

STUDYING THE DESIGN PROCESS IN CONSTRAINED ENVIRONMENT: AN EMPIRICAL APPROACH TO ANALYZING INFORMAL METAL WORKING ENTERPRISES IN TANZANIA

Keshwani, Sonal (1);
Jagtap, Santosh (2);
Opiyo, Eliab Z. (3)

1: Dayananda Sagar University, Bengaluru India;
2: Indian Institute of Technology, Guwahati, India;
3: St. Joseph University, Tanzania

ABSTRACT

Product design is one of the key features of intellectual and creative abilities of humans.

Activities of product design have attracted not only experts, but also those without any design training. Many people - working in metalworking microenterprises in the informal sector of developing countries - engage in the activities of designing and manufacturing products. However, since extant design research is mainly undertaken in developed countries, there is scarce knowledge about design activities in informal metalworking microenterprises in developing countries. This paper aims to address this issue by uncovering some aspects of design processes in such microenterprises. In particular, we explored: various product attributes that these microenterprises consider in designing products, the process steps they follow in requirements identification and solution generation, and resources (e.g., design methods, training, etc.) available to them. To explore these aspects, we conducted semi-structured interviews in 24 informal metalworking microenterprises in Tanzania. The findings have important implications for supporting their design activities.

Keywords: Conceptual design, Design practice, Sustainability, Design process, Developing Countries

Contact:

Keshwani, Sonal
Dayananda Sagar University
India
sonalkeshwani@gmail.com

Cite this article: Keshwani, S., Jagtap, S., Opiyo, E. Z. (2023) 'Studying the Design Process in Constrained Environment: An Empirical Approach to Analyzing Informal Metal Working Enterprises in Tanzania', in *Proceedings of the International Conference on Engineering Design (ICED23)*, Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.322

1 INTRODUCTION

The processes of designing products provide maximum scope to create socially, economically and environmentally sustainable products (e.g., Ulrich and Eppinger, 2007). The scientific discipline of 'design research' aims at developing systematic knowledge about design processes (e.g., Papalambros, 2015). In order to develop this structured knowledge and because design activities depend on the context (e.g., Subrahmanian et al. 2020; Jagtap 2019), there is a demand to study design processes in a broad range of socio-cultural and economic contexts, including metalworking microenterprises in the informal sector of low-income countries. Despite this demand, existing design research typically focuses on Western and relatively affluent regions of the World. As there are considerable social, cultural and economic dissimilarities between enterprises operating in the informal sector of developing countries and those in Western countries, there can be differences in their design processes (e.g., Jagtap, 2019). It is therefore important to investigate design activities in informal metalworking microenterprises in developing countries. Knowledge about design activities in such microenterprises also aids the development of effective methods and training programmes to assist them in creating more successful products, and thereby in generating employment opportunities for low-income and marginalised people in developing countries.

Because issues in the informal sector are multidimensional, researchers from several disciplines have studied it. About one-third of the non-agricultural workforce around the World has a main job in an informal enterprise (e.g., Williams et al., 2015). Previous studies estimate that microenterprises, which typically employ fewer than 10 people, constitute a large proportion of the informal sector. Most of these microenterprises are involved in making some types of products (e.g., Donaldson, 2006; Kabecha, 1998).

Because design research typically focuses on organisations in developed countries, which are highly different from informal microenterprises in developing countries (e.g. Jagtap, 2019; Donaldson, 2006; Nichter and Goldmark, 2009), there is lack of systematic knowledge about design activities in such microenterprises. In order to support design practices in informal microenterprises, it is important to know product attributes these microenterprises consider in their design processes, various steps they follow in identifying requirements and generating solutions, and different kinds of resources they use in their design activities. However, there is lack of knowledge about these aspects. This research aims to address these gaps in design knowledge through qualitative investigation of the following aspects of design processes in metalworking microenterprises from the informal sector of a developing country: (1) product attributes that the informal metalworking microenterprises consider in designing products; (2) the process steps that they follow in identifying requirements and generating solutions; and (3) various resources (e.g., design support software, training, capital investment, etc.) available to them. We explored these questions as they have important implications for supporting design practice in the microenterprises. In addition to their importance for supporting design practice in microenterprises, the findings regarding the above three aspects contribute to design knowledge. This is discussed further in the paper (Section 5 and 6). In order to explore these aspects, we conducted semi-structured interviews in 24 metalworking microenterprises (referred to as Firm A to Firm X in this work) from the informal sector in Tanzania.

Following this introduction, the remaining paper is organised as follows. Whilst Section 2 reviews requisite background literature, Section 3 presents details of the research methodology, providing information on participants in the study and data analysis. Section 4 presents findings gleaned from qualitative analysis of data collected in 24 microenterprises in Tanzania. Finally, Section 5 discusses findings, and Section 6 discusses conclusions and limitations of this study.

2 BACKGROUND LITERATURE

2.1 Research into design activities

In order to gain insights into the nature of design phenomena, design researchers typically collect and analyse empirical data collected using a broad range of methods, including interviews (Cross, 2006; Jagtap et al., 2014). Findings gleaned from such analysis have revealed many attributes of design processes. For example, it is generally accepted that designers use various types of resources such as design methods and tools, and design processes include iterative tasks such as needs-identification, concept generation, and defining product details. (e.g., Dorst & Cross, 2001; McMahon, 2012). Many

critical decisions are made in a design process. As such, a design process determines the market success and other qualities of eventual products (e.g. Ulrich and Eppinger, 2007). It needs to be noted that these characteristics of design processes have been revealed mainly from research undertaken in developed countries as there is lack of design research in informal sector in developing countries.

2.2 Informal sector and design

People in developing countries work either in the informal or formal sector. There are large differences between these two types of sectors. Whilst people working in the formal sector are protected by labour laws, get a monthly salary, and have regular working hours, those in the informal sector lack this protection provided by labour laws. In addition, they lack orderly work conditions (e.g., Jagtap, 2019; Webb et al. 2013). Although the informal sector in developing countries has been studied by researchers from multiple disciplines such as economics, anthropology, social science, etc. (e.g. Rakowski, 1994), research undertaken in the informal sector has been minor given the large extent of this sector. Some estimates suggest that the informal sector contributes about 40 to 60% to the GDP of developing countries (Schneider and Enste, 2013), while employing about 31.5% of people from non-agricultural domain (e.g. Jagtap, 2019). This shows that the informal sector is a large part of the economy in developing countries. However, there is scarce design research in the informal sector, despite the fact that people without formal education in design have the ability to design products and that there is presence of activities of product design in the informal sector.

Manufacturing microenterprises in the informal sector of developing countries exhibit several common characteristics. For example, they typically rely on existing resources and materials, operate in markets that are not regulated, and lack organisational and marketing resources (e.g. Jagtap et al., 2013a; Donaldson, 2006). Extant studies in this sector suggest that these microenterprises face many constraints, including among others, those related to availability of materials and manufacturing facilities, formal design training, etc. Despite these constraints, they can design and manufacture products (e.g. Donaldson, 2006; Muller, 2010; Cozzens and Sutz, 2012). Whilst microenterprises operating in the informal sector of developing countries have the ability to design products, researchers have given little or no attention to their design activities. Extant studies have typically given attention to many other aspects of these firms, but not to their design activities (e.g. Donaldson, 2006; Cozzens and Sutz, 2012). A recent comprehensive review in this field has identified a crucial need to examine how informal metalworking microenterprises in developing countries design products (e.g., Jagtap, 2019).

3 METHODOLOGY

In design research, numerous studies have employed interviews to collect data for exploring various design topics (e.g., Jagtap, 2022). In this study, we carried out interviews to explore some aspects of design activities in informal metalworking microenterprises in Tanzania. As previously mentioned, these aspects include: product attributes that these microenterprises consider in designing products, steps they follow in identifying requirements and generating solutions, and various resources available to them. In the following paragraphs, we present information on the ways in which the interviews were conducted, participating subjects, and the method of data analysis.

Table 1. Firm characteristics and information on two participants from each firm

Firm characteristics			Information on two participants from each firm		
Firm	Firm age (years)	# staff	Completed education	Age (years)	Experience (in years)
A	1-5	4	Bachelor's degree (engineering) and O level	26-30, 31-35	1-5, 1-5
B	1-5	3	Bachelor's degree (engineering) and Vocational training	26-30, 16-20	1-5, 1-5
C	15-20	4	Vocational training and STD II	26-30, 21-25	6-10, 1-5
D	5-10	5	Both subjects - Primary School leaving certificate	26-30, 21-25	6-10, 1-5
E	10-15	3	Both subjects - STD VII	31-35, 21-25	11-15, 1-5
F	1-5	6	Both subjects - STD VII	21-25, 26-30	6-10, 1-5
G	5-10	2	Both subjects STD VII	26-30, 21-25	6-10, 1-5

Firm characteristics			Information on two participants from each firm		
H	5-10	2	Bachelor's degree (business administration) and STD VII	31-35, 15-20	6-10, 1-5
I	1-5	4	Both subjects - STD VII	21-25, 21-25	1-5, 1-5
J	1-5	2	Both subjects - STD VII	26-30, 11-15	6-10, 1-5
K	1-5	7	STD VI and STD VII	26-30, 21-25	6-10, 1-5
L	11-15	3	STD VI and STD VII	22, 28	3, 10
M	5-10	4	STD VI and STD VII	23, 32	3, 8
N	5-10	4	VETA and STD VII	35, 30	10, 9
O	5-10	8	BA Degree-Public Relations and Form IV	32, 27	5, 3
P	1-5	4	Artisan (Vocational Training), Form IV	29, 23	15, 6
Q	5-10	20	Form IV, Diploma in Public Administration	20, 24	2, 5
R	5-10	4	Form IV, Form IV	24, 27	5, 2
S	5-10	4	Bachelor Degree in Education, Diploma in Mechanical Engineering	26, 51	5, 2
T	1-5	5	STD VII, STD VII	23, 22	7, 1
U	1-5	7	Form IV, Form IV	33, 28	11, 7
V	5-10	4	Form IV, Vocational training	18, 30	1, 4
W	15-20	4	STD VII, STD VII	36, 25	20, 6
X	15-20	3	STD VII, STD VII	28, 25	10, 5

By using direct communication plus chain referral sampling (e.g., Bryman 2004; Jagtap, 2018), we recruited subjects from 24 metalworking microenterprises from the informal sector of Dar es Salaam and Coast Region of Tanzania. Table 1 presents information on these firms and participating subjects. The firms were selected randomly to ensure that they are provided with equal chances of being chosen. This guaranteed unbiased representation of the population. The firms make many different types of products (see Figure 1). Table 1 also presents information on education of the participants. In Tanzania, educational system is as follows: 7 years of primary school (i.e., STD I - VII), followed by 4 years of Secondary School (i.e., Ordinary Level – O level), and then 2 years of Advanced Secondary School (i.e.,Advanced Level). Then, students may attend college for 3 to 4 years.



Figure 1. Some examples of products manufactured in the microenterprises: metal suitcases & charcoal stoves, corn threshing machine, and charcoal oven.

We conducted semi-structured interviews with two subjects from each of the 24 metalworking microenterprises (e.g., Gravy, 2013; Breakwell, 2006). Of these two subjects, one subject served as a spokesperson and the other facilitated arranging resources. These roles refer to their roles in the interviews. The interviews aimed at exploring some aspects of design activities mentioned in Section 1. The resource person arranged resources, e.g. verification of information provided by the spokesperson, while providing clarifications when required. In total, 48 subjects participated in this study. Most of these subjects lack formal design training, and all are males.

We interviewed all subjects at their firms. Figure 2 presents some examples of work-conditions in the firms. Prior to each interview, we sought informed consent from the participants to interview them and to audio-record the interview for further transcription and data analysis. The conversations in the interviews were around a specific project about design and manufacturing of a product. The conversations focused on attributes considered in designing products—to this end, the interviewer relied on the interviewee's knowledge on what product attributes are, steps followed in requirements identification and concept generation, and available resources.



Figure 2. Examples of working conditions and practices in the microenterprises: outdoor workbenches and showcasing spaces.

We carried out the interviews in the local 'Swahili' language. Audio recordings were transcribed and translated into English for further analysis that used an iterative and inductive approach (e.g., Gray 2013). The findings of data analysis are presented in the section that follows. We have included quotations from the transcripts to explain the findings. These quotations are translated into English and are edited for easy understanding. Any additional information is included in brackets at the end of quotations.

4 FINDINGS

The knowledge of how informal metalworking microenterprises in developing countries develop products is very scarce (Opiyo et al., 2022, 2023). This work contributes to the efforts aimed at filling this gap in this knowledge. In these interviews, we specifically explored the product attributes that the informal metalworking microenterprises consider, and various steps they follow for the identification of requirements and concept generation. We also inquired about the availability of resources such as design support software, training, and production equipment. Table 2 below summarises the findings of the study, and the following subsections present the findings in detail.

Table 2: Summary of major findings

Aspect	Investigated issue	Finding	Respondents(out of 24)
Product attributes	What are the most important considerations when developing products in informal metalworking microenterprises?	Innovativeness, aesthetics, functionality	18
		Environmental friendliness, manufacturing cost, usability	11
Major clients	Who are the major clients?	Private companies, individuals	23
Major job orders	Which major job orders do the informal metalworking microenterprises receive?	Building construction resources, metal furniture, household utilities, agricultural equipment, light machinery	24
Requirements and solutions identification steps	Which particular steps do the microenterprises follow in identifying requirements and generating solutions?	1) Identification of needs, 2) Sketching, 3) Specifications and costing, 4) Manufacturing	16
Steps needed to improve operations	Which steps can be taken to improve operations in informal metalworking microenterprises?	Design and entrepreneurship training, and more capital to improve operations.	24
Difficulties faced	Which difficulties do the microenterprises face?	Responses varied widely	N/A
Awareness and usage of design support software	Do the informal metalworking microenterprises use design support software?	Most enterprises are unaware of usage of design support software.	18
Design training	Do the designers have relevant knowledge and skills pertaining to their job?	Firms reported that they did not receive any formal training	Invariably all firms

4.1 Product attributes

An aim of this study was to know the attributes that these informal metalworking microenterprises consider when designing products. The respondents were asked to indicate the aspects considered when designing products and to rate the importance of the product attributes they consider. 18 out of 24 microenterprises indicated innovation, aesthetics and functionality as the most important attributes. In contrast, 11 out of 24 microenterprises indicated environmental friendliness, manufacturing cost, and usability as the most important attributes.

4.2 Clients

23 out of 24 informal metalworking enterprises indicated that the major clients of informal metalworking microenterprises are individual persons and private companies who come to press orders of the products they need. Only one informal metalworking enterprise indicated that it gets orders from public institutions.

4.3 Major job orders

The major job orders that informal metalworking microenterprises receive are presented below. The products are typically made-to-order in small numbers of units or batches by using low-cost hand-operated or powered production equipment.

- Building construction resources: Aluminium window and door frames, door frame grills, steel gates, door, movable kiosks, office space partitioning, window grills.
- Metal furniture: Bed frames, reading table frames, dressing tables, chair/couch frames, television stands.
- Household utilities: Cooking utensils, charcoal cooking stoves, charcoal grill stoves.
- Agricultural equipment: Various designs of chicken feeding utensils, gardening implements.
- Light machinery: Grain shelling machines, flour milling machines, brick making machines.

4.4 Steps followed in identifying requirements and generating solutions

It has been found that informal metalworking microenterprises do not strictly follow design process for requirement identification and concept generation. 16 out of 24 interviewed informal metalworking microenterprises indicated that they start by identifying needs of the clients, then sketching concepts, followed by negotiating with clients to agree on final specifications (i.e., dimensions, functional and aesthetic features, material types) and costs of the product, and finally manufacturing the designed product. See some of the interview excerpts below.

... we took the following particular steps: 1) exploring the needs/ discussion with the client, 2) sketching (rough sketches of concepts), 3) negotiation of price, 4) manufacturing, [Firm W, Charcoal stove grill]. Section 4.4.1 – 4.4.4 explain the various aspects of requirement identification and concept generation followed by these firms.

4.4.1 Requirement Identification

To identify the customer needs and the requirements for the products, the developers in these firms typically interact with clients, in some instances, visit them at their sites to explore and agree on the needs and formulate solution concepts. Conversations between the developers and customers are documented variously, namely by taking hand-written notes, drawing rough sketches; or by taking photos. However, in some cases, the developers only listen and recollect the conversations.

Informal metalworking microenterprises generally do not compile comprehensive lists of requirements, make prototypes, systematically select material or prepare detailed drawings of the intended products. In some instances, e.g., when the required product resembles those previously produced, the microenterprises only gather specific requirements, then agree with the customer on price, and then start production right away. See some of the interview quotes below.

... just exploring the needs of clients and generating concepts, followed by negotiation of prices and advance payments and manufacturing [Firm V, door grills, window grills].

... we just use our past experiences to modify designs and manufacture the products [Firm U, Aluminium windows and doors]

4.4.2 Concept generation

Typically, after requirement identification, designers use ideation methods to arrive at the concept sketches. However, these firms arrive at the solutions directly from the requirement list without implementing intermediary steps such as functional analysis or design methods (Chulvi et al., 2012). In our interviews, 19 firms reported that they directly arrive at the design solution without intermediary steps. Here are some excerpts in support of this observation:

...directly arriving at the final solution, we are unaware of other approaches to conceptual design. [Firm N, window grills, bed frames, furniture like table frames, chairs, etc.]
...showing sketches, discussing with client and arriving at a final solution, use past experiences [Firm V, doors and windows grills, gates.]

4.4.3 Deciding the dimensions of products

Formal dimensional specifications are obtained by taking measurements on site and others are decided on based on past experiences. They also reported studying the existing comparable products in the market for dimensions and that the customers provided the dimensions of the product. Here are some excerpts in support of this.

We used standard dimensions for stoves that conform with the dimensions of the pots and other commonly used home cooking utensils. [Firm G, doors and windows grills, gates.]
The main dimensions of window and door grills were taken on site. Decoration feature dimensions were established based on experience. [Firm E, door and window grills, furniture, furniture frame]

4.4.4 User feedback on the concepts and products

To understand if the customer requirements have been met, they typically take customer feedback or compare the product with the requirement checklist. It was found that there was an active involvement of the customer in the design and manufacturing of the products. 11 out of 24 firms reported that they took client feedback and 2 firms reported that they compared the product with the existing products in the market. Some excerpts in support of this are the following:

By directly asking the client to confirm whether or not the requirements have been met [Firm F, Aluminium windows and door]
Discussion with the client throughout the development and production [Firm P, Windows and door grills, fence gates, bed frames]

4.5 Design support software

Design support software exists catering to various activities of the designers such as ideation, sketching, modelling, simulation, and costing. While there are multiple software tools used to support each of these stages, we found that few firms use drafting software like AutoCAD. While 18 out of 24 firms reported that they were unaware of software used for designing, only 3 firms reported using AutoCAD. For ideation and concept representation, they reported doing hand sketches. No support software tools seemed to be used for the other design related activities. Here are some interview excerpts to support our observation.

No, I am not aware of any, but I heard there are some design support software [Firm D, metal/steel gates, door and window grills, furniture]
....none, I use hand sketches [Firm E, Door grills, gates, dressing tables, bed frames, TV stands]
No, I have not heard on any designing software [Firm K]

4.6 Difficulties faced by the designers

We also wanted to know the difficulties that the designers and product developers in informal metalworking microenterprises face in the completion of project development projects. Responses varied widely, ranging from inability to meet the requirements for products for various reasons, inaccurate estimation of product cost, inability to produce the designed products using in-house manufacturing resources, and unavailability of suitable materials. Below are some of excerpts of these responses:

Some of the requirements could not be met, e.g., due to limitations of production equipment. [Firm D, metal/steel gates, door and window grills, furniture]

... our budget estimate did not match reality... [Firm E, Door grills, gates, dressing tables, bed frames, TV stands]

Lack of equipment required to manufacture PVC products.... to bend thicker plates and sections; [Firm F, Aluminium windows and door]

Unavailability of suitable quality materials—the available materials cannot be used to produce quality products [Firm N, steel furniture]

Informal metalworking microenterprises address these difficulties in various ways, for instance, by subcontracting works elsewhere or changing specifications for products—see some of the quotes below.

...we renegotiated and changed product specification; [Firm D, metal/steel gates, door and window grills, furniture]

... the firm sub-contracted the works elsewhere, [Firm G, charcoal cooking stove]

... we chose alternative materials that satisfy the requirements [Firm N, steel furniture]

Six firms reported having the shortage of quality raw materials as a major difficulty. Two firms reported power outages as the main problem, and two firms reported fluctuation in the price of raw materials. Some excerpts to support our observations are:

'Budget estimates did not match reality. The advance payment was not enough. The price of raw materials changed/raised.' [Firm E, Door grills, gates, dressing tables, bed frames, TV stands]

'Lack of equipment required to bend thicker plates and sections.' [Firm G, doors and windows grills, gates.]

'Our main difficulty is small capital. We cannot invest in modern production equipment.' [Firm H, Bed frames, door grills, steel gate]

'Transport costs, Power outage' [Firm Q, Aluminium widows and door grills, partitioning of rooms]

Apart from the difficulties mentioned above, five firms reported that they faced difficulty in arriving at the dimensions. Three firms reported that the sketches alone were not sufficient to explain the concept to the client in full detail. Here are some excerpts from the interviews as evidence:

... yes, it is difficult to sketch the actual shape/appearance [Firm E, Door grills, gates, dressing tables, bed frames, TV stands]

... inability for some clients to comprehend the sketches [Firm F, Aluminium windows and door]

...some sketches and pictures brought by some clients don't have dimensions [Firm H, Bed frames, door grills, steel gate]

...A customer can bring a drawing or a photo which can either be smaller or larger. By just looking at the photo, it makes you wonder what the actual dimensions of the product are, in order to fabricate the intended product [Firm P, Widows and door grills, fence gates, bed frames.].

We also tried to understand how they addressed these difficulties. To address the difficulty related to the explanation of concepts through sketches, they mentioned solutions like sketching multiple views or showing photos of the comparable products. With regard to arriving at the dimensions of the product, they mentioned using the past experience, discussion with the client and observing the comparable products as the main solution strategies. Some excerpts are presented below as evidence:

...sketching multiple views and using pictures of similar existing products to explain my ideas about the product. [Firm E, Door grills, gates, dressing tables, bed frames, TV stands]

...discuss with clients and use our past experiences to decide on some of the dimensions [Firm H, Bed frames, door grills, steel gate]

4.7 Measures to improve the operations

All interviewed informal metalworking microenterprises aspire to improve their operations. Some of the steps that can be taken to improve operations in informal metalworking microenterprises include providing them with training on product development and entrepreneurship and capital mobilisation i.e., to raise more capital needed to invest in modern production equipment and other facilities. See some of the interview excerpts below.

... we need more investment in modern machines and knowledge... training on entrepreneurship, capital investment to expand our business, [Firm H, Bed frames, door grills, steel gate].

... if we get capital, we will invest in modern manufacturing equipment and open additional facilities elsewhere; [Firm I, door and window grills, furniture metal frames].

4.8 Training

Typically, enterprises provide training to the employees to impart the relevant knowledge and skills pertaining to the job. However, all the firms reported that they did not receive any formal training. Some excerpts supporting our observation are the following:

...no, I never had professional training on prototyping [Firm C, Furniture, tables, chairs, beds, couches]

...no, I only learn by seeing and doing at my friends' workplaces [Firm G, doors and windows grills, gates.]

...no, never attended a formal training [Firm P, Widows and door grills, fence gates, bed frames.]

5 DISCUSSION

The reported work contributes to knowledge on how informal metalworking microenterprises in developing countries identify requirements for products and generate solutions. It was observed that the product development process in informal metalworking microenterprises are not iterative and start by identifying needs of the clients, then concepts are developed, followed by negotiating with clients on final specifications and costs, and finally manufacturing of the products. Critical dimensions are established by visiting the site, while other dimensions are determined using prior experience or by referring to the existing products. We found that the majority of these firms are not aware of the existing design software. These firms arrive at the design solutions without much ideation and sketching is the most common method of concept representation. This is in contrast to product development in well-established firms, where it is a structured process with clearly demarcated steps and sets of activities which entails systematic execution of activities such as needs and requirements elicitation, concept development, concepts design and prototyping, detail design, and manufacturing or product realisation (Dieter and Schmidt, 2009; Opiyo, 2003).

The differences can be attributed to the fact that there are notable social, cultural and economic differences between enterprises operating in the informal sector of developing countries and those in developed countries. The differences between the traditional product development and the ways in which informal metalworking enterprises develop products are therefore expected. In general, the product development activities, e.g. the activities in the initial stages of identification of needs and requirements and conceptual design are influenced by the context in which those activities are performed. It should be noted here that the informal metalworking microenterprises oftentimes face various constraints such as lack of formal training on product development or resources needed, which obviously has an influence on the way they perform product development activities. It was also found that innovativeness, functionality, aesthetics and manufacturing cost are the most important attributes that the designers in these microenterprises consider. This can also partly be attributed to the context in which the informal metalworking microenterprises operate, e.g., the kinds of job order that informal metalworking microenterprises typically receive.

6 CONCLUSIONS AND RECOMMENDATIONS

This work investigated the design process followed by informal micro-enterprises in Tanzania. 24 firms were interviewed, in real settings, using a structured questionnaire. The following are the main conclusions drawn towards the design process of these firms: a) complete or partial unawareness of established design processes, method standards and tools; b) no access to standard training procedures or software support; c) consideration towards innovativeness, functionality, aesthetics and manufacturing cost as the most important attributes; d) active involvement of customers in the design and development process –termed as tacit co-design by Opiyo et al. (2023). The last conclusion (d) was unexpected as co-design - a recent approach, was found to be followed intuitively with no prior introduction or training. These contributions can have several implications such as: a) the observations from this work can be used for developing improvement measures such as bespoke design methods, tools and training modules for resource constrained environments; and b) the finding that design process is context sensitive should be considered in design decisions. The questionnaire was created in

English and converted into Swahili. The interview transcripts were converted from Swahili into English. This must have influenced our findings. However, our findings align with prior knowledge of design practices in resource-constrained enterprises in other developing countries (see, e.g. Donaldson, 2006; Kabecha, 1998). Future studies include quantitative analysis of the current work, comparative analyses of the design process for informal micro- enterprises in developed and developing countries, and investigation of co-designing in resource constrained environments.

ACKNOWLEDGMENTS

This work was funded by the Swedish Research Council.

REFERENCES

- Breakwell, G. M. 2006. "Interviewing Methods." In *Research Methods in Psychology*, edited by G. M. Breakwell, S. Hammond, C. Fife-Schaw, and J. A. Smith, 232–253. 3rd ed. London, UK: SAGE.
- Bryman, A. 2004. *Social Research Methods*. 2nd ed. Oxford, UK: Oxford University Press.
- Chulvi, V.; Mulet, E.; Chakrabarti, A.; López-Mesa, B.; González-Cruz C. (2012). Comparison of the Degree of Creativity in the Design Outcomes Using Different Design Methods. *J. Eng. Des.* 23(4): 241-269. <https://dx.doi.org/10.1080/09544828.2011.624501>
- Cozzens, S.; Sutz, J. (2012). *Innovation in informal settings: a research agenda*. IDRC, Ottawa, Canada.
- Cross, N. (2006). *Designerly ways of knowing*: Springer.
- Dieter, G. E, and Schmidt, L. C (2009) *Engineering design* McGraw-Hill, 4th ed.
- Donaldson, K. M. Product design in less industrialised economies: constraints and opportunities in Kenya. *Research in Engineering Design*, 2006, 17(3), 135-155.
- Dorst, K.; Cross, N. Creativity in the design process: co-evolution of problem-solution. *Des. Stud.*, 2001, 22(5), 425e437.
- Gray, D. E. 2013. *Doing Research in the Real World*. London: Sage.
- Jagtap, S., Larsson, A., &Kandachar, P. (2013). Design and development of products and services at the base of the pyramid: A review of issues and solutions. *International Journal of Sustainable Society*, 5(3), 207-231.
- Jagtap, S. (2018). Intentions and inspiration in shaping visual appearance of products: the practice of professional industrial designers in india. *The Design Journal*, 21(1), 85-107.
- Jagtap, S. Design and poverty: a review of contexts, roles of poor people, and methods. *Research in Engineering Design*, 2019, 30(1), 41-62.
- Jagtap (2022) Co-design with marginalised people: designers' perceptions of barriers and enablers, *CoDesign*, 18:3, 279-302, <https://dx.doi.org/10.1080/15710882.2021.1883065>
- Kabecha, W. Technological capability of the micro-enterprises in Kenya's informal sector. *Technovation*, 1998, 19(2), 117-126.
- McMahon, C. A. (2012). Reflections on diversity in design research. *Journal of Engineering Design*, 23(8), 563e576.
- Müller, J.; (2010). Benefit for change: Social construction of endogenous technology in the South. Paper presented at the FAU Conference-Workshop 4 on Community Entrepreneurs and Local Economic Development.
- Nichter, S.; Goldmark, L. Small firm growth in developing countries. *World Dev*, 2009, 37(9), 1453-1464.
- Opiyo E.; Jagtap S.; and Keshwani. S. (2022) "Conceptual Design in Metalworking Microenterprises: An Empirical Study in Tanzania", *International Design Conference – Design 2022*, pp. 2493-2502, <https://doi.org/10.1017/pds.2022.252>.
- Opiyo, E., Jagtap, S., &Keshwani, S. (2023). Conceptual Design in Informal Metalworking Microenterprises of Tanzania. *Sustainability*, 15(2), 986.
- Opiyo, E. Z.; *Facilitating the Development of Design Support Software by Abstract Prototyping*, Ph.D. Thesis, Delft University of Technology, ISBN 90-6734-136-3, 2003.
- Papalambros, P. Y. *Design Science: Why, What and How*. *Design Science*, 2015, 1(1), 1-38.
- Rakowski, C. A. (1994). *Contrapunto: The informal sector debate in Latin America*: SUNY Press.
- Schneider, F., Enste, D.H. (2013) *The shadow economy: an international survey*: Cambridge University Press, Cambridge
- Subrahmanian E, Reich Y, Krishnan S (2020) *I are not users: dialogues, diversity, and design*: MIT Press
- Ulrich, K. T.; Eppinger, S. D. (2007). *Product design and development*: McGraw-Hill
- Webb, J.W.; Bruton G.D.; Tihanyi L, Ireland RD Research on entrepreneurship in the informal economy: framing a research agenda. *J Bus Ventur* 2013, 28(5):598–614
- Williams, C.C.; Shahid MS, Martínez A (2015) Determinants of the level of informality of informal micro-enterprises: some evidence from the city of Lahore, Pakistan. *World Dev.* 84:312–325.