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Abstract:

*Over the past few years, the use of scenarios in participatory design has proved its worth. It has resulted in some interesting tools for capturing the context of use. However, these approaches have been almost exclusively developed and used for software design. In this article, we shall describe the development of scenarios in the specific context of tropical food processing equipment design in developing countries. As well as exploring this original field of application, this article raises fundamental questions about scenario use, taking us beyond the limited framework of the proposed application. We shall outline a methodological framework for structuring the deployment of scenarios according to the different design phases: the COSU*1 *method. This method implements the scenario concept in an original way. It comprises four types of scenario whose aim is to create interaction between designers and users in order to foster a shared understanding of both the problem and the solutions. We shall also show that the scenarios are objects that mediate the user-designer dialogue that is of prior importance in the context of developing countries. The applicability of the method is presented through various case study examples.*

Key words: scenario-based design, participatory design, collaborative design, food processing equipment, developing countries, intermediary object

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COSU: Conception Orientée Scénario Utilisateurs (i.e. User oriented scenario-based design method)

Introduction

In Benin, as in most Developing Countries, there is a high level of post-harvest loss, sometimes reaching as much as half of the production. This constitutes a considerable source of food insecurity. One of the causes lies in users' lack of suitable equipment for processing and preserving food. The most widespread economic model in these countries is that of small-scale units made up of members of the same family or groups of individuals. Equipment is often adapted or copied by local craftsmen who lack the basic notions of how to design and build simple farming machinery. As underlined by Donaldson (2006) in an analysis of product design in Kenya, the products are marketed according to four main approaches: *"(1) Imitated design, (2) imported design, (3) basic original design, and (4) specialty design (…)"*. In Benin, the same typology of product development approaches can be observed. However, in the small-scale processing equipment sector, where Donaldson's analysis qualified the "*imported design*" as tending *"to be of relatively high quality",* the equipment transferred from the developed countries often does not meet users' expectations2, notably owing to the extremely high acquisition costs, spare part prices and the skills required for maintenance.

The analysis performed by Godjo and al. (2003) shows that the major limitation to appropriation stems from the fact that:

- the equipment does not operate according to users' expectations (in terms of ergonomics or functionality), or it does not have the right capacity in terms of the unit's production volume;
- the cost of equipment and spare parts is too high for users;
- the equipment frequently breaks down and there is a lack of skilled repair people in the villages.

In this context, joint efforts have been made by research teams in order to transform the conventional approach based on technology transfer into an approach where the aim is to develop methods and tools in order to train and enable stakeholders from the developing countries to develop their own products. As recently shown by (Jagtap et al., 2014), development process of BOP countries is less efficient than development processes in developed countries regarding the transition between requirements and solutions and they show that the topics of requirements are more oriented towards materials, energy and costs than ergonomics, supply chain and maintenance.

This article deals with the particular problem of the end users' involvement in the design process in the aim of improving acceptability and ergonomics of the products. The path towards successful innovation in developing countries appears to be highly dependent on the ability to respond to users' needs in a context where these needs are not very well known and have been far less analysed than in developed countries where marketing studies are commonly conducted. Moreover, cultural differences prevent any possible comparison with existing studies in developed countries. We cannot assume therefore that marketing data are available or even that designers share any cultural characteristics with users (who are mainly women from rural areas while designers are mainly urban

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Nevertheless, there are some successful examples of transfer, particularly if local appropriation is given proper support through the transfer of skills and the development of partnerships (mainly financial) with the developing country. However, in most cases the production line is implanted locally and users remain dependent on the developed country for spare parts or specific technological skills. The case we are interested in concerns the agro-food sector made up of small-scale units and relying only on local resources for their development.

males). In the light of user-centred design approaches and participatory design principles, we propose to study this particular case in order to provide design teams with a methodological solution to this problem. Furthermore, the research project carried out as part of this study showed that it was possible to transfer design methods rather than products to developing countries by co-developing these methods.

1. Developing methods and tools for bottom-up innovation

1.1. From technology transfer to bottom-of-the-pyramid sustainable development

In the past, transferring technologies from the developed countries was the main solution provided by developed countries to development-related problems. Introduced in the colonial era, it became the dominant approach in terms of meeting southern populations' demand for modern technologies. The "Regional Network for Agricultural Machinery" (RNAM) is one example of technology transfer in the field of farming machinery (Rahman, 1988). The equipment transferred mainly covers all stages of farming product production and processing. In Benin, for example, the transfer of Bielenberg Presses and Naguézé Pumps (Figure 1) by the American NGO Appropriate Technology International (ATI) can be cited, along with an Imex mill imported from England for grinding corn, a motor-driven oil press transferred from Germany by Expeller, cultivators, etc. The transfer process is led by actors described by Howells (2006) as "Intermediaries in innovation": *"An organization or body that acts as an agent or broker in any aspect of the innovation process between two or more parties. Such intermediary activities include: helping to provide information about potential collaborators; brokering a transaction between two or more parties; acting as a mediator or go-between for bodies or organizations that are already collaborating; and helping find advice, funding and support for the innovation outcomes of such collaborations"*. The author also underlines that "*Watkins and Horley (1986, pp. 244-245) have taken a more prospective look into what intermediaries might do to help the technology transfer process between large and small firms as part of a policy initiative. They identify the role that such intermediaries could play in: identifying partners in the first place; helping package the technology to be transferred between the two firms; selecting suppliers to make components for the technology; providing support in making the deal between the firms concerned*".

(a) Bielenberg press

(b) Naguézé press

Figure 1: Examples of some of the technologies transferred to Benin.

Although some transferred technologies have been able to help free farmers from difficult manual tasks (e.g. the Imex corn grinder), most have had to be considerably modified in order to satisfy local requirements, while others have simply been doomed to fail. For example, in the case of the transfers to Benin, the failure of the Bielenberg press was due to little or practically no knowledge of the processing product and process while the introduction of the Naguézé press was undermined by a lack of user-specific ergonomic considerations in the technology design. Finally, both presses suffered from the very poor integration of cultural and local economic dimensions in the product design. Indeed, the Bielenberg press was designed by Carl Bielenberg in 1986 for the small-scale processing (15 to 30 kg/hour) of most oleaginous seeds. After having demonstrated its performance in Kenya and Ethiopia for the extraction of sunflower oil, it was transferred to Benin in the 1990s for peanut pressing and oil extraction. While working well for sunflower oil extraction, the press was not efficient enough for peanut oil extraction. This problem might have been overcome if a local design phase had been organised. As for the Naguézé pedal pump, this was developed to irrigate market gardening crops. The technology failed in Benin because the users found it too difficult to handle. On top of this, replacement parts were difficult to find. As for the Expeller motor-driven press transferred to mechanise the extraction of peanut oil, this was rejected by many users because once the oil had been extracted (with a higher efficiency than with the traditional process), it was not possible to use the oil cake as animal feed, as with the traditional process, hence upsetting the traditional organisation of the production line and use of products and by-products. The shortcomings of these technology transfers have been underlined by several authors. After recalling the problems of technologies transferred to industrially developing countries, Alain Wisner (1985) emphasised the urgent need to develop *" ...genuine anthropo-technologies, adapting technology to a given population, like taking ergonomic considerations into account, calls on human science knowledge to improve the design of a technological system..."* For Martinelli (1987: p 32), the problem *"does not arise from a lack of interest in practical problems but from a lack of scientific resources able to solve them".* Finally, for Donaldson (2001), the lack of resources for technology design often encourages the least industrialised countries to import technologies.

More recently, a number of economists and major industrial companies have considered that the 4 billion poor people around the world actually constitute a huge potential market: the bottom-of-the-pyramid (BOP) market. Apart from the tremendous success of mobile and information technologies, there are few examples of successful market developments in BOP countries. This question continues to generate much literature in the field of management and many companies are keeping a watchful eye on these potential emerging markets. However, these approaches are rightly raising the question of global sustainable development and therefore integrate the production phase in the overall picture. Prahalad (2009) proposes an infrastructure for BOP based on improving the purchasing capacity of local populations, providing them with better access to products (distribution, communication), shaping their aspirations (consumer education, sustainable development) and growing a healthy market (bottom-up innovation, tailored product development). For this author, bottom-up innovation appears to be an important success factor for BOP products. He stresses the importance of people getting actively involved at the local level, which ties in with the idea of providing them with proper methodologies in order to foster their commitment.

This short state-of-the art review shows that despite the high number of projects carried out and industrial companies' renewed interest in the "4th tier" of the world's population, there is still much to be done to fulfil people's expectations. Future efforts need to focus on: (1) the cultural gap between the different value systems (developed vs. developing countries); (2) users' lack of education; (3) the limited understanding of the context in which the equipment is used.

Our work over the last 15 years has been to encourage local initiatives in the case of small-scale food processing equipment3. In our approach we consider (or take as a premise) that what we previously referred to as bottom-up innovation can be an efficient means of better taking into account local value systems, functional needs, and economic and sociological realities in order to devise the right methods and implementation for local contexts.

1.2. The need to better integrate users in the design process

We have seen that many failures are due to a lack of timely buy-in to the product by local users. It is clear that the value associated with the equipment does not therefore rely only on the object's technical performance. This value is partly built on trust and partly on the sum of money users are willing to spend in order to acquire the object. It can therefore be hypothesised that some failures are due to the fact that some equipment is made available free of charge (through NGO projects for example). Once the equipment collapses, the users find it of no more value and stop using it. In other words, there is no user appropriation. Putting financial commitments aside, appropriation can be fostered as the user progressively learns about the equipment during the design phase. The prototype can thus be tested, modified by a local stakeholder, tested again and so on.
In this paper we propose an original participatory design approach (the COSU method) to take into account user expectations and set up an appropriation process. This method draws on human-centred design approaches (Maguire, 2001) and scenario-based design methods. The method proposes to include users in the design process of the equipment they will be using. It is based on a set of scenarios developed by the design team using the information provided by the user surveys. These scenarios act as intermediary objects; they mediate interactions enabling the designers to present their solutions and the users to assess these in realistic situations of use. Thus, the effect is twofold: the method backs up product evaluation during the design phase and fosters user commitment to the product. We intend to reach a "capability sensitive design" method (Oosterlaken, 2009) which proved its efficiency in various cases in developing countries (Frediani, 2009).

Before describing our participatory design approach and the scenario-based method, it is important to present some elements of our research methodology.

2. Research methodology

Our research methodology is extensively based on fieldwork and empirical studies (Yin, 2009). The result of our research is a design method that is grounded in real experimentations and draws its legitimacy from a systematic testing process through an action-observation-action loop. In order to achieve our objective we have followed three iterative steps on 4 development projects and one evaluation step based on 5 other projects.

2.1. Field studies

The field studies are essential in our participatory approach. We have followed an action research paradigm and a constructivist approach in this work. The first period of fieldwork lasted 4 months and was related to the implementation of the preliminary phases of the CESAM design method (see section 5.1). This study was related to the palm oil extraction process and led to the identification of several solution principles for a proper oil extraction. This fieldwork was dedicated to the study of local design teams, not directly involving users. The second period was the most important in terms

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In an effort to foster bottom-up innovation, a research programme bringing together the French research centre for agricultural development in developing countries (CIRAD), the G-SCOP laboratory at the Grenoble Institute of Technology, and several local Universities in western Africa, aims to develop an approach for improving the "development of tropical food processing design methods and tools for developing countries involving local design teams."

of time and concept development. It was dedicated to the involvement of users in the design process. Based on direct observation, interviews, films and direct involvement of the researcher in the design process (action research), the research team came out with some material including preliminary intermediary objects that supported the user-designer interactions. This phase lasted approximately over a period of one year. Finally the Klui-klui project allowed the longitudinal testing and refinement of the whole methodology along all the period of this study, i.e. three years (2004-2007).

2.2. Data analysis conceptual work

The first step of this study, based on the oil extraction project allowed to identify and formalise some key intermediary objects (Godjo and al., 2003) and highlighted the importance and difficulty to develop a real collaborative design process in local settings. The second step showed the importance and difficulty of users involvement in early design phases, before any real object can be shown and tested by the users (Godjo and al., 2006)). This phase, based on three other cases (see section 5.1) allowed to integrate the concept of scenario and scenario based design in this very particular context, leading to adopt an original point of view on the concept of scenario.

2.3. Testing and refinement

After the conceptual work of designing and developing the method an important testing and refinement phase started. The inherently constructivist nature of the method requires an evaluation framework in order to characterise its implementation. We have implemented 5 other cases and built an evaluation framework for characterising the performance of the method regarding our particular context in these 5 cases (section 5).

From a methodological point of view we have implemented fieldwork and user-centred design principles in the preliminary steps of the method definition and the implementation phase allowed the determination of an evaluation framework relying on other case studies. The scenario concept to foster user integration.

2.4. State-of-the-art in major user-centred design concepts

For Carroll (2000), products play a wider role than that of providing the functions for which they were designed. Indeed, over the course of their design work, designers have to take into account the transformations and/or requirements that may arise from the context in which the future product is to be used. One direct way of doing this is to imagine and explicitly document typical and significant user activities very early on and throughout the design process. Such descriptions are referred to as *scenarios*. Scenarios provide a narrative description of an activity (Rosson and Carroll, 2002). They indicate events relating to situations of use and during which one or more stakeholders (i.e. with personal motives, but limited knowledge and capacity) handle(s) various tools and objects (Carroll 1994). The scenarios are developed with the aim of designing a product and can be presented in the form of texts, videos, pictures, models, prototypes, etc. They are design representations (Carroll 1995), objects describing human activities (Carroll, 2000; Bardram and al., 2002), as well as representations of the context of use (Nielsen, 2002).

Literature on Scenario-Based Design suggests that such processes are constantly evolving. Based on criticism of user characterisation in human-computer interface design, Nielsen (2004) points out a number of limitations stemming from the artificial nature of certain scenarios that are nothing more than poor stereotyped representations of users' activities. However, the scenario-based design approach has afforded a substantial improvement in the field of software engineering, and, although this method was initiated by interdisciplinary HCI (human-computer interaction) research teams scenarios are commonly used by software design teams for other design objects (e.g. business plans, requirements lists, etc.) (Hertzum, 2003).

Some of the latest developments in scenario-based design have introduced the notion of *persona* as a means to overcome the shortcomings mentioned above. These shortcomings are mainly due to the lack of depth in the scenarios, which often remain too general (or "disembodied"). As archetypal representations of individuals (the targeted users), personas are the characters of the scenarios and therefore provide a new dimension to the descriptions that is likely to better inform the designers.

For Nielsen (2004)*, "A persona is a description of a fictitious user. The fictitious user can function as: (1) A vehicle to create empathy and identification, (2) A storage for information (3) A method to create a focus on particular market shares."* The concept of persona helps to enrich the team's perception of users by making them more "real" rather than simply providing an image based on a list of requirements or abstract statistical data.While marketing studies provide information on the average user, the persona provides a deep insight into one particular user. Alan Cooper (1999) has shown how the creation of Personas can lead to design insight. A successful experience at Microsoft has also been described by Pruitt and Grudin (2003). It shows how personas can become indispensable fellow members of the development team by putting the users at the centre of the discussions.

For Gudjonsdottir and Lindquist (2008) associated personas and scenarios are also effective communication devices making it possible to inform project participants about the context of use and ensure that this is taken into account and shared by members of the team, the ultimate goal being to understand why the system should behave in a certain way. This particular aspect will be developed in our study as we believe that communication is one of the key points for successful user participation.

Taking an opposite stance to the above authors, Blomquist and Arvola (2002) rightly remind us that the persona approach physically excludes users from the design process, which can also be seen as a serious drawback of the approach. Although the design team may readily accept the personas, they may also come to over-rely on these imaginary individuals, to the extent that they actually neglect to meet the real users on a regular basis throughout the development process.

In our case, the users are identified and fairly accessible (putting local transportation problems to one side) compared to the millions of internet users that exist or car owners for example. Using a persona approach is of little help to us as whenever the user can be easily identified and involved it is worth making their physical involvement possible rather than expending lots of energy on building an imaginary persona.

On the other hand, although our users can be easily identified, it is often difficult for them to take part in the design meetings. Most of the time they live in remote areas and are not well enough educated to efficiently participate in design meetings, read plans, etc. This is why we have developed a set of mediations (called scenarios) that allow the users to actively participate in the decision-making process. In the next section we shall explain how the concept of scenario is applied in our particular case.

2.5. The scenario as a keystone in the user-designer dialogue

Scenarios are often presented as a narrative account of the real activity carried out by specific users in their everyday environment. However, a scenario can also reflect an imaginary activity envisaged by the users (or sometimes by designers) on which to base the search for new principles. This is particularly useful for devising the use of new technologies. Furthermore, these scenarios can be backed up by various forms of prototypes. Depending on the complexity of the activity considered, video can also be introduced.

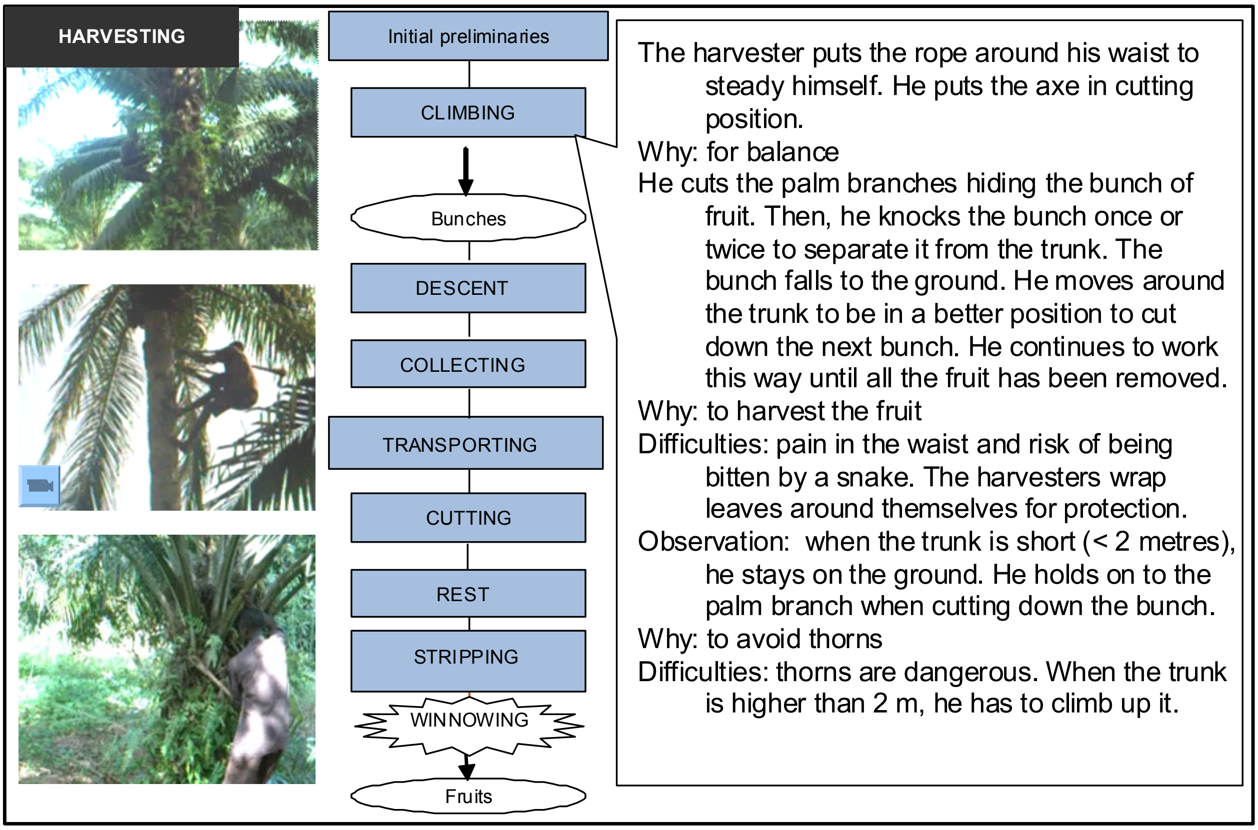


Figure 2: Excerpt of the "harvesting scenario"

Figure 2 shows an example of a scenario developed to describe the complex activity of collecting palm fruits and particularly the harvesting operation. The example is based on the real activity of palm fruit cluster picking and was part of a design project we developed with a local governmental organisation. The aim of the diagram is to describe the process and identify the problem(s) encountered by the users with a view to mechanising the process. The operation described in this example is the cluster "cutting" operation. The scenario has been purposely broken down into three sections. The central part is a conventional flow chart and is thus easily handled by the designers. The left hand side displays visual data of the operation considered. Video can also be included at this stage. The photos intend to remind the designers of their own experience in the field. On the right hand side we have added a textual description of the activity putting the harvester at the centre. This description contains contextual aspects (dangers that can occur, hardness factors, justifications, etc.). This description is designed to answer basic questions (what, why, and difficulties). In this example the operation does not require any interaction with other people. But on other occasions the scenario can describe the relationships between people, the information to be shared, etc. The scenario can therefore represent a collective activity as well.

The concept of scenario is used here to qualify this object for two reasons. First of all this is a description of the activity of a particular user (or a group) and we clearly see the narrative dimension of the description on the right hand side (figure 2). Secondly, the description only presents the user and the context of use while it never includes any requirements or design elements.

The main interest of the scenario, and which is often neglected in conventional user-centred approaches, is that it creates common ground for sharing knowledge between the design team and the users: the users are called on to explain their work practices and the designers then analyse these in detail. However, the users can also ask questions in order to gather additional information about the intentions of the designers and hence are in a position to properly evaluate the solutions presented by the designers. The objective of the scenario is therefore to foster interaction between the user and the designers and thus create a shared understanding of the design objectives, the problem to be solved, the solutions and the overall context of the project. Finally, over the course of the interactions, the scenarios created by the designers are discussed and evaluated and a better perception of their use is established.

2.6. The dynamics of scenario development: a learning process

Figure 3 illustrates the process of creating a scenario taking as an example the project of palm fruit harvesting. The scenario defined here is a fairly structured object developed according to a three-stage process:

S1. collecting the information

S2. developing the scenario

S3. testing the scenario with the users in order to integrate their point of view into the design.

During stage 1 (S1), the information needed to build the scenario is collected from the users at their workplace. The information is collected during interviews with the users in the need analysis phase. The S1 stage has to lead to precise information that can be easily exploited by the designers in order to create the scenario. In the example in Figure 3, during the S1 stage the designers visited the village and met the workers, produced a working video and filled out a questionnaire about the palm fruit processing procedure and activities. During the S2 stage, the designers must develop the scenario based on the information collected in the field. In our example, during the S2 stage, the designers analysed the data collected in S1, formalised the work observed and produced the scenario. During the S3 stage, the scenario developed by the designers is presented and discussed with the users. This mainly leads to certain modifications of the scenario. The initial scenario is then enhanced in order to take into account user feedback. In the next design phase the scenario then becomes an independent object and acts as a spokesperson4 for the users in the design work.

The term spokesperson is used here in reference to the work of the French Sociologist Michel Callon (1986) who first proposed this concept in order to describe the effects of certain objects in the decision making process. According to Callon, the characteristics of objects cause them to act in a certain way, as if their creator were present. This concept has traditionally been limited to human actors, i.e. “y” is the spokesperson of group “z”.

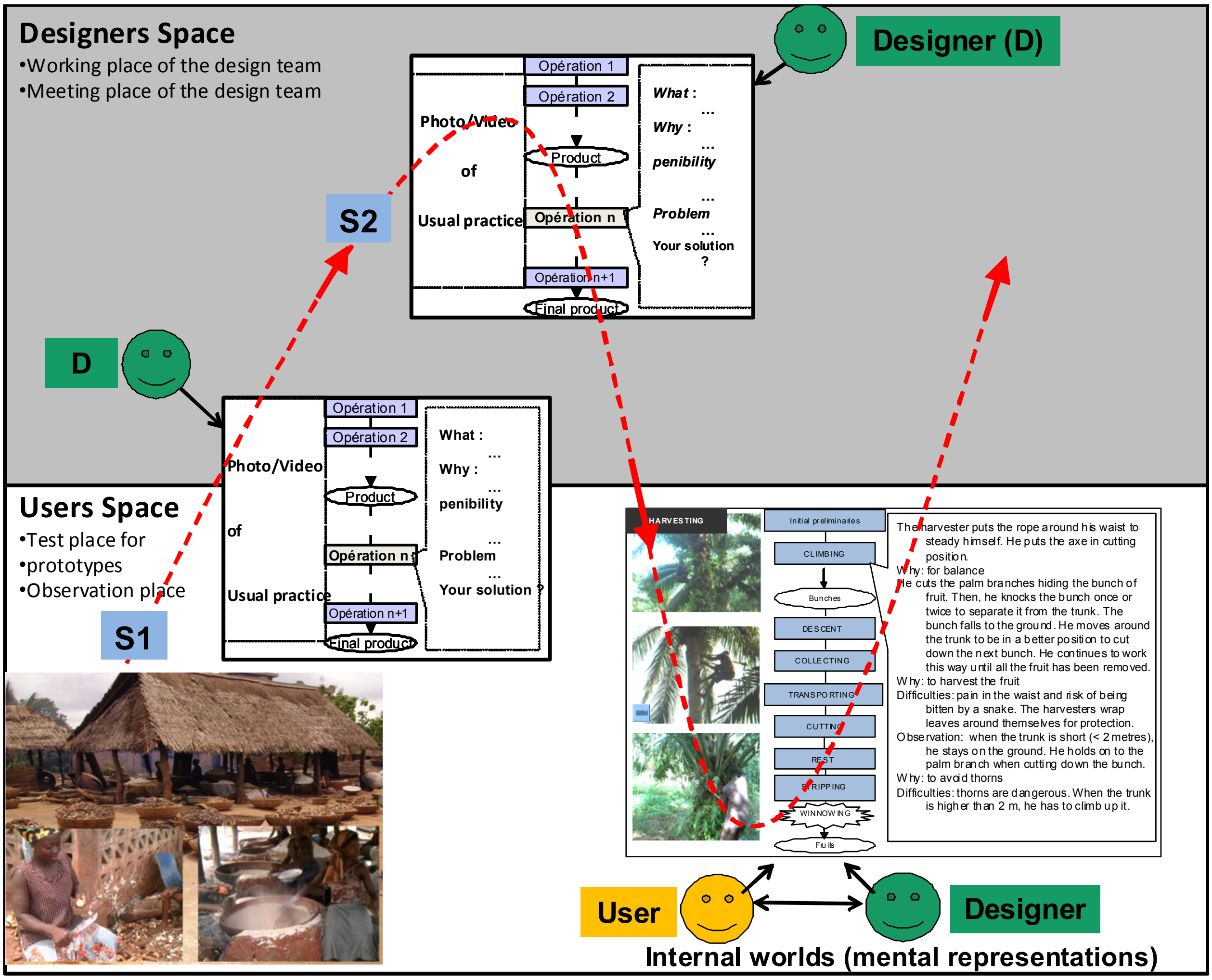


Figure 3: Dynamics of scenario building

To conclude this section it is important to stress the rationale underlying the form of the scenario. Indeed, the scenario is purposely synthetic as opposed to a more narrative and conventional representation. Our aim here was to provide a representation that the designers could easily create, modify and use in their everyday work. This is why the form of this representation is of great importance to allow both designers and users to handle it easily.

2.7. Three important underlying concepts

In Figure 3 we have also distinguished between the two physical spaces occupied by the respective actors, i.e. the design office and the investigation field. These two physical spaces are populated with very different objects and artefacts. Furthermore, given that the actors are likely to have very different expertise and experience their respective object "worlds" (Bucciarelli, 1996, 2002) may be relatively different. The scenario creation process acts as a bridge between the two worlds and, as the objects navigate from one to the other, they can be considered as vehicles of knowledge creation. The scenario can therefore be considered as a communication with three major facets.

2.7.1. Two physical spaces: Designer Space and User Space

Scenarios are bridges between designer and User spaces. We consider that there are two physical spaces where the stakeholders (designers and users) perform their work activities. The *Designer*

Space (in green in Figure 3) designates design team meeting areas, model and prototype test stations and the respective workplaces of the design team members. These areas can be qualified as the "designer space". The *User Space* (in yellow in Figure 3) designates the physical area where the users do their food-processing work. The distinction between these two spaces comes from the fundamentally different nature of the activities performed there. Similarly, the point of view on the object being designed changes from one space to the other: in the *Designer Space,* the product is seen as the design object (with functions, a structure, performance characteristics, etc.) while in the *User Space* it is a working tool to be used for processing. The participatory design approach developed here aims at reducing this difference and the scenarios are in fact the vehicle of this process.
Furthermore, besides this spatial distinction, the designers and the users build up different cognitive representations of the product being designed depending on whether they work in the designer space or in the user space.

2.7.2. Representation worlds: a cognitive dimension

Representation world refers to this cognitive dimension of the design process. This dimension is of prime importance if we want to transfer or translate elements from the users' world to the designers' world and conversely. The representation worlds are design worlds in the sense of Mer (1998), in other words they at once refer to culture, expert knowledge, experience and mental construction. Education plays a fundamental role in shaping this design world, as well as the experience shared with the other stakeholders during past projects. But they are also object worlds in the sense of Bucciarelli (1996), and thus relate to the individual. Indeed, every experience is also individual and differs from one stakeholder to another, the object worlds being very much linked to the domain of expertise (e.g. structural analysis, material science, economy, etc.) of each participant in the project.

For Mer (1998), *a design world is an heterogeneous set of entities (that may be tools, objects or people) developing the same action-based logic, belonging to the same scale of values and sharing collective knowledge.* Mer thus uses three sociological notions to characterise the concept of *design world*: *action-based logic, scale of values* and *collective knowledge*. *Action-based logic,* previously defined by Vinck (1995), combines the rationale behind the action, the objective of the action and the action itself. It sets up continuity between all the actions of a stakeholder and includes a constant: a "main theme", or logic. The *scale of values* supports stakeholders' judgement about their actions, their knowledge and the products being designed. It is often considered as an element of culture and is very much related to the context in which a person has grown up, lives and works.. Finally, *collective knowledge* refers to conventions, rules, language, etc., shared by different persons belonging to the same world. For example, it enables team members to make cognitive and organisational savings without constantly having to reinvest in a process of knowledge learning or building of social coordination. However, it may also cause serious misunderstandings with people that belong to a different design world.

For Bucciarelli, the notion of "*object worlds*" (Bucciarelli, 1996) refers to worlds of individual effort where engineers, working alone mostly, apply their expertise in order to perform tasks specific to their discipline. For Bucciarelli, during a design process the different participants with their different skills, qualifications, responsibilities and interests, occupy different worlds. Although they work on the same object, they see this object differently, mostly depending on their technical background and education (Bucciarelli, 1999). This means that the words used by a designer to describe a product may be misunderstood by the user who understands the words according to their own experience.

In Figure 3, the designers (D) and users (U) belong to two different representation worlds as defined above. The scenario created in the Designer Space by the designers using information collected from the users is taken back to the User space to be enriched and validated. During the working session, the users imagine using the product for their work while the designers think of it in terms of how it should be structured or manufactured. However, the designers and the users have to cross the boundaries of their respective representation worlds in order to integrate each other's point of view. This means that the designers' representations have to take into account the way the product will be used and, conversely, that the users' representations have to include the technical solution. The aim of the scenarios is therefore to facilitate the creation of representations of use for the designers so that they can design the system properly and, on the other hand, to help the users establish representations of the technical solution in order to build their own representation of the use of the future product in their working environment.

2.7.3. Shared objects

The scenarios are also *Design Intermediary Objects* (Jeantet, 1998) in the user-designer interaction.
Figure 3 shows the trajectory of the scenario as it passes from the Designer space to the User space. To begin with, it is created by the designers in the Designer space (S2). It is then taken by the designers to the User space for the users to give their feedback. The designers use the scenario to reformulate their understanding of the design problem for the benefit of the users. In that sense the scenario is a *translation* of the users' message and of the designers' observations. An interaction is therefore created between the designers and the users encouraging both to readjust their mental representations: the users in relation to the product's use and the designers in relation to their domain knowledge. The scenario acts as a *mediation* between the representation worlds described above as it navigates between the different physical spaces. Once enriched by the users' feedback, the scenario returns to the designer space and, once more, becomes a validated object, used by the designers to capture the users' expectations. It is therefore a *representation* of the user's activity. Thus, it progressively switches from its role as problem describer to that of problem specifier, at which point it acts as a spokesperson and vector travelling from one physical space to another and from one mental space to another.

Having defined our approach of the concept of scenario, we shall now see how it can be expanded and used in the design process through the COSU method.

3. COSU: a method to foster user participation in the design process

3.1. The CESAM Methodology

CESAM5 is a methodological framework that was set up for Developing Countries. Its aim is to improve the coordination of local design projects based on adapting the functional design methods of developed countries.

Based on the observation and analysis of traditional design processes in five countries (Senegal, Ivory Coast, Columbia, Vietnam and Tunisia), and using the experience of local designers, the CESAM methodology enables a cooperative design process to be organised and structured within the specific environment of developing countries (Marouzé and Giroux, 2004). This method applies the conventional sequential design models currently implemented in industrial companies. While these

CESAM: Conception d'Equipements dans les pays du Sud pour l'Agriculture et l'agroalimentaire : Méthode (design method for agricultural and food processing industries in developing countries) conventional methods cover the entire scope of product and process design (for example (Pahl and Beitz, 1996)), the CESAM methodology concentrates on the conceptual phases starting with the idea and ending with the prototype. Indeed, this method is geared towards fostering innovation and new product development (figure 4).

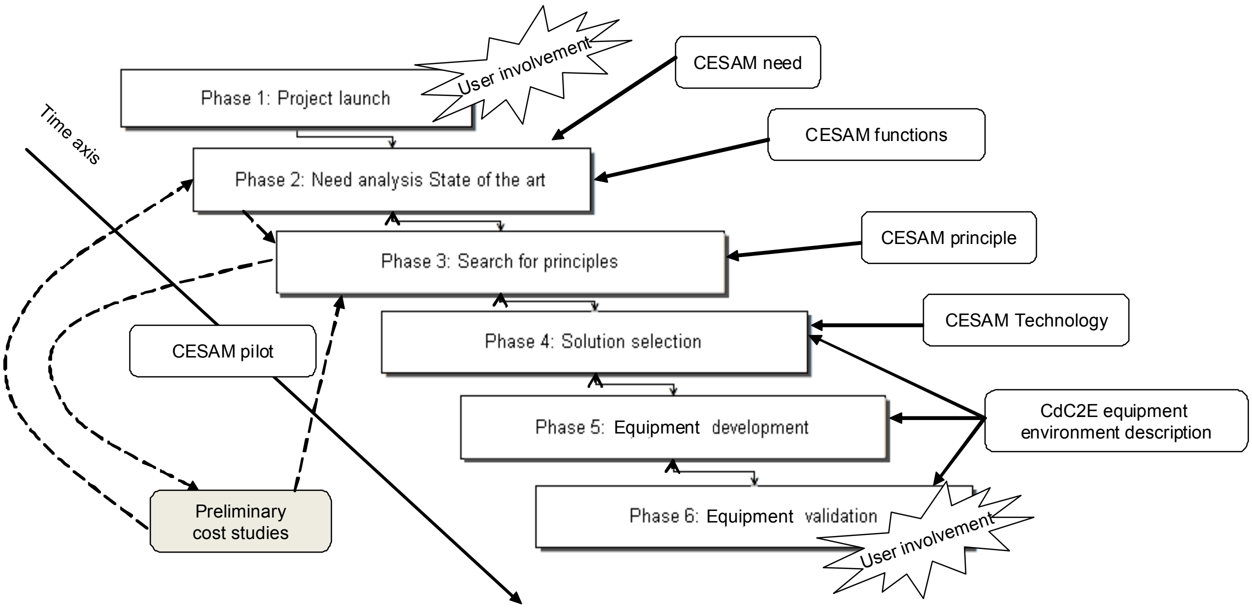


Figure 4: Basic diagram of the CESAM methodology

The method draws its originality from its tools that have been developed for the specific environment of developing countries. These tools are adapted from the usual functional analysis tools and specialised to meet the specific needs. For example, the “CESAM need” tool is a field study based on questionnaires and carried out by the design team in a set of villages where the designers meet potential users. This study of course differs considerably from conventional marketing studies although it does have more or less the same function: collecting users’ needs. New tools are also provided such as “CdC2E”, a specific requirements list detailing manufacturing capacities and repair facilities and including the network of local actors (further developed by Bationo and al. (2009)). Then there is the “CESAM pilot” tool, which helps the design team to check completion of each design phase. “CESAM Principle” and “technology” are conventional technological solutions databases adapted to the local context. Some interesting connections can be drawn between this method and the TRIZ method applied by Totobesola-barnier and al. (2002) in the context of developing countries. The TRIZ experience proved to be successful in fostering creativity during phase 3 (figure 4) where new solution principles are identified.

Another original aspect of the method stems from the management of the process. The design process is managed by a small multidisciplinary team (3 to 5 people) with various skills, and covers the entire life cycle of the project. This means that the design process does not just concern the mechanical engineers; it also takes into account all perspectives relating to the future equipment to be produced, especially the above-mentioned aspects pertaining to socioeconomics and use, which are of prime importance in our context. The design team works by sharing information, by conducting debates and by taking decisions during regular meetings. Design activities, such as customer surveys and document searches, or technical developments, are carried out individually or in teams in between the meetings.

The project management applies concurrent engineering principles allowing each phase to overlap. This means that the design activities are grouped into interactive phases. For example, the initial information relating to the need is used to identify the most relevant principles possible (Figure 4). These are then presented to the customers, who then either approve of them or not, etc. The CESAM methodology especially focuses on identifying the need and then translating this functionally, taking into account costs (a concern that is present right from the start of the project). Alternative operating principles and technological solutions must then be devised to meet the identified need. Unfortunately it appeared through the various case studies that the design team rapidly disconnected from the users' needs as the projects went on. Figure 4 shows that the meeting points with the users are mainly at the beginning and at the end of the project, which proved to be insufficient.

An analysis of the implementation of the CESAM methodology in Benin (Godjo, Marouzé and al., 2003) showed that the approach only involves the user at the start of the design process (need analysis), via questionnaires, and then at the end when the users are asked to physically try out a prototype of the equipment made available to them. Throughout the intermediate period the design team works alone on representations based on the initial questionnaires. This proved to be insufficient and caused many shortcomings during the test projects. This clearly limits the method. While in developed countries designers have a good knowledge of users thanks to marketing studies and cultural similarities, there is no such common ground among African designers. This paper explores this major shortcoming and puts forward an integrated method for efficient user participation in the design process.

The CESAM methodology has been validated through 8 projects carried out in Senegal, the Ivory Coast, India and Columbia. Today, CESAM is used in several countries by local teams (Benin, Burkina Faso, Togo, Cameroun and the Ivory Coast).

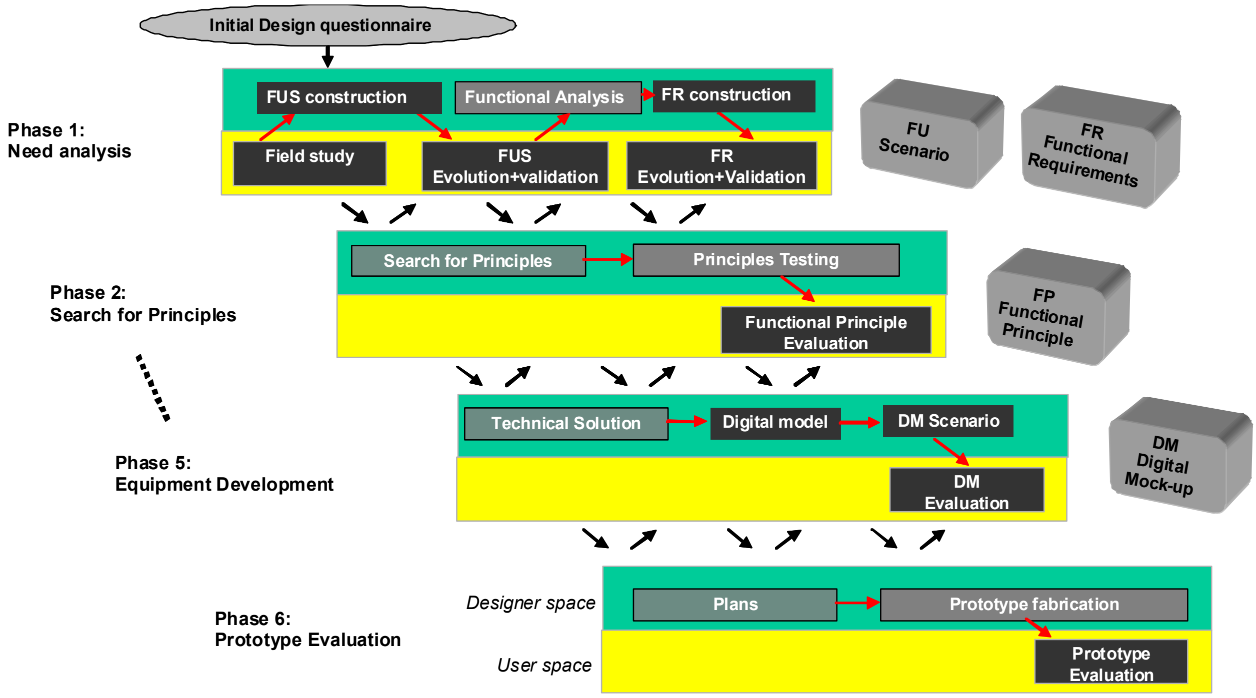
3.2. COSU: a user oriented scenario-based design method

3.2.1. General framework

The COSU method is an extension of the CESAM approach (Marouzé, 1999) allowing better participation of users throughout the design process. The CESAM methodology described above serves as a backbone to the COSU method. The latter provides the basis for users-designer interaction.

We have previously seen (section 4.1) that in the literature the concept of scenario is mainly limited to the description of users' behaviour or habits in a given situation. The scenario details or illustrates the possible use of a future product and is supposed to help designers to figure out suitable forms of products or integrate new functionalities. Scenarios are more commonly used in preliminary design phases as a means to capture user characteristics. Our intention here is to enlarge the concept of scenario by using it during the design process right through to the testing of functional principles. At each stage the scenarios considered are descriptions of the problem or product in the context of use and which also serve as a basis for user-designers interaction.

In this method, four scenarios have been defined to cover the entire design process. These are the *Functional Understanding scenario* (Godjo, Marouzé and al., 2006), the *Functional Requirements scenario*, the *Functional Mock-up* scenario (Marouzé and Giroux, 2004) and the *Digital Model scenario*. In the previous section, we used the functional understanding diagram of the palm fruit case as an example. We shall now examine how the four scenarios interact in the overall design process.



Caption:
FU Scenario (FUS): Functional Understanding Scenario
FR Scenario: Functional Requirements Scenario
FP Scenario: Functional Principle Scenario
DM Scenario: Digital Model Scenario

Figure 5: COSU Method at activity and phase level within the CESAM framework

Figure 5 gives an overview of the COSU method within the CESAM framework. As we saw earlier the users and the designers operate in two distinct worlds materialised by the *designer space* and the *user space*. This is true throughout the process. The COSU method operates mainly in three phases: need analysis, search for principles, equipment development. Prototype evaluation is the ultimate stage involving the users and was already part of the original CESAM methodology. Each phase is made up of a set of activities. Some of these activities are already included within the CESAM methodology (grey in Figure 5) while others (black in Figure 5) are new activities generated by the participatory design approach.

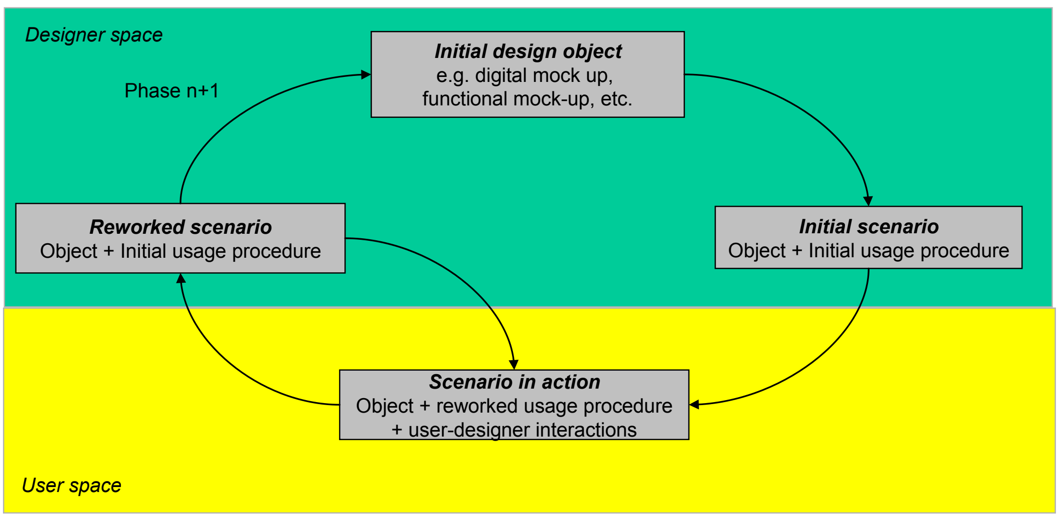


Figure 6: General procedure for the development of a user scenario in the COSU method

The general procedure presented in figure 6 summarises the process of creating a scenario in COSU. At each phase of the design process this procedure has been systematically applied to the four scenarios mentioned in figure 5. It stresses the active part the users play in the creation of the scenarios. This is coherent with the human-centred approaches described by Maguire (2001) in the domain of software design.

In the next sections we shall describe the four scenarios and the new interactions they enable between users and designers.

3.2.2. Functional Understanding scenario

The functional understanding scenario could also be called "problem scenario"as it is the first object that describes the work activity in its context. In some ways it defines the state-of-the-art of the problem to be solved by the design team. The aim of this scenario is to make a picture of the users' points of view regardless of any solution or technology. As we have seen, it is a semi-narrative and formatted description of the real activity performed by the users in a real setting. This description takes the form of the Functional Understanding Scenario (FUS) described in section 4.2 (figure 2). From the initial field study carried out by the design team, the first draft of the FUS is sketched out. Then a second loop allows the users to comment on the scenario and propose modifications or additions. This provides the opportunity for extensive exchange between the design team and the users, allowing the team to express its intentions and the users their needs in a very precise manner. All this is documented in the functional understanding scenario. It is important to recall that this scenario, like the following scenarios, is for use by the design team. This is why we have adopted a formal style very similar to that applied in designers' usual tools. An overly narrative style has been purposely avoided. Relying on the participants' memory for the very fine details, a narrative scenario would be too complicated to compile into a document which, in the end, nobody would be able to use.

3.2.3. Functional Requirements table

The design team translates the functional understanding scenario into functional requirements making it easier to then define the technological principles. The *Functional Requirements* table is first drawn up by the design team on the basis of a conventional functional analysis. The functional analysis performed by the designers during the design meetings is presented to the users. Each service function is translated and explained in the local language6 as well as the satisfaction criteria and levels. The users complete or reformulate certain functions, add criteria, and then change the performance levels to be reached. Table 1 gives an example of a functional requirements table drawn up during the Klui-Klui project (Godjo and al., 2003). The summarised users' contributions are highlighted in bold italics. The designers must aim to obtain explanations about the modifications requested by the users. It is through this interaction that the designers' point of view becomes clearer so that it can be formalised into a simple functional requirements list, leaving aside all the contextual elements of the initial scenario.

This translation process is not taken down in writing. The reader should not forget that African countries mainly have oral cultures and that much information is transmitted during long discussions. We have integrated this cultural dimension in our method. This is why table 1 does not reflect the full richness of the information exchanged.

Table1: Example of a functional requirement drawn up for the klui-klui project

Service functions	Criteria	Level
The equipment must …. F1: transform the partially deoiled paste into sticks ***If manual and easy to do, the boss will do the work herself***	Flow rate	~~6~~kg /h ***40 kg/h***
	Efficiency	~~95~~ % ***100%***
	Final product quality	traditional (b) No foreign bodies
	Length	[18-25] cm
	Diameter	[8-13] mm
F2: enable the operator to load the partially deoiled paste	Loading height	0.55 m above ground
	Storage capacity	~~3~~ kg ***12.5 kg***
F3: mix the seasoning with the partially deoiled paste	Homogeneity	No lumps
…	…	…
F8: use available energies	Level of power available	***Motor, but easy to start, not like a mill motor*** (b) Manual or ***Motor-driven***
F9: enable the operator to adjust the kluiklui diameter in relation to peanut cost If possible for four kluiklui sizes: F 175 (Covè), F 150 (elsewhere), F 125 (Cotonou), F 100 (Sagnon)		
F10: enable the operator to sample the paste for spiciness (check seasoning)		

In this section we show how a functional requirements breakdown can be used as a basis for user-designer interaction if it is associated with a proper translation process and integrated into a recursive process that fosters the progressive commitment of the stakeholders. This is also true for the ensuing scenarios. The oral dimension is not to be neglected even though it does not appear in the formal presentation of the paper-based (or digital) objects.

3.2.4. Functional Principle mock-up

The *functional principle mock-up* is materialised through a concrete physical object designed to work according to the main technological principle chosen by the design team and on which the users and the designers must agree during the principle testing phase. The functional mock-up is a simplified version of the final object that can be quickly tested from a strictly functional point of view. It is not meant to last. It is by no means a prototype requiring full technical design and development.Its aim is to make the level of design work less abstract to the users and demonstrate the validity of the operating principle. It is a physical translation that allows the users to directly test the concept. The functional principle mock-up is therefore made up of the physical functional mock-up and a paper-based description of its use (and misuse) by the users. This commented part allows the main shortcomings, remarks, etc., to be noted. Again we consider these objects together with the oral environment operate as a scenario because the purpose of these objects is to foster designer-user interaction and encourage the users to get involved not only as final evaluators but also as actors of the process. In the particular case of the Klui-Klui project, the physical mock-up made it possible for the designers to validate the operating principle of "*shaping between two cylinders*" together with the users: they wanted to check that the klui-klui coming out of the two cylinders sufficiently resembled the traditionally-made product and was therefore acceptable (figure 7). Each functional mock-up is then tested and the processed food product evaluated. This dual evaluation, i.e. sensorial (based on the food product) and functional (based on the operation of the functional mock-up) by the users is then discussed and possible modifications put forward. The idea is not for the users to simply test the model. By observing the way the model operates and the quality of the food product, they are asked to imagine themselves using it in order to identify any missing points.

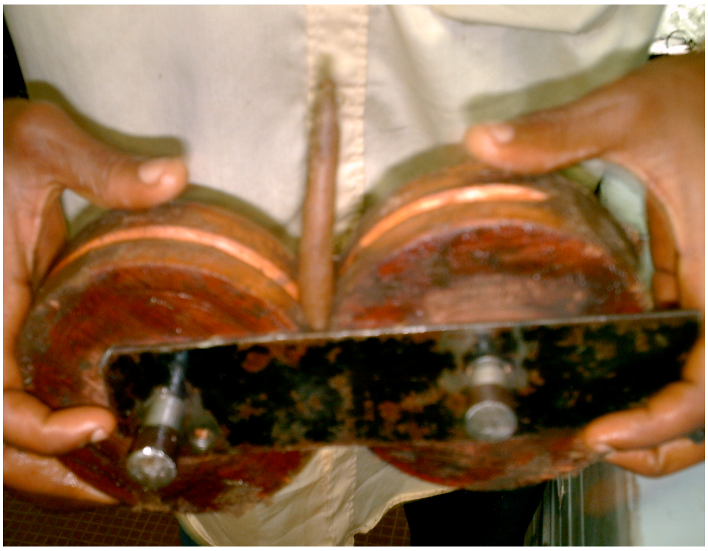


Figure 7: Example of a physical mock-up part of the functional principle scenario

Unfortunately, in the case of the Klui-Klui project, the first version of the physical mock-up did not meet the users' expectations as the ends of the sticks were found to be unacceptable. The interaction that followed this evaluation allowed the designers to propose a new solution to overcome this problem. An agreement between the designers and the users on how to use the functional principle was found. It was only after this discussion that the scenario (i.e. the mock-up + the associated usage descriptions) was considered satisfactory at this stage in the design process.

3.2.5. Digital Mock-up

The *digital mock-up* is a virtual representation of the technical solution, backed up by contextual aspects (other equipment nearby, human model, etc.), and enriched by the users during their interaction with the designers. Figure 8 is an example of a digital mock-up developed in Benin as part of the Klui-Klui project. The digital mock-up presents the entire equipment and is therefore an interesting alternative to the physical prototype especially if the operating principle has not yet been validated. The two scenarios (i.e. Functional principle and digital mock-ups) appear to complement each other. A virtual model makes it possible to present the overall machine before embarking on the development of an expensive prototype. It can thus be used as back-up to the functional principle scenario and provide an overall view of the envisaged system. Thus, the Digital Scenario is a contextual presentation of the overall system whereas the Functional Principle mock-up is the physical embodiment of the operating principle of the equipment. Both are necessary in order to initiate proper interaction between designers and users and eventually validate the solution. These two key objects appear to be an economic and efficient way to progressively make the user familiar with the future equipment.

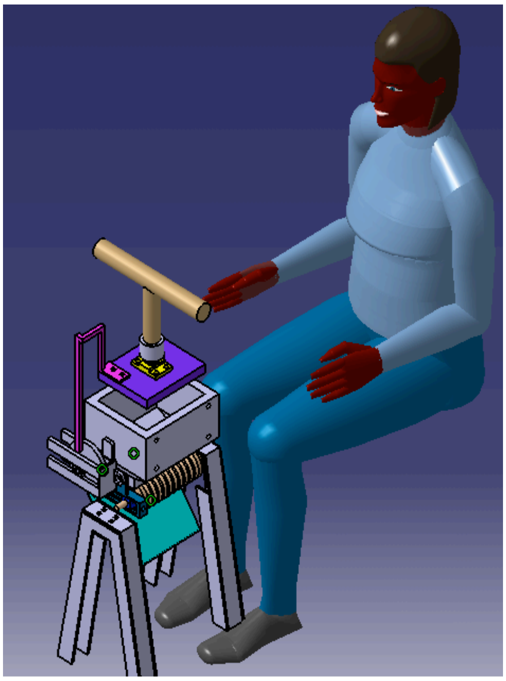


Figure 8: Example of a digital model scenario

The digital mock-up can have various levels of refinement, particularly kinematic animations allowing the users to see the respective movements of the system. However, the aim of this representation is not to simulate the object but rather to provide a preliminary demonstration of the concept to the users. This representation does not allow for easy interaction with the users, which is why it has not been extensively used up to now.

3.2.6. Working prototype

In a participatory process the prototyping phase is very important because it allows to present a concrete and synthetic response to the users' expectations. It allows to check the perception and the usability of the product. The equipment manufactured and tested from a technical point of view is then presented to the users that were previously involved in the other design phases. The users are invited to give their opinion in terms of both operating performance and ease of use. An illustration is presented on the Klui-Klui project. We note that the design team had to make tricky choices and take into account manufacturing and economical constraints that led to produce a simpler version of the machine than the one presented in figure 8.

Figure 9: Working prototype of the Klui Klui project

Figure 9 shows the final prototype during the preliminary experimentation. This final step closes the loop of the experimentation of the COSU design method.

4. Method experimentation results

We present in this section the most significant projects that allowed the method to be tested and validated. A total of nine projects were completed between 2004 and 2012. The first four projects have served as a basis for the design of the method (2004-2007) and some partial tests. The other five were used as a validation and improvement of the method (2009-2012).These projects were conducted by local universities and national research centres to solve working conditions problems and low production performance in Benin food industry.

4.1. Summary of preliminary projects

We have summarised in Table 2 the major projects that served as a basis for the inspiration and test of the COSU method. Among these projects only the Klui Klui get through all the phases of the method. The first user experimentations were very successful and show that the method provides a significant help on the usability side. In that sense it is a first positive element of validation. However one should not underestimate the insight gained from the other projects. For example the peanut oil extraction project served as a first field study and allows the researchers to draw a first version of the problem scenario concept that has been tested later in the Klui-Klui project. The final version of the problem scenario has been eventually tested in the palm fruit project. The functional requirement table scenario has been initiated during the peanut oil extraction project that was basically a classical CESAM project. During this project the team had faced a problem and had to elicit user interactions at an unusual moment. The design team had to invent a new interaction media (the functional requirement scenario) that has been tested later during the klui-klui project. Finally the digital mock-up has been tested during the manioc peeling project. At this occasion the design team has been very successful in fostering the user feedback, when a dummy was integrated into the scene. But this also showed the design team that a unique digital mock up was insufficient and that the functional principal scenario was missing to the project. This led to choose an unsatisfactory solution and killed the manioc peeling project.

Table 2: Summary of the projects involved in this study

Projects names	Problem scenario	Functional requirement scenario	Functional principle scenario	Digital mock-up scenario	working prototype
Klui-Klui project	✓*	✓	✓*	✓*	✓*
Manioc peeling project				✓	
Palm fruit stripping project	✓				
Peanut oil extraction project	✓*	✓*			

✓* method development ✓ method testing

Among the four projects that have been the source of experimentation and development of the method, only one ended up with a working prototype. The complexity of the socio-economic context led to freeze the other projects waiting for further resources.

4.2. Summary of the evaluation projects

In this section we present five design projects used for the evaluation of the method. From the analysis of these projects we draw lessons on the implementation and performance of the method.

4.2.1. The case studies

The case studies include five projects carried out during the period from December 2009 to December 2012. The characteristics of these five projects are summarised in table 3.

Table 3: Summary of the main projects characteristics

		Capacity (kg/h)	Productivity (%)	Users feedback
Project 1	Cashew Apple juce extraction	126	85	Improved ergonomy, Good technical performances, Juce quality.
	Existing technology	*25*	*80*	*Poor ergonomy, Low capcity, poor product quality (unappreciated by customers)*
Project 2	Palm oil cake pulping	440	85	Good technical performance
	Existing technology	*30*	*70*	*Poor technical performance(low productivity, low quality of the final product)*
Project 3	Palm oil extraction	300	80	Improved ergonomy, Good technical performances,
	Existing technology	*40*	*75*	*Poor technical performance (poor grinding quality, excessive screw shaft wear), Poor ergonomy,*
Project 4	Néré seeds grinder	350	90	No final evaluation
	Existing technology	*45*	*80*	*Hard working condisiotns, low productivity*
Project 5	Solar equipment transformation	350	85	No final evaluation
	Existing technology	*350*	*85*	*High operating costs*

The five projects were completed with a strong involvement of the users that is a first positive result. The user participation in line with the COSU method has been carried out and documented on project 1 (audio recording).
We have had the opportunity to fully test the method on the first three projects, while the last two stopped before the physical prototype due to a lack of funding. The palm oil cake pulping and the

palm oil extractor (projects 2 and 3) are already on the market while cashew apple juicer (1 project) is being marketed.

Each project team were composed of a project leader, one mechanical designer, one manufacturing expert, and one food technology expert. For the fifth project we added an expert on solar technology. The project team were meeting periodically every two months for checking the progression of the project, sharing feedback on the users' experiments and make decisions.

Figure 10: Example of initial technology and working prototype for project 1

4.2.2. Case studies analysis

The sample we studied is composed of the five above-mentioned projects plus one that followed a classical design process where the users are only involved through questionnaires at the beginning and at the end of the process.

Criteria

We have defined three main criteria for our analysis: i Applicability appropriation, ii user participation, iii performance of the method.

- *C1: Method appropriation*

This criteria will mesure the degree of applicability of the method and the ease of appropriation by the local design teams. More precisely we evaluate:

- The number of competences of the team
- The number of design meetings
- The number of artefacts produced (drawings, mock-ups, etc.) before the final prototype.
- The completeness of the scenarios
- The participation rate of the designers
- The number of phases actually achieved by the team

- *C2: User participation*

In order to measure the user participation we have selected indicators that would allow the evaluation whether the users brought knowledge to the product development. More precisely we evaluate:

- The number of users involved
- The number of user meetings
- The number of user feedback
- The number of design options that have been impacted by the users
- The number of questions asked by the users
- The number of interactions (users/designers)

- *C3: Method performance*

This criterion allows the verification the method in terms of user satisfaction and designers satisfaction. More precisely we evaluate:

- The duration of the project
- The number of iterations on the prototype
- The percentage of requirements met
- The project achievement (percentage)
- The product performance (capacity, productivity, quality)
- The user satisfaction

The data collected along the five projects are summarised in table 3.

Analysis

Data analysis shows that the percentage of the requirements reached is apparently related to the number of design meetings and to the amount of interactions with the users. Consequently the product performance and the quality of the end product has increased, which is observed in our results. This tends to show that the interactions between developers and users contribute significantly to the success of the project.

When we look at the number of users involved in each project we notice that the level of goal achievement reaches 100% for teams that collaborate with 14 to 18 users. The other projects involved less than 10 users. As a guideline 15 users seems a good number. Furthermore a too important number of users raises logistics and financial problems which can be critical in developing countries.

Four different expertises were involved in the first four projects and five in the fifth one, when the control project only involved three participants. In every project the number of expertise involved is directly linked to the product itself and the technology that has been chosen. However, in the case of small scale equipments in developing countries organisational complexity can be an issue. In our cases we experimented that four specialties were a minimum for achieving a proper design. A guideline should be then to minimise the number of design stakeholders by strictly limiting this number to the project necessity. In most cases for small size food processing equipments in sub-Saharan countries four experts appear to be sufficient.

The level scenario completeness is 100% in all the participative projects including project 3 and 4 that are still in the prototyping phase. The number of artefacts produced during the process is significantly higher in the 5 studied projects (between 8 and 11) than in the control one (4). If we refer to the level of success of the studied projects we can argue that the controlled involvement of users in the design process improves significantly the quality and the acceptability of the equipment.

The Cosu method appears to be adapted to the design process of small scale food processing equipments in the context of Western African small production units as our preliminary experiments show. The results of the evaluation process tend to prove that the method is applicable in this context and provides satisfaction to both designers and users. More over the results demonstrate a good usability of the method and the output in terms of user satisfaction and product quality are good indicators of the utility of the method.

5. Conclusion

Coming back to figure 5, we have now screened the four scenarios that populate the design process. Compared to the initial CESAM methodology we have intensified user-designer interaction in the first phase and allowed this interaction to occur in two other phases (i.e. the search for principles and the development phases), which is fairly uncommon in conventional design methods.

The definition of the scenario concept that we have adopted appears to differ from traditional definitions. The narrative dimension of the scenario as it is commonly used in software development is acceptable if the users behaviour is easily described and understood when expressed in an everyday language and do not refer to specific know-how or technical skills (typically traditional food processing techniques). Furthermore, in our case, the cultural aspects (the predominant oral culture) and the level of education of the users led us to adopt a different approach. We considered that paper-based descriptions of scenarios would not be useful. However the word “scenario” has been purposely kept as we consider that the objects described in the paper describe problematic situations and capture the expression of future usage. The users can therefore postulate a sequence of possible actions related to the product. The fact that we do not keep systematic and highly documented traces of the users’ interactions may be seen as a shortcoming of this method and can certainly be improved. But we should not forget the context of western African countries where the oral and direct face-to-face meetings is of tremendous importance for the success of projects.

The COSU method is a specific human-centred design method applied to the specific context of Western African countries. It was developed through four different design projects (peanut oil extraction, Klui-Klui, cassava root peeling and palm fruit cluster harvesting projects) and tested through five different other ones (Cashew Apple juice extraction, Palm oil cake pulping, Palm oil extraction, Néré seeds grinder, Solar equipment transformation). The test projects demonstrate the usability of the method and tend to validate its utility. Moreover they have provided precious information on the suitable size of both the design team (number of involved competencies) and the group of users.

The very specific and demanding context of Africa renders the task of developing a method very tricky. However, one of the unexpected lessons learnt from this experience is that the questions raised in the field are also valid for developed countries. For example, the necessary scenario co-construction phases imposed by the local cultural context involving time for discussion is often underestimated in conventional user-centred design methods that concentrate on the co-construction of the product only. Here, we were faced with the necessity to co-construct the solution and the scenario (which may also be referred to as the "problem") in a co-evolutionary paradigm (Maher and Tang, 2003).

In this article we have presented an original approach inspired by scenario-based design principles and proposed an original definition of the concept of scenario. This approach addresses the problem of taking user needs into account in design. In our view, it is an avenue to be further explored as it may help to lessen the shortcomings of conventional technology transfers and create a sustainable model of development for these countries based on bottom-up innovation.

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