World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Preliminary of Maintenance Criteria Analysis tool, "PMCA" to integrate maintenance into the design

Frederic Bationo [1,*] and Jean François Boujut [2]

[1] *National Center for Scientific and Technological Research, Research Institute in Applied Sciences and Technologies, Laboratory of Renewable Energy Systems, Environment, Mechanical and Industrial Engineering, 03 BP 7047 Ouagadougou 03, Burkina Faso.*
[2] *Grenoble Institute of Technology in the Industrial Engineering school- Laboratory G-SCOP 46 av, Félix Viallet 38 000, Grenoble, France.*

World Journal of Advanced Research and Reviews, 2022, 16(03), 125–134

Publication history: Received on 17 October 2022; revised on 27 November 2022; accepted on 29 November 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.16.3.1299

Abstract

The objective of this study is to propose a tool for Preliminary of Maintenance Criteria Analysis. It makes it possible to integrate maintenance into the design of agri-food equipment for small and medium-sized enterprises and micro-enterprises in developing countries. It is a graphic tool which is similar to a "maintenance wall" built by the various actors intervening in the life cycle of the equipment and makes it possible to highlight through the "missing bricks" and the profile of the wall the points related to maintenance to be taken into consideration during the definition phase of the equipment. It is based on the ex-ante analysis of the risks of rejection of the equipment to be designed, taking into account the whole of its future social, cultural, economic and technical environment.

Keywords: Maintenance; Agro-food equipment; Participatory design; Preliminary of Maintenance Criteria Analysis

1 Introduction

In Africa and more particularly in Burkina Faso, the agri-food sector is considered to be an engine of agro-pastoral development and a factor of food security. A dynamic of local development in the food industry has been activated, implementing, among other things, on the one hand, the local production or improvement of equipment and, on the other hand, a North-South equipment technology transfer mechanism. One of the major constraints that arises is the sustainable integration of equipment, used in a real environment. The questions of appropriation and sustainability of the use of equipment in the agricultural sector cannot be addressed without taking into account the maintenance and the conditions of use by the end operators [3].

According to a study by the federation of food industries of Burkina (FIAB), in Burkina Faso, out of 180 companies including agri-food processing associations or groups, 62% are of the artisanal type, 37% carry out semi-industrial production and only 1% are considered industrial units. Small-scale and semi-industrial production companies are hampered in their growth by maintenance constraints on their means of production, which consist largely of shelling, milling, drying and oil extraction equipment [3].

For the vast majority of processing equipment, the real local services are provided by the many poorly equipped craftsmen. They are forced to travel to nearby urban centers to do the welding and drilling for the production of spare parts [12]. All these difficulties affect the availability of equipment. How to design equipment that takes into account the realities of the socio-cultural and technical environment but is maintenance-oriented? Is there maintenance specific

* Corresponding author: Frederic Bationo; Email:frederic.bationo@hotamail.com
National Center for Scientific and Technological Research, Research Institute in Applied Sciences and Technologies, Laboratory of Renewable Energy Systems, Environment, Mechanical and Industrial Engineering, Ouagadougou, Burkina Faso.

to southern countries which, once defined, can be integrated into the design of this equipment ? Our problem is part of a participatory design process integrating as a priority for all the concepts of equipment maintenance [3].

The recent emergence of adapted design processes, including the design of equipment for the agro-food industry in developing countries (CESAM method), designed by the Agricultural Research Centre for International Development (CIRAD) does not offer specific tools to integrate service from design [3]. Several authors have worked on the integration of maintenance in the design of equipment of small agro-food units in Africa. Bationo and al (2009a) have shown that this can be done by taking into account the socio-technical networks of maintenance: modelling and analysis of these networks are an essential prerequisite for the design of equipment [4]. Azouma and Giroux (2009) proposed tools and methods to integrate maintenance into the process of designing agri-food equipment for Africa [2]. Bationo and al (2009b) identified significant maintenance indicators for small agri-food units in Burkina Faso that could provide guidance on the design of new equipment [5]. Work in Bangladesh has confirmed the need for co-construction of actors to overcome maintenance difficulties by bringing together manufacturers, importers, traders/wholesalers and retailers in the manufacture of agricultural machinery, but have not proposed specific tools [1]. Bationo and Boujut (2022) proposed the design for the maintenance of the "DFM_{SN}" socio-technical network consisting of a set of guidelines to improve the operational availability of equipment for small agri-food units in West Africa [6]. However, these tools do not allow the various actors in charge of maintenance to make a preliminary analysis of the maintenance of equipment. We offer a design support tool that will allow for the direct participation or involvement of stakeholders grouped by business lines in the process of analysing the constraints to be taken into account in equipment maintenance. In order to provide equipment to agri-food processors in West African Countries (WAC), it is essential to take into account their maintenance at the design stages, given the specific socio-technical and economic context [10].

2 Material and methods

To address these concerns, a field survey is essential to understand maintenance practices. In order to analyze the characteristics of maintenance during the life cycle of four (04) standard agri-food equipment, a survey was carried out among a sample of 28 companies comprising equipment manufacturers, spare parts traders and users in three (03) towns in Burkina Faso. The analysis will concern the three levels of actors in the survey, i.e. understanding their maintenance practices at the design stage, during use and all the support logistics. This involves identifying maintenance indicators by category of actors in charge of maintenance. On the basis of knowledge drawn from the field and analogous concepts for integrating maintenance, a tool has been proposed for a preliminary analysis of maintenance.

2.1. Identification of maintenance criteria by category of actors

The surveys are carried out using the stepping stone method (Shiba, 1995) which allows, with the questioning of only a dozen people, to collect at least 70% of the useful information. It is a question of cross-checking information in information by practicing the Japanese step. "The Japanese step is the way of crossing a river by putting your foot on flat stones and advancing gradually: you step on a stone and then decide what the next step will be". Indeed, it is for example a question of exchanging (figure 1) with the designer / equipment manufacturer of equipment then the users and finally the structures participating in its maintenance. The choice of people to interview will depend on the orientation provided by the previous information [16].

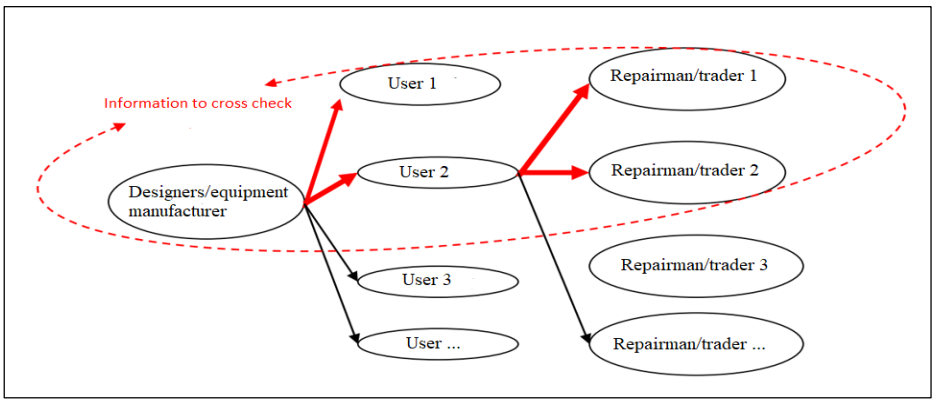

Figure 1 Interview process

Twenty-eight (28) companies were surveyed, including thirteen (13) equipment manufacturers, eleven (11) users and four (04) traders. For equipment manufacturers, there are six (06) small and medium enterprises (SMEs), five (05) micro enterprises (MEE) and two (02) non-governmental organizations (NGOs). For users of agri-food equipment, there are two (02) SMEs, and nine (09) micro-enterprises.

2.2. Similar Works

There are design support tools and methods that allow maintenance to be taken into account in the context of participatory design. Those which take into account the needs of maintenance by feedback, through an in-depth functional analysis of the equipment, without a mathematical analysis are among others: the Preliminary Risk Analysis (PRA) and the Failure Modes, Effects and Criticality Analysis (FMECA) [2]. They propose corrective or innovative actions to improve the equipment. Also the Dependability of operation (Sdf), the integrated logistic support (Sli), the FMECA and the APR were developed taking into account the environment of the company which favors the traceability of the histories and considers the collective knowledge of machinery maintenance. The SMEs and micro-enterprises of agro-food processing in Burkina by their typology are characterized by a scarcity of structured methods. These companies operate with a small staff, the majority of whom are illiterate. Also, the exploitation of performance indicators may lack reliability because of the weak organization of the production activity. As for the cause-effect diagram, which seems to be a simple tool to use by a light team, it is used to pose the potential causes of equipment failure. Unfortunately, it does not make it possible to systematically assess the aspects of maintenance to be taken into account when designing equipment.

The concept of Design for X through the “Design for Assembly” (DFA) and the “Design for Manufacturing” (DFM) are used for the redesign of products or equipment [18-7-17]. They integrate manufacturing and assembly into the design, while the integration of maintenance is specifically driven by Design for Maintenability (DFMt), Design for Reliability (DFR) or Design for Maintenance (DFMAIN) [8-11]. These concepts for the most part aim to solve problems of mass production, complex or very advanced technology in a competitive context of industrialized countries. The design for the "DFM_{SN}" socio-technical maintenance network for the equipment of small agri-food units in West Africa was also proposed to respond to the specific concern of the design of equipment for Small and Medium Enterprises (SMEs) in East Africa. 'West. But it is a tool that uses guidelines to integrate the practices of maintenance network actors in the design of future equipment [6]. We could also cite other concepts such as frugal design focused on reducing product costs by taking into account the low purchasing power of the user as is the case with low-cost [14-15] and respect for the environment [9].

3. Results

3.1. Univariate analysis for the identification of maintenance criteria

The analysis will concern the three levels of actors (companies) in the survey. This is to understand their maintenance practices in design, use and all supporting logistics.

3.1.1. Equipment manufacturers

Of the thirteen (13) equipment manufacturers, seven (07) make adaptation reproductions and use Computer Aided Design (CAD) or the drawing board to define the equipment. The six (06) others make pure copy using copying template. Design teams consist of a maximum of three engineer-level mechanics or experienced technicians. The design is reserved for the engineers while the technicians are simple executors at the manufacturing level. These design teams are not multidisciplinary and the user is not taken into account. The total staff complement varies between ten (10) and ninety-seven (97). Non-Governmental Organizations (NGOs) and Small and Medium-Sized Enterprises (SMEs) are managed by engineers or technicians experienced in mechanical engineering who use the usual rules of mechanical design in a sequential design approach. The criteria (figure 2) that hold the attention of equipment manufacturers are: the availability of the work material (M), the frequency of maintenance (F), the cost (C) and self-maintenance (A). Criteria that are not taken into account such as disassembly and accessibility can be found in the ease of repair.

The two (02) NGOs listed draw up a written guarantee contract (six months) for the monitoring of their equipment. SMEs and micro-enterprises do so verbally and the word given serves as a guarantee. Although this phenomenon is cultural, explain the craftsmen, the lack of control releases the manufacturer from all responsibility for the reliability of its equipment. All equipment manufacturers are also agricultural or industrial equipment maintainers, because the single manufacturing activity is not enough to cover the company's expenses. They also ensure the reproduction and supply of spare parts at the request of the user.

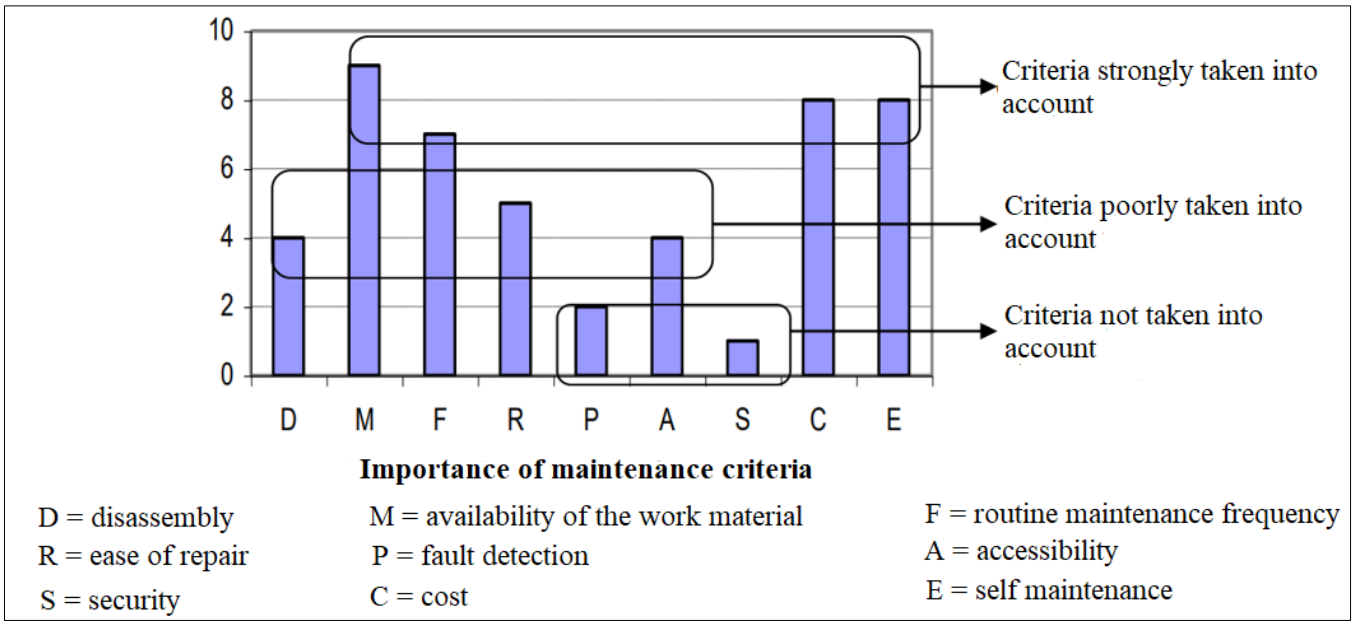

Figure 2 Analysis of equipment manufacturer maintenance criteria

3.1.2. Users

Two (02) SMEs essentially practice corrective maintenance and occasionally systematic maintenance. The use of registers or software for recording the history of failures is being learned in a single SME, and does not yet provide data for the calculation of availability indicators. In these two SMEs, maintenance is provided by a light team (three (03) to five (05) agents) with an average number of staff being eleven (11). The production operator is limited only to handling and cleaning (level one (01) maintenance) of the machine. They do not have spare parts in stock. In the case of the nine (09) Medium Enterprises (ME), corrective maintenance ranging from level two (02) to three (03) is carried out 100% by the operator. The latter takes pleasure in mastering the repair and appreciates the ease of repair of the equipment at the same time. Indeed, self-maintenance requires the local availability of spare parts, financial resources and repair tools (keys). Traceability of failure history does not exist. Estimated repair or uptime is based on memory. A processor will say, for example "every month I change the bearings for a repair of at least half a day" in the case of hullers. These companies do not have maintenance contracts but metal construction operations are subcontracted with equipment manufacturers.

3.1.3. Traders

They confirmed their satisfaction with the sale of the huller. According to them, the supply of spare parts is easy and customers increasingly prefer to buy locally manufactured equipment. Spare parts (pulleys, belts) originally intended for other equipment can be mounted on the thresher.

It appears that the equipment manufacturers who manufacture machines are primarily those who ensure their maintenance. During design, they integrate maintenance criteria which are the availability of local work, the frequency of systematic maintenance, the cost of maintenance and self-maintenance corresponding to level 2 and 3 maintenance 13]. Equipment users, on the other hand, only carry out corrective maintenance without a prior stock of spare parts. In the event of a breakdown, they mobilize either open networks or closed networks [4].

3.2. Presentation of the Preliminary of Maintenance Criteria Analysis (PMCA)

The basic principle of the PMCA is based on the joint construction of a wall by the actors to highlight the potential maintenance problems encountered by a piece of equipment [3]. It plays the role of an intermediary object between the actors because it translates their thoughts, represents their actions and constitutes a support or space for discussion and mediation. The problems of adaptation to maintenance are posed by the common action of the actors. This action results in inter-business collaboration in which the designer or manufacturer is the main facilitator.

It is a question of building a wall whose idea is inspired by a very frequent local practice on the initial conditions for the allocation of a plot to an individual by the town hall. The plot is counted if:

- The individual already lives in the plot
- The house built in the plot is habitable
- The fence of the plot is well done.

In many cases, for reasons of economy or compliance with the notice period, the mason, assisted by the individual, builds on the wall. The town hall checks whether the wall is well built (at least five brick levels) before issuing a housing number. It is therefore a question of building a wall together to avoid difficulties related to maintenance. Indeed, the tool (figure 3) is presented as a wall delimited in the zone by actors (table 1) at a height of five (5) levels or bricks. At least three actors participate in its operation. The subset or element is analyzed from left to right in the direction of the arrow (E) according to the criteria (Table 2). The evaluation is done by coding by checking the boxes from bottom to top.

The coding depends on the appreciation of the actor and is spread over a scale of five (05) levels. The profile (figure 5) of the bricks then makes it possible to assess the state of construction of the wall. Solutions or strategies will be proposed by the actors with the aim of having a wall completely built. The assessment is given according to the coding in Table 3.

Table 1 Definition of actors

Actors	**Definition**	**Area**
Manufacturer / designer	It is characterized by its ability to identify customer needs and materialize them through design (innovative, copy adaptation) and manufacturing.	1
Users	Refers to the category of actor who operates equipment in a company	2
After-sale services/ Dealers	Independent of other actors, they sell spare parts of equipment	3
Other Manufacturers	Refers to those who do the same thing as the first but are located in the background in relation to a technology. They can replicate technology and make replacement parts	4

Table 2 Analysis criteria

Coded	**Criteria : manufacturer**	**Définition**
Ma	Material availability (spare parts)	the availability of the material to reproduce the subassembly
St	Standardization/(Commercial parts)	the availability of the components of the sub-assembly on the market place
Fr	Frequency (breakage, wear)	the reliability (breakage, wear) of the sub-assembly under working conditions (cleaning, greasing, handling)
Au	Self-maintenance (2 to 3 levels)	the qualification of personnel (users or other manufacturer) to maintain the subassembly up to the third level
Co	Cost	financial accessibility of the subset
1	**Criteria : user**	**Definition**
Au	Self-maintenance (level 2 to 3)	Qualification of personnel and repair equipment for level 2 to 3 self-maintenance
Di	Availability of spare parts	Marketplace parts availability
Rp	Ease of on-site repair	Proximity maintenance provided on site by the manufacturer or other manufacturer
Co	Cost	Financial accessibility

Coded	Criteria: Other Manufacturers	Definition
Rp	Ease of on-site repair	Skill and means required for the repair
Fo	Part supply	Possibility of reproducing spare parts
Coded	**Criteria: Trader**	**Definition**
Ap	Part supply	Ease of sourcing
Di	Availablity	Marketplace Subset Density
Ec	Flow	Volume sold
Co	Cost	Financial accessibility

Table 3 Codification

Level / brick	Appreciation
1	None
2	Insuffisant
3	good enough
4	Good
5	Very well

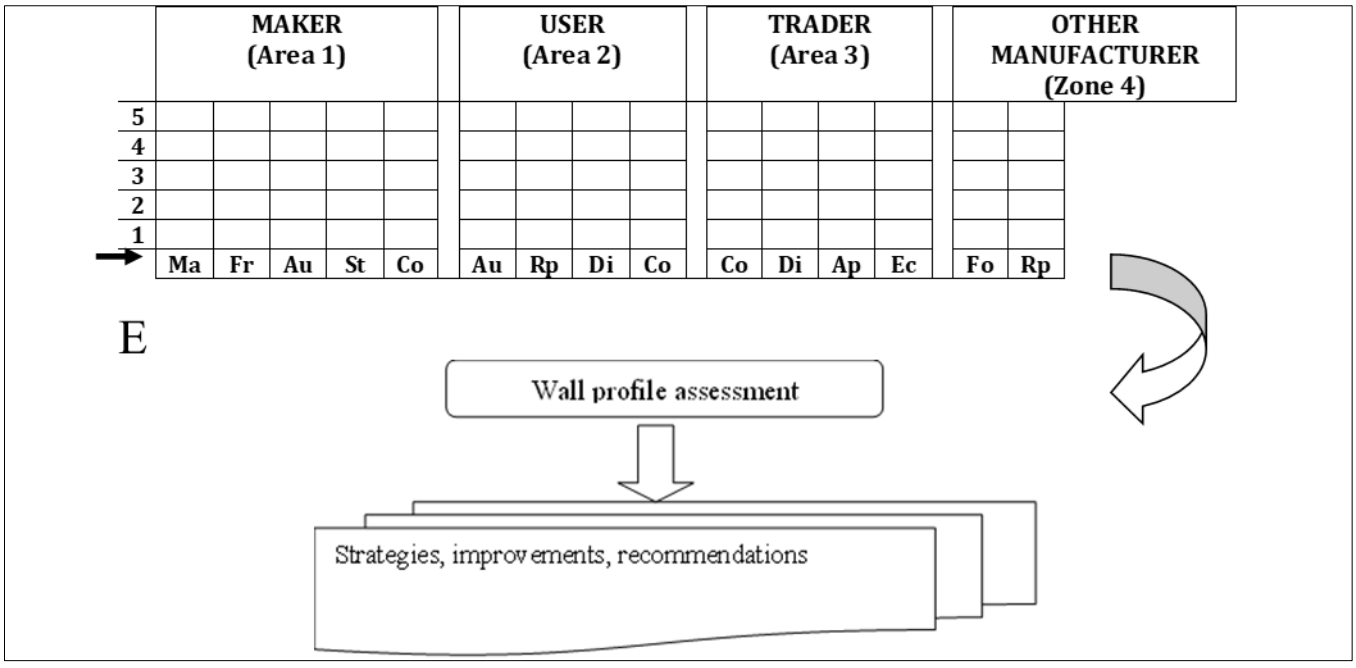

Figure 3 Preliminary Maintenance Criteria Analysis tool (PMCA) [4]

The PMCA tool has been proposed for a complete and effective integration of maintenance from the design of equipment for small agri-food units in Burkina Faso [3].

3.3. Implementation of the PMCA tool

The PMCA implementation project mobilized a multidisciplinary team made up of manufacturers, economists, equipment manufacturers, maintainers and users. The study concerned a preliminary evaluation of the maintenance criteria of a worm screw cottonseed oil press. A team of six (06) actors was brought together for this purpose: the manufacturer, the user, the trader (spare part seller), and another manufacturer ensuring the maintenance of the equipment. The animation was provided by a designer who masters the tool well. The implementation takes place in three phases as shown in Figure 4 below.

3.3.1. Phase 1

Choice of actors, preparation and planning. The step of choosing participants (network actors) is carried out by a design team. The participants are chosen according to the level of expertise in the trade, either in the maintenance, manufacture or operation of equipment to be improved or similar: They must have sufficient experience for agri-food equipment. The maintenance criteria related to the environment are predefined only once by a field survey. These criteria are subject to change depending on the environment. The subassemblies are already known through an internal functional analysis of the equipment.

The animating actor remains the leader of the design team or another member who can manage. The design team plans and prepares the implementation of the following phases.

3.3.2. Phase 2

Analysis of the object by joint construction of the maintenance wall (figure 5). This collaboration step is only possible if at least the technical drawing of the equipment is already defined or the example can be applied to subassemblies or elements of similar existing equipment. The design team (or equipment supplier) is responsible for building their part of the wall without the others. This is to avoid influencing the analysis of the actors. Then, the facilitator will bring together the team of actors for the construction of the wall by an area of intervention. The actors will evaluate the equipment according to the maintenance criteria by checking the boxes. The checked boxes correspond to the level of appreciation and represent the bricks.

3.3.3. Phase 3

Analysis of the general appearance of the profile and proposal. This phase of collaboration consists of identifying the unbuilt parts, then through a common action, to make recommendations for solutions or strategies in order to perfect the construction according to the criteria.

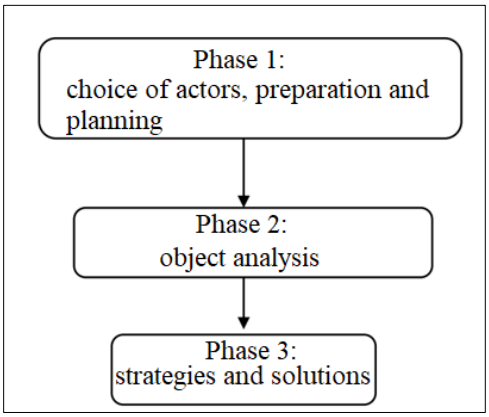

Figure 4 The PMCA implementation phases [3]

The construction results show an incomplete wall. This assumes that at the level of each criterion a solution must be found or guidelines to be taken into account in the design. These orientations are formulated by the actors themselves and not the designer. This evaluation is fast and allows for half a day to have an evaluation of equipment to be redesigned, oriented maintenance. This is the redesign of a 3 tons/hour auger cottonseed oil press. The manufacturer is in charge of almost all the maintenance of the equipment at the expense of the user.

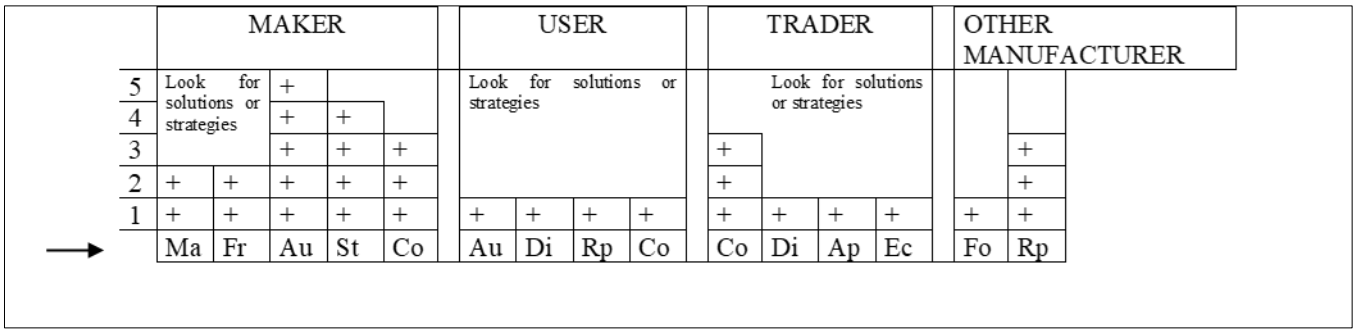

Figure 5 Example of wall built after analysis of a locally manufactured oil press [3]

For the manufacturer

- the availability of the material to manufacture the subassembly must be better taken into account;
- to increase the reliability (breakage, wear) of the sub-assembly, it is necessary to integrate the calculations of resistance of the materials in the design.

For the user

- The equipment must integrate enough, the qualification of the personnel, the equipment of repairs for a self-maintenance of levels 2 to 3;
- The components used must be sufficiently marketed on the local market;
- Take account of local maintenance carried out on the site by the manufacturer or another manufacturer;
- The equipment must be financially accessible.

For the trader

- The components to be identified must be easy to source;
- Use spare parts of equipment widely available in the environment;
- Promote the sale of the manufactured equipment;
- Take into account the purchasing power of traders for the acquisition of components for sale.

These guidelines will be fed back to the design team during the equipment definition phase. These orientations are close to those of DFM_{SN} (06), but dynamic since they vary according to each PMCA team. The sketches of solutions given by the various actors will be analyzed by the design team for their consideration.

4. Discussion

The DFM_{SN} aims to offer equipment that is easy to maintain by a network of actors governed by social ties. It relies on the networks of equipment maintenance players, such as the PMCA. In addition, the DFM_{SN} approaches the design from the angle of significant network indicators, while the PMCA proposes an assessment of the maintenance criteria by stakeholder profession, i.e. a co-constructed action which precedes and prepares for the integration of maintenance in the design of equipment. Then the actors by profession will propose technical solutions so as to fill the missing bricks. These solutions are knowledge and know-how upstream of the design which will eventually be used to orient the design on the maintenance constraints which pose the most problems. Today, the view of frugal design as a target cost approach is nuanced. Indeed, frugal innovation is distinguished from cost-driven innovation (i.e. low-cost alternatives to existing products) because it offers new value propositions, which means new features [19]. "Low-tech," aims to offer simple technology products, without rejecting high-tech. It is a sustainable approach and not a tool like the PMCA [11]. The orientations given by the PMCA tool are dynamic, on the other hand, the guidelines used in the DFM_{SN} are fixed.

5. Conclusion

This work initiates research in industrial engineering in a developing country and ends with a proposal for a tool intended for the integration of maintenance into a participatory design process. The knowledge of the methods of integrating maintenance into the design and the concepts of maintenance served as a reference for the PMCA. This tool

is part of a logic of continuous and collaborative improvement. It is similar to Failure Modes, Effects and Criticality Analysis (FMECA) or Preliminary Risk Analysis (PRA) in its anticipatory action on maintenance problems largely due to the environment. The PMCA results from a field study based on cases of equipment designed by equipment manufacturers according to a maintenance orientation. This orientation in the design activity was dealt with by all the actors in relation to maintenance and was formalized in different criteria. These criteria are similar to those of integrated logistics support and self-maintenance because they characterize the environmental conditions in terms of maintenance. The criterion of self-maintenance (level 3 and 4 maintenance) carried out by a majority of users and taken into account by equipment manufacturers shows the specificity of the consideration of the human dimension. Also, the criterion such as the availability of the work material shows the dependence on the environment. It can be presented as an intermediate object between the business actors and also between the design team. However, coordination, communication and organizational difficulties may arise during the collaboration phase. Using such a tool also means taking local manufacturing issues into account. But the PMCA has a good chance of succeeding in its objective based on the recommendations and strategies developed by the actors:

- They are familiar with these criteria;
- The construction of the wall is a usual practice;
- The advantage of being informed, of participating or of being consulted for the creation of new equipment is a mobilizing element. Nevertheless, it must be applied in several equipment design projects and certainly enriched.

Compliance with ethical standards

Acknowledgments

We would like to thank the French Embassy in Burkina Faso, International Centre of Cooperation in Agricultural Research for Development, National Polytechnic Institute of Grenoble and Research Institute in Applied Sciences and Technologies for their contribution to this study.

Disclosure of conflict of interest

The authors have no conflicts of interest to disclose in this article.

References

[1] Alam, M.M., Khan, M.I.N., Saha, C.K., Rahman, A., Bhuyian, M.G.K. Manufacturing of agricultural machinery in Bangladesh : Opportunities and constraints. Agricultural Engineering International: CIGR Journal. 2017; 19(1), Art. 1. pp.122-135.

[2] Azouma, O.Y., Giroux, F. Maintenance Integration in Equipment Design Process for Africa. Bangladesh Journal of Scientific and Industrial Research. 2009 ; 44(3), Art. 3. pp.319-326.https://doi.org/10.3329/bjsir.v44i3.4405.

[3] Bationo, F. Proposition d'une démarche structurée et intégrée de la maintenance industrielle dans le cadre d'une méthode de conception participative (CESAM) (Burkina Faso) [DEA en génie industriel, Institut National Polytechnique de Grenoble], 2003 ; 41p.

[4] Bationo, F., Marouzé, C., Boujut, J.F., Giroux, F. Disponibilité opérationnelle et coûts de réparation des équipements dans les petites unités de transformation agroalimentaire au Burkina Faso. Sciences Naturelles et Appliquées. 2009a ; 3(1 et 2), Art. 1 et 2. pp.33-44.https://revuescience-techniqueburkina.org/index.php/sciences_naturelles_et_appliquee/article/view/612.

[5] Bationo, F., Marouzé, C., Boujut, J.F., François A. Giroux. Socio-technical networks: a tool for integrating the maintenance dimension in the design of equipment for small food-processing units in West Africa. J. Design Research. 2009b ; Vol. 8, No. 1, pp.23-41.

[6] Bationo, F. and Boujut, J.F. (2022). Design for the socio-technical maintenance network "DFM_{SN}". AMA, Agricultural Mechanization in Asia, Africa and Latin America. 2022; Vol.53, N°10, pp.10005-10016, ISSN: 00845841.

[7] Boothroyd, G. and Alting, L. Design for Assembly and Disassembly. 1992; CIRP Annals,41(2), pp.625-636, https://doi.org/10.1016/S0007-8506(07)63249-1.

[8] Chen, L., Cai, J. Using Vector Projection Method to evaluate maintainability of mechanical system in design review. Reliability Engineering & System Safety. 2003; 81(2), pp.147-154, https://doi.org/10.1016/S0951-8320(03)00075-9.

[9] Colin, C., Martin, A. The user experience of low-techs: from user problems to design principles. Journal of User Experience. 2022; 19 p. https://hal.archives-ouvertes.fr/hal-03716402.

[10] Bationo F. Prise en compte du réseau sociotechnique de maintenance dans la conception d'équipements : cas des petites unités de transformation agroalimentaire des Pays d'Afrique de l'Ouest. [PhD thesis, Institut National Polytechnique de Grenoble - INPG] ; 2007. 176p.

[11] Kuo, T.C., Huang, S.H., Zhang, H.C. Design for manufacture and design for 'X': concepts, applications, and perspectives. Computers & Industrial Engineering. 2001; vol. 41, no 3, pp. 241 260.

[11] Monchy, F., Vernier, J.P. Maintenance - Méthodes et organisations. 3ème édition ; 2010.

[12] Ouattara, A. Etude sur la fabrication artisanale d'équipements agricoles au Burkina Faso. PAMA/DPV. 1998 ; 33p.

[13] Sarkar, S., Mateus, S. Value creation using minimal resources - A meta-synthesis of frugal Innovation. Technological Forecasting and Social Change. 2022; vol. 179, pp.121-612, doi: 10.1016/j.techfore.2022.121612.

[14] Singh, R., Seniaray, S., Saxena, P. A Framework for the Improvement of Frugal Design Practices. Designs. 2020; vol. 4, no 3, Art. no 3, doi:10.3390/designs4030037.

[15] Shiba, S. La conception à l'écoute du marché - Organiser l'écoute des clients pour en faire un avantage concurrentiel. (INSEP Editions, Paris). 1995 ; 126p.

[16] Stoll, H.W. Design for manufacture. Manufacturing Engineering. 1988 ; vol. 100, no1, pp.67-73.

[17] Williams, D.J. A review of: Design for Manufacture: Strategies, Principles and Techniques. Edited by John Corbett, Mike Dooner, John Meleka and Christopher Pym. (Addison Wesley) [pp.357]. Level: Graduate/research. International Journal of Computer Integrated Manufacturing. 1991; 4(5), pp.321-322.