ANALYSIS OF THE BARRIERS TO THE ADOPTION OF INDUSTRIAL ENGINEERING DESIGN METHODS AND TOOLS IN THE AGRICULTURAL AND AGRI-FOOD SECTORS IN WEST AFRICAN COUNTRIES.

ABSTRACT

Growth in the agricultural and agri-food processing sectors is crucial to food security and economic development in West African Countries. In Burkina Faso, local equipment manufacturersplay a leading role in these fields. Furthermore, equipment design methods and tools have evolved from a linear approach to parallel engineering. Indeed, they integrate major context-specific constraints such as manufacturing, maintenance, and the user's point of view. The aim of this work is to carry out a literature review of equipment design methods and tools applied in West African Countries, and to analyze their adoption by local equipment manufacturers. This enabled us to identify the methods and tools used, and the difficulties encountered by local equipment manufacturers in adopting them. These difficulties include: the lack of training of local equipment manufacturers, the unfamiliarity and complexity of the methods and tools, and above all the unsuitability of the methods for the understanding of local equipment manufacturers, since they were initially intended for design teams. As a result, we were able to envisage a design approach close to local equipment manufacturers perception. Field surveys will enable us to refine this study and formalize a new, simplified approach adapted to the perception of local equipment manufacturers.

Keywords: Design tools and methods, Local manufacturers, Design teams, West African countries, Agri-food and agricultural equipment, Burkina Faso

1. INTRODUCTION

The mechanization of agriculture and agribusiness is a major challenge for the development of West African countries (WAC). When actors in the sector need high-performance equipment adapted to local conditions, they usually turn to locally produced equipment [1]. However, while locally manufactured equipment meets the need for proximity, it often has limitations in terms of performance and reliability. To improve the competitiveness of such equipment and to meet the specific needs of farmers, many innovative design methods have been developed. [2]highlights the diversity of design issues and the need to develop a range of adapted methods. [3]lists about forty methods, of which value analysis, QFD and NPD are the most widely used. Methods specific to the context of developing countries have also been proposed, such as the CESAM method (Conception d'équipements dans les pays du

Sud pour l'agriculture et l'agroalimentaire)) [4]or the DFMSN developed by [5]. In particular, the latter aims at improving the availability of equipment in small agri-food units in West Africa.[6-8]highlights the importance of integrating logistics, maintenance, and hygienic and nutritional food quality into equipment design. [9]proposes a methodology for an integrated approach to equipment eco-design in agro-equipment manufacturing SMEs. Several other studies, in particular those [10, 11]and [12, 13],[14, 15]have respectively emphasized the importance of considering the user, maintenance and the socio-technical network in the design process. Despite the relevance of these methods and tools, their adoption by local manufacturers remains limited. The aim of this study is to review the literature on design methods and tools used in WAC for the design and manufacture of agri-food and agricultural equipment. This review will allow us to analyze the difficulties associated with the adoption of these methods and tools.

2. MATERIAL AND METHODS

First, the research question was clearly formulated: What are the barriers to the adoption of industrial engineering design methods and tools? The scope of the study was then narrowed to include only the agri-food and agricultural sectors in West African countries. Scientific journal articles and theses dealing with equipment design and manufacturing were consulted in databases such as Google Scholar, Scopus, Web of Science and JSTOR. Finally, these articles were analyzed to identify the methods and tools used and any barriers to their use.

We refer to local manufacturers (LM) as those who manufacture, sell and/or install agro-food and/or agricultural equipment. They have the ability to read industrial plans and have a level of education limited to the baccalaureate. Design team: a multidisciplinary team with a level of education higher than the baccalaureate that carries out design and/or manufacturing projects.

In the rest of this article, we'll look at design methods such as the traditional method, which is defined as a sequential, structured approach to product design. It is characterized by a linear progression through defined stages with minimal backtracking. [16]presents a traditional design process. Frugal design is a design approach that aims to create efficient, high-quality solutions using a minimum of resources [17]. User Centered Design (UCD), which places the user at the center of the development process, is a methodological approach that aims to understand users' needs, expectations, and behaviors in order to design solutions that are useful, usable, and desirable to them. The so-called agile methods, which have similarities with UCD, are new methods that are being proposed in new design projects. Initially developed for software development, they have gradually gained ground in other fields, notably industrial engineering. Their use in industrial engineering has been tested by [18]. The Experimentation-Modification design method is an iterative approach to design in which a prototype is created, tested under real or simulated conditions, strengths and weaknesses are identified, and necessary modifications are made before the cycle begins again. The steps are described in [19]. [20]shows how to achieve low cost, which is a strategic approach aimed at significantly reducing the cost of producing a product or service while maintaining sufficient quality to meet consumer expectations. The world of design has not remained on the sidelines of artificial intelligence, as we are witnessing the birth of generative design. This is a revolutionary approach to computer-aided design (CAD) that uses artificial intelligence and algorithms to generate multiple design options based on specific parameters and constraints. [21] shows the changes that the development of a generative design system will bring to manufacturing.

3. RESULTS AND DISCUSSION

Table1. listing agricultural and agri-food equipment design and manufacturing projects in West African countries.

No.	Equipment project	Method	Tools	Country
1	Tuber cutter [22]	Functional analysis	HornedBeast Octopus diagram FAST CAD Prototyping	BURKINA FASO
2	ATESTA Dryer [23]	Functional analysis	Octopus diagram Functional Specifications FAST MCA CAD Prototyping	BURKINA FASO
3	Grain threshers [24]	Functional analysis	Octopus diagram Functional Specifications FAST CAO Prototyping	BURKINA FASO
4	Direct seeder [25]	UCD	CAD Simulation Prototyping	BENIN
5	Hybrid solar dryer [26]	Frugal conception	CAD Simulation Prototyping	BENIN
6	Portable maize dryer [27]	Traditional Method	CAD Simulation	GHANA
7	Séchoir de feuilles de Moringa [28]	Traditional Method	CAD Prototypage	GHANA
8	Hammer Mill [29]	Redesign	CAD Simulation Prototyping	GHANA
9	Rotary roaster [30]	Traditional Method	CAd Prototyping	GHANA
10	Forced Convection Solar Dryer [31]	Traditional Method	Prototyping	GUINEE
11	Amaranth seed drill [32]	Low-Cost conception	CAD Prototyping	NIGERIA
12	Motorized plantain slicer [33]	Traditional Method	CAD Prototypage	NIGERIA
13	Cereal Grinder [34]	Traditional Method	CAD Simulation Prototyping	NIGERIA
14	Manual Hydraulic Palm Oil Press [35]	Frugal conception	CAD Prototyping	NIGERIA
15	Bicycle Sprayer [36]	Traditional	CAD	NIGERIA

		Method	Prototyping	
16	Dual Function Seed and Fertilizer Spreader [37]	Traditional Method	CAD Prototyping	NIGERIA
17	Dryer for pounded yam flour [38]	Traditional Method	CAD Prototyping	NIGERIA
18	Semi-automatic cassava planter [39]	Frugal conception	CAD Prototyping	NIGERIA
19	Direct seeding under vegetative cover with animal traction [40]	Experimentation-Modification	CAD Prototyping	SENEGAL
20	Design of organic manure spreader [41]	CESAM	Prototyping	TOGO

Design Methods Used in Equipment Design Projects

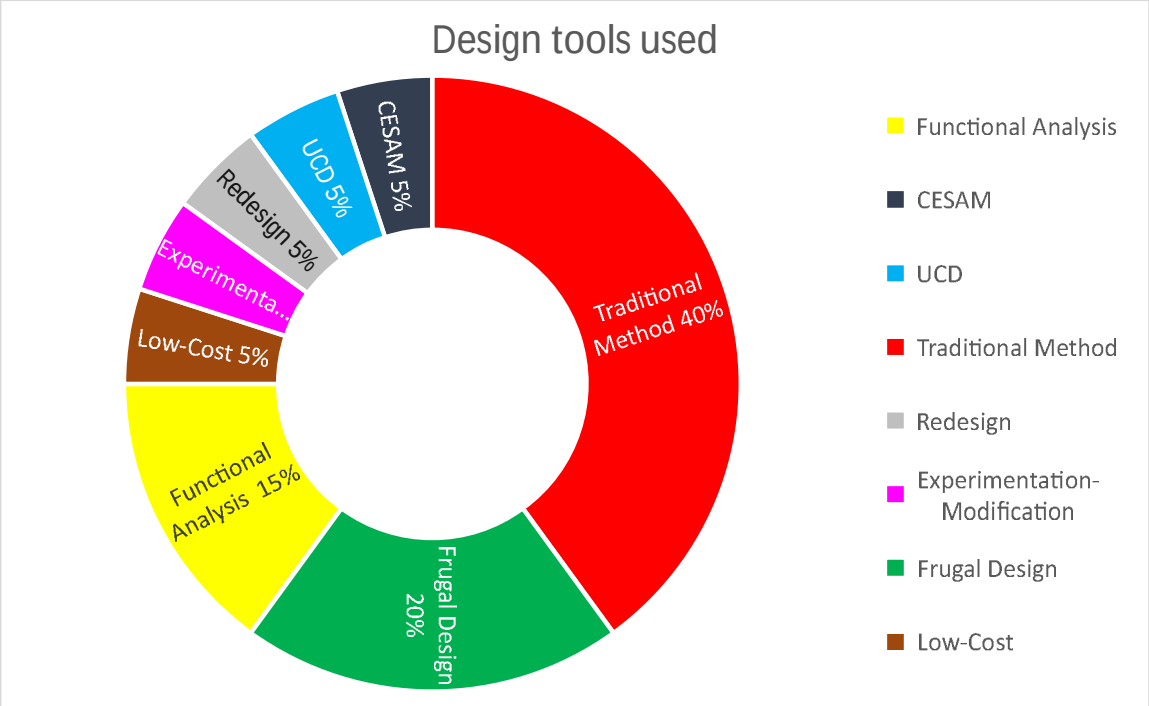

Fig.1.Design methods used in West African countries for the design of agricultural and agri-food equipment.

Figure 1 shows the different design methods used in the agricultural and agro-food sector in WAC. It clearly shows that the traditional method is the most widely used with a representation of 40%. [4]had already noted the dominance of the traditional method, but the difference is that today we are witnessing the use, albeit timid, of other design methods such as the frugal method at around 20%, followed by functional analysis at 15%, which shows that design teams are beginning to optimize the equipment development cycle. Several factors may explain this situation. First, the other methods may be less well known. Second, they may be more complex and costly to implement. Finally, these methods may not be suitable for WAC.

Design Tools Used in Device Design Projects

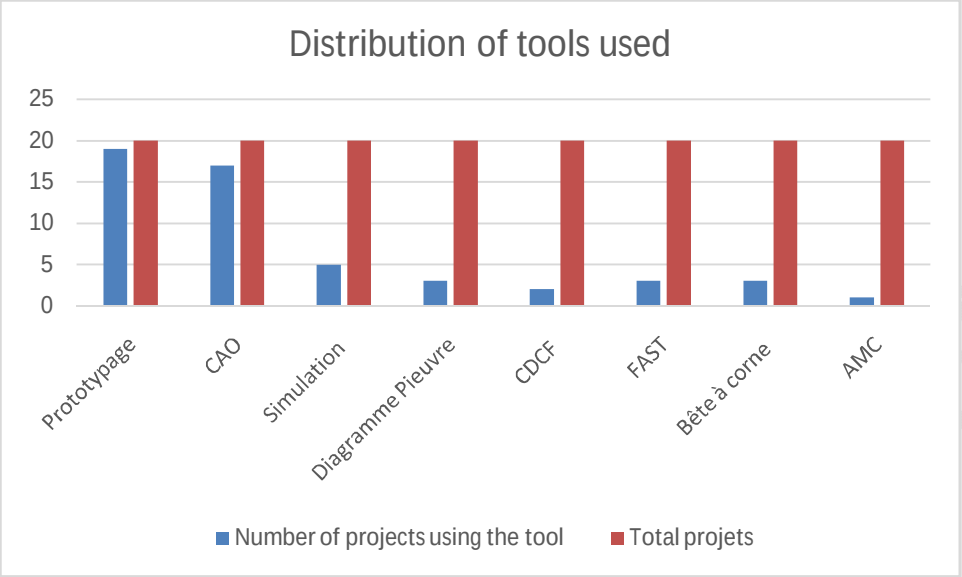

Fig.2.Design tools used in West African countries to design agricultural and agri-food equipment.

Figure 2 shows that the most commonly used tools are prototyping and computer-aided design (CAD). The dominance of these tools can be justified by the fact that they significantly speed up the design and production processes, while reducing the costs associated with product development. What's more, they act as mediating objects [42], fostering effective collaboration between design teams.

Simulation is increasingly used because design teams have a better understanding of CAD. However, tools such as the octopus diagram, Functional Specifications, and FAST are not widely used because they are likely to require more time and a multidisciplinary team, thus increasing development costs. Other design tools, such as FMEA [43], or in general tools that use quantitative or qualitative criteria, are also little used. These criteria, which are generally measurable or evaluated, require the use of historical data, which is often not available. The question is why tools that use feedback from design teams to evaluate these criteria are not used?

Discussion

The literature review revealed a diversity of methods and tools used in the design of agricultural and agri-food equipment in West Africa. In contrast to methods used in northern countries for large-scale industrial production, the methods and tools identified are used to design small-scale equipment, generally with one or two functions that can be easily produced locally. Our preliminary findings suggest similarities with practices observed in India, particularly in terms of traditional, low-cost and frugal design.

While traditional methods and tools such as prototyping and CAD continue to dominate, more innovative methods are emerging that promote more reliable design. Unfortunately, these innovative methods do not include some of the newer methods such as generative design and agile methods. However, the available data is still limited. Due to the lack of

scientific literature on the subject, our analysis focuses mainly on the practices of design teams and does not fully reflect the practices of local manufacturers, which represent the majority of equipment suppliers.Is it a lack of knowledge, a lack of training of the actors involved, as highlighted by [44], the difficulty of implementation or the incompatibility of these methods and tools with the local context?

To better understand the reasons behind these methodological choices and to identify the obstacles to the adoption of new practices, it would be appropriate to conduct field surveys among a representative sample of local agricultural and agri-food equipment manufacturers. This survey would complement our literature review and provide qualitative data on the perceptions, needs and constraints of LM.

4. CONCLUSION

This study has provided an overview of the methods and tools used to design agricultural and agri-food equipment in West African countries. The traditional method is still widely used with a rate of 40%, but is losing ground compared to previous years. In terms of tools, prototyping and CAD are present in virtually all design projects. The results also underline the scarcity of scientific productions in the majority of WAC dealing with the methods and tools used in equipment design projects. This situation probably limited our results, as we were only able to touch on the practices used by design teams to the detriment of local manufacturers. Since local manufacturers are one of the main sources of supply for agricultural and agri-food equipment, this leads us to ask the following question: are the design methods originally intended for design teams adapted to local manufacturers?

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