Product Performance	Shelf life	1	2.80%	1	100.00%
Product Performance	Material selection	2	5.60%	1	100.00%
Product Performance	Energy requirements	3	8.30%	1	100.00%
Product Performance	Maintenance issues	3	8.30%	1	100.00%
Ergonomics	Human interface issues	4	11.10%	1	100.00%
Ergonomics	Comfort issues	3	8.30%	1	100.00%
Product Environment	Pollution	4	11.10%	1	100.00%
Product Environment	Product life cycle	1	2.80%	1	100.00%
Product Environment	Hazards	3	8.30%	1	100.00%
Aesthetics	Traditional design	1	2.80%	1	100.00%
Aesthetics	Affective design	2	5.60%	1	100.00%
Aesthetics	Visual appeal	2	5.60%	1	100.00%

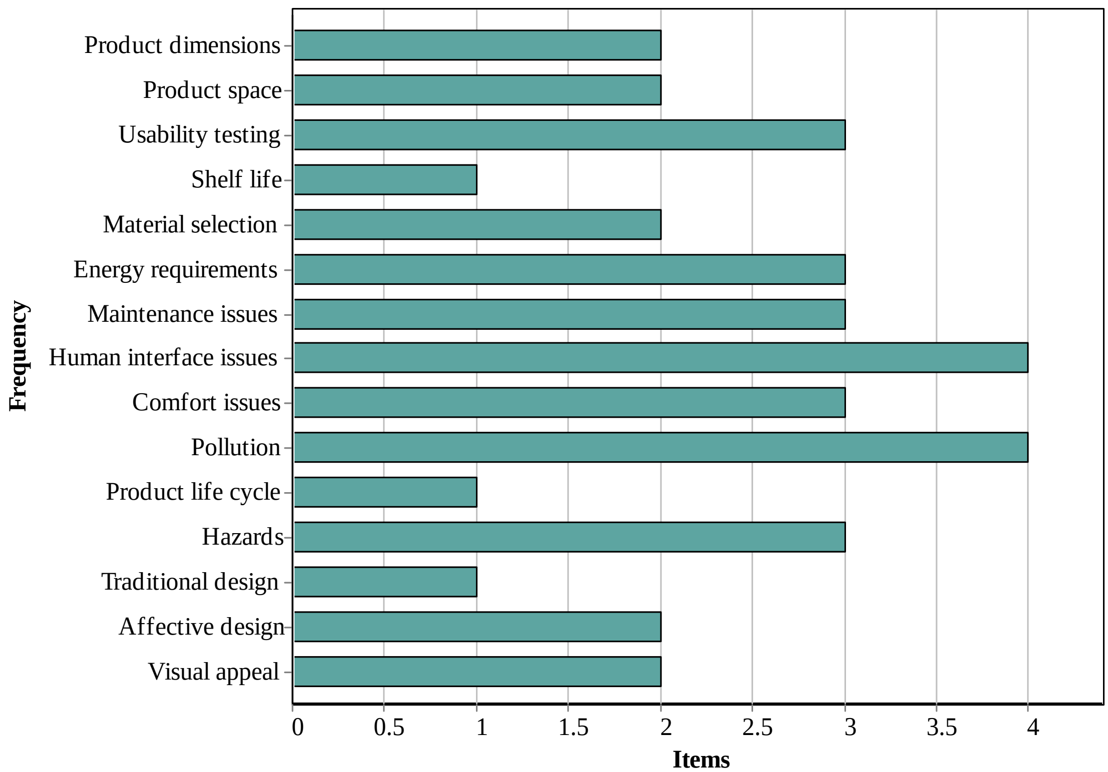


Figure 57: Distribution of key words

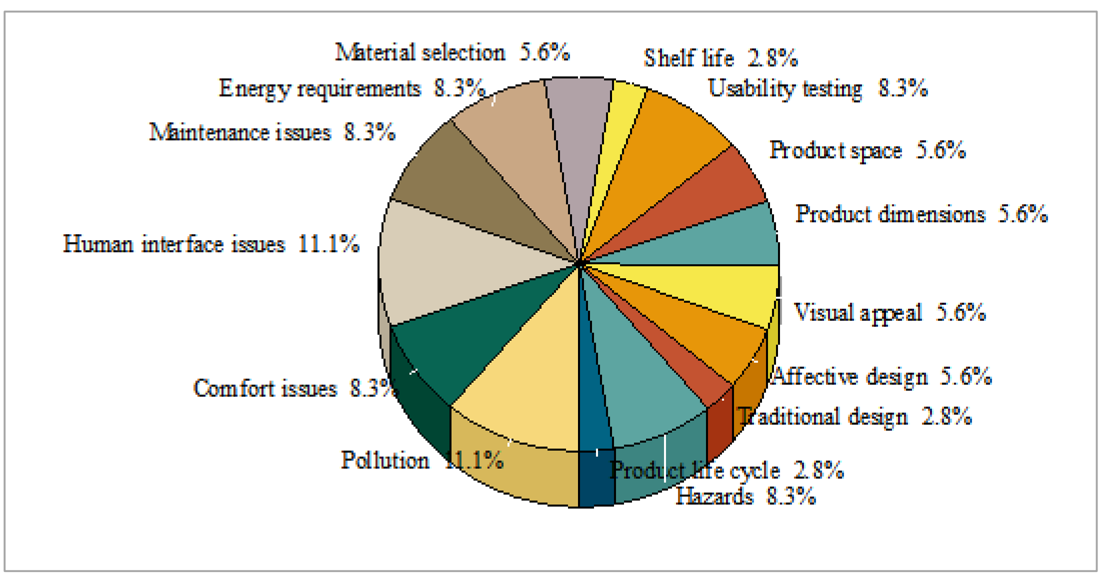


Figure 58: Percentage distribution of key words

From the photograph derived from the premises of one food seller (Ref Figure 56) analyzed on (Ref Table 9) and presented graphically on (Ref Figure 57 and 58), human interface issues achieved a count of 11.1%. Product dimensions and product space as part of geometry specification were treated with equal importance with both achieving 5.6% of the counted codes. Product life cycle and shelf life had the lowest count of 2.8% each. The product life cycle as an important aspect of product environment and retirement was not afforded the necessary consideration under the product performance. Aspects of product retirement were also not clearly predicted by the aluminium cookware users and producers.

5.0. CHAPTER FIVE

5.1 SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.2. Introduction

This final section of the research project summarizes what the study established. The chapter provides inferences and suggestions on the way forward through recommendations and further research in areas of interest. The study sought to establish the level of application of product design specification by artisans producing cookware at the Kamukunji *jua kali* cluster in Nairobi County.

5.3 Summary of findings

The first research question sought to find out if artisanal aluminium cookware exhibit design deficiencies. The result from the study has revealed that some of the methods used to preserve cookware designs are sheet metal templates for sheet aluminium cookware and cooking pot models for sand casting. The templates made of galvanized steel in use for aluminium sheet fabrication are durable but are vulnerable to tearing after long periods of use. The aluminium casting workshops had no written design project steps or sketches. Veteran artisans served as the main repositories for expert knowledge in cookware fabrication. Artisans in the workshop indicated that photography was used to preserve the best designs but this was not provided for evaluation. The workshop owners indicated that customer feedback and input on cookware design were important aspects of improving cookware design. The major setback was that new design ideas were limited to workshop facilities and capacities for production.

The second research question was geared towards establishing hazards associated with production of aluminium cookware. Some of the potential dangers were inadequate workshop conditions such as open furnaces and contamination from dust, fumes and sweaty hands on displayed cookware. Insufficient knowledge on finishing methods also exposed the workers to substances used for finishing products such as car battery acid. Lack of knowledge on the chemical composition of recycled materials also posed health risks to the artisan and users of cookware.

The third research question was to establish if informal workshops had appropriate strategies in the production of cookware. Majority of the workshops had no proper methods in workshop management. The artisans were exposed to long residency periods at the workshops. The artisans in the aluminium casting workshops were unable to determine the right aluminium melt temperature and timing for pouring in sand molds. This phenomenon resulted in inconsistent cast cookware with uneven surface finish. Repeatability of cast cookware was also a challenge as cast cookware had to undergo rigorous machining to achieve product dimensions. One successful method of production for cookware was metal spinning. Metal spinning method used to make serving trays and plates was efficient in achieving dimensional accuracy with minimal wastage of material. The major defects in aluminium sheet fabrication were directly attributed to artisan's level of training and the use of basic workshop facilities.

The fourth research question sought to establish standard product specification for aluminium cookware. Usability testing for aluminium cookware in the artisanal workshop was not conducted appropriately. Important user information for aluminium cookware was assumed to exist in the public domain. Important parameters for testing cookware such as product capacities, energy to be used by customers and food types to be cooked in specific type of cookware were not considered. Most of the products were considered to be of good quality if passable functionality was achieved.

5.4. Conclusions

Out of the observations made in the foundry and aluminium sheet manufacturing workshops the production of cookware is affected by inconsistent inputs. The artisans within the informal workshops lack the expertise to deal with knowledge sources. Artisans approach design problems through methods such as reverse engineering to make iterations of different products. They only focus on the direct needs by their enterprises of creating profit which achieves less in improving a product. The artisans partially engage customers in the designing of products but the articulation of this information is only limited to reproduction of already existing products that are derived from photographs or existing prototypes. Effort made to create an aesthetic piece of work is influenced by finishing and machining methods. The workshop owners are deficient on basic equipment for determining quality of their product and this is manifested in the methods of selecting scrap metal. The only classification provided for scrap metal is soft and hard as opposed to wrought and cast aluminium. When melting the scrap no separation is conducted thus the resulting melt may have impurities. Workshop conditions in the informal clusters are not conducive for efficient production. The furnaces are located in narrow spaces that are not safe for the artisan. The artisan also is exposed to foreign chemicals during the production process such as lead. Aesthetics is only perceived in the physical attributes of cookware at the foundry workshops in Nairobi. The consideration of human emotions in the overall cookware design is of secondary importance. There is no proper mechanism for testing the usability of manufactured products.

This research informs artisans of the need to establish principles that can lead to better production by following a thorough scrutiny of manufacturing processes. Adapting product design specification in the production of aluminium products will help to capture the tacit knowledge that is inherent in the expert artisans. When knowledge on production processes is written in a description that is quantifiable, expert artisans will have a reference knowledge that is easy for interpretation by apprentices.

5.5. Recommendations

5.4.1. Adapting environmental responsible manufacturing to product design specifications

Observations from the results that were established in the study demand for a detailed Classification of the stages in the development of aluminium cookware products. The quality of artisanal aluminium cookware products is affected by lack of proper documentation of the design processes as established by the study. All levels of production need to be scrutinized from an environmental impact assessment point of view. The production levels include user feedback, the design phase, prototype making, manufacturing, usability testing and the retirement of a product. The environmentally responsible manufacturing (ERM) methods are linked to the product design specifications outlined in the conceptual framework of the study. Each product design specification is broken into constituent attributes and further linked with the potential environmental considerations in production. The classification of environmentally responsible manufacturing is categorized into two with regard to aluminium sheet metal fabricated cookware (Ref Table 10 to 17) and cookware produced by sand casting and die casting (Ref Table 18 to 25).

5.4.2. ERM considerations in product design specifications for sheet aluminium cookware

Table 10: Presentation of sheet aluminium cookware from case study

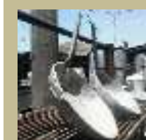
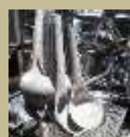
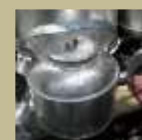
						
Frying pan	**Scoops**	**Plate and trays**	**Boiling drum**	**Cooking basin**	**Boiling pot**	**Tea kettle**

Table 11: Presentation of assembly methods and products for sheet aluminium cookware

Aluminium sheet Metal assembly method	**Products**
Forged sheet and cast metal assembly	Tea Kettles
Forged sheet metal assembly	Boiling pots, boiling troughs, cooking basin, Frying basin ,frying pan,
Blank sheet metal spinning	Serving trays , plates ,and troughs

Table 12: Classification of ERM for ergonomics

Ergonomics: human interface issues, comfort issues		
Parameters	**Attributes**	**Environmental considerations**
Material weight **Finishing of product ends** **Product handles** **Workshop conditions and schedules**	Medium density and high density aluminium sheet metal. Recessed handle. Loop handles Rounded ring neck Size of seamed edges workshop space Storage facilities Protective equipment Rotation of artisans in the workshops	Metal density and rate of consumption of material. Handles and user's lifting position or posture Types of cookware handles and material consumption. Injury by sharp edges. Sufficient working space for artisans. Short residence time when working.

Table 13: Classification of ERM and product performance

Product performance: quality assurance		
Parameters	**Attributes**	**Environmental considerations**
Material choice • **Standard sheet metal** • **Recycled sheet metal**	Vulnerability to corrosive fluids Potential for chemicals leaching. Annealing Number of riveting corrosion proof rivets and handles Matching cooking energy and choice of cookware Cleaning requirements	Migration of chemicals to food. Advise to users on appropriate food types for specific cookware. Consumption of biomass fuel. Consumption of cleaning agents. Type of fuel for annealing furnace. Alternative energy source.

Table 14: Classification of ERM and design

Design: drawings, patterns ,templates, project design steps		
Parameters	**Attributes**	**Environmental considerations**
Technical drawings	Model and prototype reliability. Templates Customer design feedback and workshop capacity. Project design steps. Considerations in design execution. Reverse engineering	Adjustments to customer design and material consumption. Distinction between demand and a wish from customers to prevent wasteful production. Number of iterations before reliability is achieved in relation to material consumption.

Table 15: Classification of ERM and product environment

Product environment: Pollution contaminants ,energy efficiency		
parameters	**Attributes**	**Environmental considerations**
Polishing chemicals **Material off cuts** **Emissions** **Energy needs**	Cleaning methods Steel wool battery acid Dust and fumes Wrought iron and cast iron Energy efficiency Revolutions on metal spinning lathes Hammering and vibrations Lubricants metal spinning wax Product life cycle	Disposal of machining fluids and waste material. Hoods and vents for furnaces. Noise levels from vibrating and revolving machines. Number of machine revolutions and production efficiency. Sweat contamination from hands handling cookware. Machining methods and waste disposal.

Table 16: Classification of ERM and product geometry

Geometry: product space product dimensions		
Parameters	**Attributes**	**Environmental considerations**
Finishing methods **Deformed shapes and edges**	Efficient blank sheet metal spinning Number of assembly parts for products unvarying thickness Variability in material constituents in assembled parts Repeatability of assembled parts Disc size and metal spinning lathe speed Mandrel shape and dynamics of forming. Cold spinning hot spinning Product stability Wall thickness for metal spinning process. Wrinkling and cracking during metal spinning	Number of deformed products from forging processes. Relation between product dimensional stability and possible accidents. Reduction of heat generated for thick blank sheet spinning. Mandrel shape and Number of rejects before final successful product. Reduction of Number of assembled parts in relation material consumption.

Table 17: Classification of ERM and product aesthetics

Aesthetics : product appeal, product semantics		
Parameters	**Attributes**	**Environmental considerations**
Decorative elements **Affective design** **Novel design**	Surface finish Cultural design Modern design	Effect of annealing recycled aluminium on amount of acid treatment used for shininess of cookware surface. Cultural design appeal and material consumption. Alternative materials for aesthetics and effect on aluminium cookware components such as corrosion.

5.4.3. ERM considerations in product design specifications for cast aluminium cookware

Table 18: Presentation of cast aluminium cookware from case study

						
Stew servers	Boiling pot	Cooking basin	Cooking spoons	Maize shredder	Frying pan	Flat disc pans

Table 19: Presentation of aluminium casting methods and product range

Aluminium casting method	**Cookware Products**
Sand mold casting	boiling pots, boiling troughs, cooking basin Frying basin frying pan, spoons and stew servers
Steel mold Die casting	Flat disc pans, maize shredder gas cooker cylinder grill

Table 20: Classification of ERM and ergonomics

Ergonomics: human interface issues, comfort issues		
Parameters	**Attributes**	**Environmental considerations**
Handles for cookware **Workshop conditions and schedules** **Physical hazards** **Psychological hazards**	Types of handles and knobs on cast cookware Surface finish. Artisan's posture for pouring melt. Inadequate studio space and corridors Minimizing furnace accidents Lifting procedures for aluminium melt Protective clothing Vibration from furnace blower Workshop ventilation and hoods Workshop precautions	Injury to users from sharp edges or rough surface finish on cookware. Sufficient working space for artisans and reporting incidents of injury. Short residence time when Working. Exposure to extreme heat from furnace during melt pouring in sand and steel die casting moulds. Reporting of injury severity Proximity of furnace to melt pouring yard. Clear warnings and signs for potential occupational hazards

Table 21: Classification ERM and product performance

Product performance: quality assurance , usability testing		
Parameters	**Attributes**	**Environmental considerations**
Material choice **Product retirement**	Material classification Material weight Vulnerability to corrosion from food types and contaminants.	Migration of chemicals to food. Weight and consumption of materials. Advise to users on appropriate food types and energy for specific cookware.
	Material and cleaning Procedures.	Retirement period before product becomes hazardous. Disposal of cleaning agents
	Cookware expiry period Energy to be applied by user Product defects Material consumption.	Amount of waste material generated in manufacturing process. Number of defects and rate of recycling. Anodizing to prevent corrosion.

Table 22: Classification of ERM and design

Design : models, patterns ,project design process		
Parameters	**Attributes**	**Environmental considerations**
Documentation **Customer feedback**	Mold design Templates patterns Number of cast section Compatibility of assembled parts Project design steps. Considerations in design execution. Reverse engineering	Prototype material durability. Cast durability. Design for minimal material consumption. Minimize number of cast sections to reduce rejects and tooling. Number of design steps before product actualization. Number of iterations before reliability is achieved in relation to material consumption.

Table 23: Classification of ERM and product environment

Product environment: contamination and pollution		
Parameters	**Attributes**	**Environmental considerations**
Exposure to pollutants **Energy requirements** **Potential hazards**	Fumes and dust from furnaces Appropriate furnace temperatures Waste generated by sand molds and die cast moulds Type of energy in use Biomass and mineral fuel	Cleaning and recycling used sand. Reusable moulds Number of casts and use of energy sources. Fumes from aluminium alloy melting. Cleaning recycled aluminium. Determining safe sources of recycled aluminium in terms of previous use. Determining compositions in aluminium alloys before melting. Number of casting errors and energy consumption. Safety measures in using sources of fuel.

Table 24: Classification of ERM and product geometry

Geometry : product dimensions, product space		
Parameters	**Attributes**	**Environmental considerations**
Mold quality **Finishing methods** **Quality of materials**	Exposure of defects through machining Appropriate temperature for pouring aluminium melt Quality of sand Separation of alloy constituents e.g. aluminum from aluminium zinc alloy Cast cookware distortion Die cast mold reliability Repeatability	Amount of tooling to achieve cookware dimensionality. Mould geometry and consumption of aluminium. Casting processes that can be done locally without flaws and wastage of material. Reusable moulds. Separation of impurities from scrap aluminium metal. Casting sand disposal.

Table 25: Classification of ERM and aesthetics

Aesthetics : product appeal, product semantics		
Parameters	**Attributes**	**Environmental considerations**
Decorative elements **Affective design** **Novel design**	Surface finish Cultural design Traditional motifs Modern design Display methods	Disposal of Chemical compounds used in finishing cookware surfaces. Cultural design appeal and number of mold sections and impact on efficient use of energy and waste material generated. Material consumption on decorative elements. Choice of sticker brand labels and chemical migration to cookware.

The classification of environmental considerations under the product design specification is not supposed to be treated as an exhaustive taxonomy. New materials and designs of cookware are being introduced to the artisanal workshops. The impact of these new materials and methods of production should be scrutinized to make a more comprehensive classification.

5.4.4. Alternative uses for recycled aluminium metal

According to the findings established in the study the workshop owners do not have appropriate technology to handle aluminium efficiently. The lack of facilities for testing for toxic substances and checking appropriate melt temperature demands for alternative uses for aluminium as a material. Workshop owners in the casting shops have observed this deficiency in technology and are producing products that are not used for cooking. The products range from machine parts decorative finials applied on curtain rods and floral additions for door panels and gates, table stand bases (Ref Figure 59 and 60) and weighing scales used by retail traders.(Ref Figure 62 to 63).

Figure 59: Cast floral patterns and a restaurant table stand base

Source: Author

Figure 60: Die cast decorative finials

Source: Author

Figure 61: Sand casting workshop for parts of weighing scales

Source: Author

Figure 62: Cast weighing scale base and sections

Source: Author

Figure 63: Finishing process and an assembled weighing scale

Source: Author

5.4.5. Alternative metal surface treatments

Anodizing is one method that is recommended for coating aluminium cookware. The coating reduces the potential of cookware corroding when in contact with heat and the cooking process. The major challenge is to acquire standard facilities for coating cookware in the informal workshops.

5.4.6. Reduction of cookware defects

Artisans in the casting workshops require training on hazards associated with the production and use of cookware. This can be achieved by collaborative training with formal institutions. The sharing of knowledge should be taught in the informal context as the artisans are not academically oriented and operate in rudimentary conditions of production.

5.5.7. Areas for further research

- Aluminium sheet metal spinning was identified in the research results as a successful method in cookware production. This technique is reliable in the manufacturing of identical cookware that require the quality of repeatability. The spinning process is not labour intensive. The craftsman works on a single lathe and can produce a considerable number of items within a short period. Studies on the spinning process need to be done to establish the level expertise by artisans in the informal metal work clusters.The posssibilities of using different metals such as copper with the spinning process can be explored within the context of informal workshops.
- Artisanal aluminium cookware is faced with major challenges such as corrossion and contamination. Studies on achieving coatings that are resistant corrosion within the informal workshops are necessary. An economic survey can be conducted to to gauge the feasibility of coating artisanal aluminium cookware with glazes that are derived from local sources.

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7.0. APPENDICES

7.1. Work schedule

Table 26 work schedule for research project

SCHEDULED TASK	MONTH					
	JUNE 28, 2017	OCTOBER 10, 2017	NOVEMBER 17, 2017	JANUARY 30, 2018	FEBRUARY 14, 2018	FEBRUARY 28,2017
Concept note presentation to supervisor						
Preliminary proposal thesis presentation						
Presentation of research preliminary findings to supervisor						
submitting of project proposal report to school						
Submitting of draft project report to supervisor						
Project report presentation seminar						

7.2. Financial considerations

Table 27: Brief on research project budget estimates

Item	Description	Cost
Fees	Visitors registration at the Kamukunji Jua Kali Welfare Association office(Ref Figure 67)	5,000.00
Miscellaneous costs	Travel time, during reconnaissance study and field research work and data collection	3,000.00
Project presentations	Printing and binding costs for project reports	4,500.00
Consultation time	Project report corrections and editing	2,000,00

7.3. Case study area map

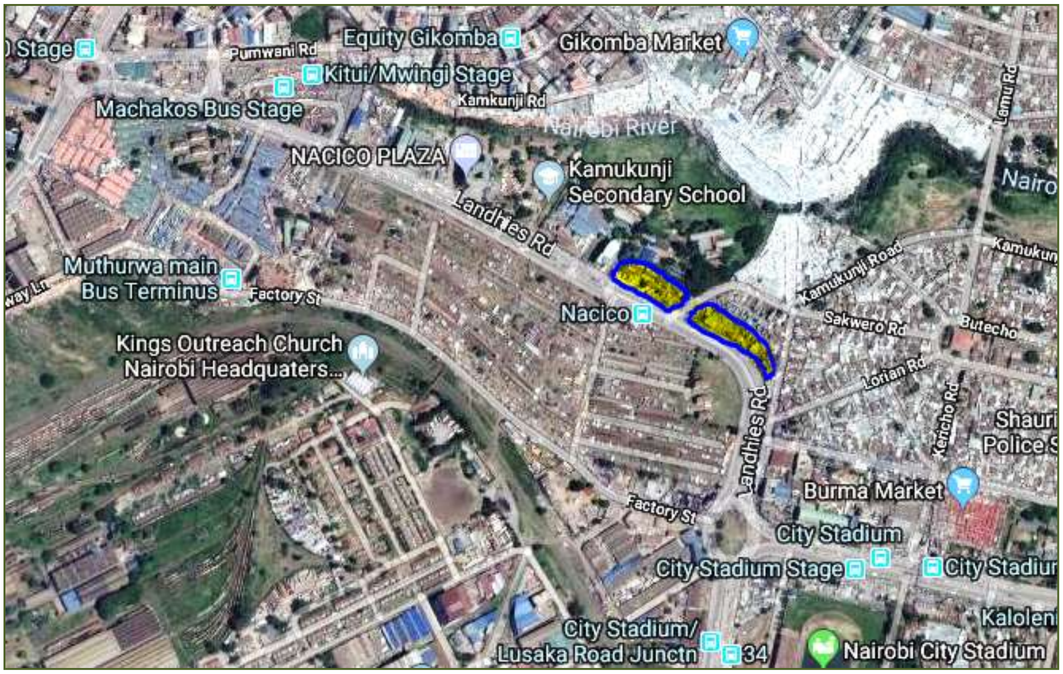


Figure 64: Case study area map Kamukunji cluster marked in blue outlines

Source: https://www.google.com/maps/

Figure 65: Location for National Jua kali Demonstration and Training Center

Source: https://www.google.com/maps/

Figure 66: Map location of input suppliers (Marked in blue) for Aluminium casting in Kariobangi Nairobi County

Source: https://www.google.com/maps/

7.4. Research permission document from case study area


RECEIPT

JUAKALI KAMUKUNJI
ASSOCIATION PROJECT

No. 3595

Date: 10-10-2017

Received from SAMUEL M.K. NKUUBI

the sum of shillings THREE THOUSAND ONLY

TO PAY KSH. 2000 LATER

Being payment of: Monthly Contribution (Month).

With Thanks

Kshs. 3,000/=

Cash/Cheque

Figure 67: Registration fees receipt

Source: Author

7.5. Images from reconnaissance study

Figure 68: Fabricated sheet aluminium boiling pots at the cleaning stage at Kamukunji

Source: Author

Figure 69: Furnace for annealing metal at Kamukunji

Source: Author

Figure 70: Cast aluminium pots and lids at the finishing workshop at Kamukunji

Source: Author

Figure 71: Cleaning section of an informal workshop

Source: Author

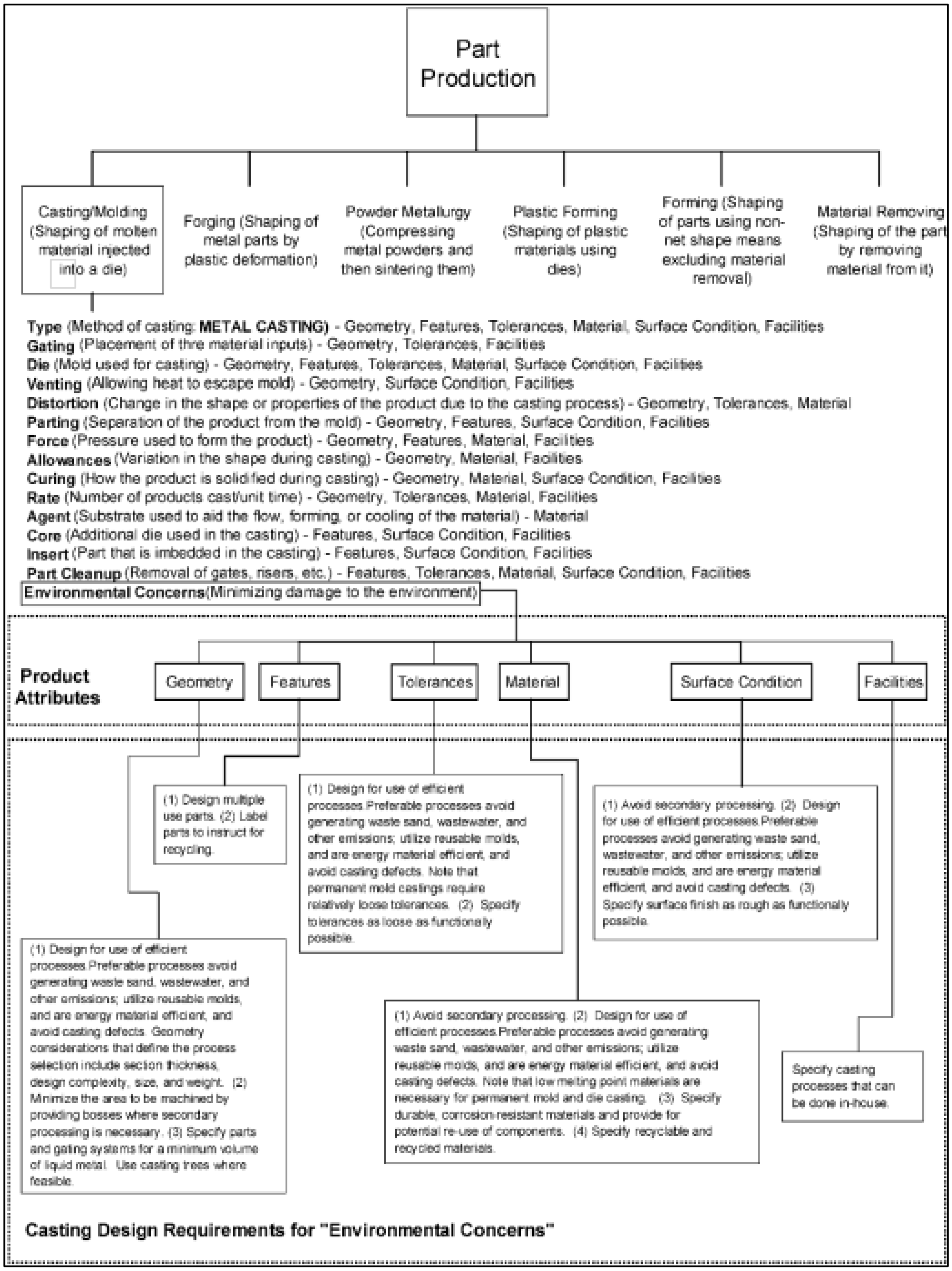
7.6. Contact detail for key informants

Table 28: Contacts for Kamukunji Jua Kali Association leadership hierarchy

Name	**Designation**	**Contact details**
Eliud mbiyu	Chairperson	+254 722 277 092
Joseph Nyaoro	Treasurer	+254 726 970 671
Dan Odhiambo	Assistant treasurer	+254 721 961 229

7.7. Sample taxonomy of ERM from literature

Table 29: Design requirements for environmental concerns .Source: (Rounds & Cooper, 2002)



7.8. Questionnaire

UNIVERSITY OF NAIROBI

SCHOOL OF THE ARTS AND DESIGN

<u>RESEARCH TITLE</u>

PRODUCT DESIGN SPECIFICATION FOR ARTISANAL ALUMINIUM COOKWARE: A CASE STUDY OF LANDHIES ROAD PRODUCERS

<u>Purpose for the study</u>

To propose product design specification for the production of artisanal aluminium cookware by informal workshops.

<u>INSTRUCTIONS</u>

<u>TICK/FILL APPROPPRIATELY</u>

<u>Demographic data</u>

1. Gender Male ☐ Female ☐

2. Name of enterprise/workshop

…………………………………………………………………………………………………
………

3. Training level/channel Apprentice ☐ Certificate ☐
Diploma ☐ Degree ☐

4. Previous employment
…………………………………………………………………………………………………

5. Position in workshop
………………………………………………………………………………………………...

6. Workshop capacity

Large ☐

Medium ☐

Small/jua kali ☐

7. Products range

…………………………………………………………………………………………………
…………………………………………………………………………………………………

<u>To establish the design deficiencies in artisanal aluminium cookware</u>

1. Do you have drawings or sketches of the aluminium cookware you make?

   a) Yes ☐
   b) No ☐

2. Do your assistants have access to the drawings/ As an assistant or apprentice do you have access to the drawings?

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……………….……………………………………………………….………………………
………………..

3. What other methods do you employ in creating designs apart from drawings and sketches?

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………………..………………………………………………………..……………………

4. How do you generate ideas for the design of aluminium cookware?

   a) Reproduction of successful designs ☐
   b) Restyling existing products ☐
   c) Creative thinking ☐

5. What methods do you use to keep a record for reference on acquired knowledge on the process of restyling or iteration of your designs?

   a) Prototypes ☐
   b) Models ☐
   c) Photographs ☐
   d) Templates ☐
   e) Written description ☐

6. Which method do you think is effective in the preservation of knowledge/ideas on cookware production.

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7. Which of the following do you think are some of the defects you experienced in the production of aluminium cookware?

a) Leakages ☐
b) cracks ☐
c) Open pores on cast surfaces ☐
d) Irregular dimensions ☐

8. Identify any other defects apart from the ones above?

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…………………………………………………………………………………………...

9. Are the defects on the aluminium cookware caused by the following factors?

a) Choice of raw materials ☐
b) Workshop conditions ☐
c) Finishing methods ☐
d) Technical skill ☐
e) Basic facilities ☐
f) Storage facilities ☐

10. Explain your choice above choice above.

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<u>What are the hazards associated with the production of aluminium cookware?</u>

1. Which of the following do you think are hazards you are exposed to in the production of aluminium cookware?

a) Fumes and dust from furnaces ☐
b) Exposure to weather elements ☐
c) Noise pollution ☐
d) Explosions ☐
e) Burns /extreme heat ☐

2. Indicate any other hazards.

………………………………………………………………………………………

3. Which of the following hazards do you think customers are exposed to when using artisanal aluminium cookware?

a) Migration of chemicals from cookware to food ☐

b) Corrosion of cookware ☐

4. What are the causes of the hazards above?

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<u>Do the informal workshops have appropriate strategies in the production of cookware?</u>

1. Do you think recording the production process in making aluminium cookware is necessary or Important?

a) Yes ☐

b) No ☐

2. If yes give reasons for recording

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3. Which of the following is the source of your raw materials for cookware?

a) Recycling scrap metal ☐

b) Off cuts from Manufactured sheet metal ☐

c) Standard sheet metal ☐

4. How do you determine the quality of scrap or sheet metal?

a) Eye recognition and selection ☐

b) The source of the material ☐

5. Give any other method of scrap selection

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6. Are you conversant with the following classification of scrap aluminium?

a) Wrought ☐

b) Cast ☐

7. What methods do you use to classify aluminium scrap?

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8. What energy sources do you use for production of cookware?

a) Fossil fuel ☐

b) Solar ☐
c) Biomass ☐

9. Are methods of production energy intensive or energy efficient?

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10. Do you have alternative energy sources for production of cookware?

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11. How do you organize your workshop for efficient production of cookware?

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12. Do you consider the physical look of the cookware as being important to the users of cookware?

……………………………………………………………………………………………………

13. Do you allow customers to determine the design of cookware or you use standard designs?

a) Yes ☐
b) No ☐

14. What liquids do you use for product finishes and machining processes?

a) Fossil mineral based ☐
b) Water based ☐

15. Indicate others

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16. How do you clean your products for your market customer?

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19. Which of the following are sources for contamination during the production of aluminium cookware?

a) Sweat from touching ☐
b) Dust from environment ☐
c) Smoke from vehicles or other workshops ☐

d) Proximity to toilet facilities. ☐
e) Workshop conditions ☐

<u>What are the standard product specifications for aluminum designs of cookware?</u>

1. Do you have a method of testing the quality of aluminium cookware?

a) Yes ☐
b) No ☐

2. Are you able to determine the following from the cookware you produce?

a) What energy source should be used on specific cookware? ☐
b) Appropriate methods for food preparation for specific cookware ☐
c) Shelf life for cookware ☐
d) What foods are appropriate for specific types of cookware ☐
e) Capacity the cookware can handle ☐
f) Maintenance needed for cookware ☐
g) Cleaning methods to be practiced by users of cookware ☐
h) Stage for disposal of cookware ☐

3. Are you able to quantify or measure above parameters?

a) Yes ☐
b) No ☐

4. If yes how is it done?

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…………………………………………………………………………………………………

5. What surface finishing methods do you use on the cookware?

a) Dry machining ☐
b) Anodizing ☐
c) Buffing ☐
d) Texturing ☐
e) Painting ☐

6. Which of the surface finishes do your customers prefer?

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…………………………………………………………………………………………

7. Does your workshop have the capacity to apply anodized surface finish on cookware?

a) Yes ☐

b) No ☐

8. What fluids or liquids are used in the finishing and machining methods for aluminium cookware?

a) Vegetable based oil ☐

b) Fossil fuel based ☐

c) Water ☐

9. Give reasons for your choice of machining fluids.

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10. Are the machining fluids easy to recycle and re-use?

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………………

11. How do you recycle the used machining fluids for aluminium cookware?

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12. Have you heard of green machining?

a) Yes ☐

b) No ☐

13. If yes have you applied it in the production of cookware?

a) Yes ☐

b) No ☐

14. How do you dispose fluids used for machining aluminium cookware?

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15. What are the appropriate workshop conditions for manufacturing of cookware?

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16. Do you consider customer sentiments in determining the design of cookware?

a) Yes ☐

b) No ☐

17. Explain your choice above

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18. What do the customers demand in terms of design?

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Sign:

…………………………………………………………………………………………………

………………

<u>RESPONDENT CONTACT DETAILS</u>

Name: …………………………………………….

Telephone: ……………………………………….

Email: ……………………………………………

<u>Observation check list</u> **Tick the appropriate choice following parameters in use by artisans on a scale of** **1. strongly agree** **2. agree** **3. disagree** **4. don't know** **5. Strongly disagree**	**1**	**2**	**3**	**4**	**5**
Aesthetics					
Environmental sustainability approaches in manufacturing					
Quality assurance methods					
Design methods					
Appropriate Material selection methods					
Advise on Maintenance requirements					
Application of ergonomics					
Application of geometry					