Towards a Better Frugal Design using Persona
- issues and insights from an ethnography on prosthetics in Vietnam -

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Chloé Lecomte, G-SCOP Laboratory, Grenoble, France
Eric Blanco, G-SCOP Laboratory, Grenoble, France
Pascale Trompette, UMR Pacte, CNRS, Grenoble, France
Céline Cholez, UMR Pacte, Grenoble INP Génie Industriel, Grenoble, France

Abstract

Whether being guided by business, philanthropy or humanitarian objectives, design approaches for low income population try to propose innovative solutions with a sustainable logic. The issues remain in understanding what an appropriate technology is, by articulating product and service, bonding economic and social purposes, and exploring new business models. One strategy developed in the literature is the frugal engineering approach that simplifies the features of the product, lower the cost while keeping the quality high. The first step of designing for the Base of the socioeconomic Pyramid is to understand the local context and users' needs. However, this knowledge is very located, distributed through the stakeholders' chain, and difficult to translate into requirements for product development.

The aim of the paper is twofold. First, we aim to understand the "local intelligences", indicators of adaptations and appropriation, which are part of the product (re)design. Design is there taken in its brad sense, meaning conceptualizing, manufacturing, developing and using the product. Second, we focus on understanding how to formulize this complex new knowledge – complex because driven from ethnographic methods and carrying a lot of impactful socio-technical dimensions – for frugal design. Our hypothesis is that Personas (specific and concrete model of the users) are likely to carry representation of the users and several dimensions of the ecosystem, and thus help to pilot frugal design.

To answer to our goals, we conducted ethnographic studies on six rehabilitation centers in Vietnam to gather data on design, manufacturing process, and uses of low cost prosthesis for poor amputees. The results show the mechanisms locally implemented to provide frugal prosthesis for Vietnamese amputees. Along the design and manufacturing chain, designers, technicians, P&O professional and end-users set up regulations strategies and "bricolage", integrating several dimensions, such as manufacturing technics, professional practices and historical partnerships. Our study shows also a users' segmentation from the field and several simplification's strategies to provide frugal prosthesis, which can be a basis for constructing personas.

The results is coherent with our hypothesis, and open new questions on the personas role and into collaboration, for articulating implicit, local, embedded and grassroot expertise with more formalized information and methods. The implications are for both managerial practitioners and researchers to ask the good questions on how to make knowledge more representable and transferable in a research-design collaboration.

Introduction

The growing market on essential products and services in developing countries are redefining trajectories of innovation. Assuming that simple technology transfer from North to South is not sufficient (London, 2011; Rangan et al., 2007), the challenges that are facing companies today is how to design innovations that fulfill effectively the '4A' criteria: Accessibility, Affordability, Availability, and Awareness (Anderson and Markidès, 2007). The frugal innovation paradigm addresses these issues by proposing a new approach of engineering, based on cost reduction, features simplification and quality focus (Radjou et al., 2012; Seghal et al., 2010; Zeschky et al., 2011). Frugal innovations are closed to grassroot innovations, also called jugaad innovation in India, which emphasizes local and successful practices while designing in a high-constrained environment. These "local intelligences" and grassroot innovations are good indicators of potential innovation and needs (Seyfang & Smith, 2007), and understanding them offer useful orientations for the design process. More and more companies focus on these grassroot innovations taken as lead users (Von Hippel, 2005) to create a niche at the base of the socio-economic pyramid. However, a review of cases described in literature had shown that projects have difficulties to scale up outside the place where they were developed (Lecomte, Blanco, & Boissin, 2012). Thus the tension between the adapted, local, grassroot innovation and the required scaling up of product that proposes frugal design to maintain affordability is still not solved. Literature and practical cases miss some clarification about 'what' to observe in the ground that would actually impact the product design, and 'how' to hold observations into manipulable data for designers.

Using an ethnographic study on prosthetics design, this paper aims at understanding how local designers re-think design to provide frugal products, and how these local intelligences can be rationalized and integrated for frugal design. Design is taken here in its broader sense, as the "human power to conceive, plan and realize all of the products that serves human beings in the accomplishment of their individual or collective purpose" (Buchanan, 2001). All dimensions of design are thus observed, from conceptualization to realization and adaptation (Freeman & Hart, 2004).

The first section of our paper will present a short review of literature on frugal design to set down the challenges and the need to inspire from local practices. These descriptions of challenges will directly link to the requirement of mediation, allowing designers to represent the complexity of the uses and practices. The Personas tool appears to be candidate to support this representation of socio-technical ecosystem. This hypothesis is explored through the case study of the design of prosthetics in Vietnam. The third section describes the ethnographic methodology, and our six case studies of locally designed and manufactured prosthesis. The results highlight the different dimensions that have to be represented. We will finish by a discussion on the utility of this approach and the benefits and limits of using personas to articulate implicit, local, embedded and grassroot expertise with more formalized information and methods.

1. Frugal design and its complexity: the challenge of formalization

1.1. From local and grassroot practices…

Grassroots innovations are described as bottom-up innovations with social objectives (Church & Elster, 2002). The solutions invented answer to the local constraints, and the interests of the communities (Seyfang & Smith, 2007). Grassroots innovations are driven by two motives towards sustainable innovation: social need and ideology (Seyfang & Smith, 2007). With the help of a flexible

and localized social economy, grassroot design ensures that social needs are met in all situations. The ideology behind that concept is mostly carried by networks of activists and organizations, such as NGOs or research institutions, that deeply believe in "small is beautiful" (Schumacher, 1973).

Very similar to grassroot innovation in the sense of focusing on local constraints and local interests, the jugaad design adds the dimensions of dynamics and flexibility. Void of process, Jugaad means dealing with scarce resources to makeshift a solution for a direct problem, "transforming scarcity into opportunity" (Radjou et al., 2012). The jugaad design is practiced by all Indians in their daily lives to make the most out of what they have around them. In other countries, this improvised arrangement may called system D, bricolage, or kludge.

1.2. … To frugal design

Like jugaad innovation, frugal engineering is an engineering process that responds to severe resource-constraints environment, whether financial, material or institutional. Unlike jugaad or grassroot design which sticks to solve a unique problem, frugal design is more formalized and systematized for optimizing design processes (Krishnan, 2010). The goal is to make "more with less for more" (Prahalad and Mashelkar, 2010), targeting an economy of scale. Nowadays, frugal innovation has become a new marketing slogan to drive costs in large and medium companies targeting developing markets.

The first criterion for successful frugal innovation is to make it financially affordable. As (Seghal et al., 2010) point out, "cost discipline is an intrinsic part of the process, but rather than simply cutting existing costs, frugal engineering seeks to avoid needless costs in the first place". It entails a new approach of product development, as the engineering processes/products are to be broken into basic components with cost-efficient materials, and then rebuilt in the most economical manner possible. The second criterion is to make simpler products with high-quality accuracy (Zeschky et al., 2011), rethinking the entire design to fit into the end-users needs. And finally, a recent report on frugal innovation emphasizes the need for remodeling products, and not simply de-featuring or degrading quality (Bound and Thornton, 2012).

1.3. Frugal design is not so obvious

Just like companies inspire from lead users (Von Hippel, 2005), jugaad or grassroot innovation are useful to give the trends of the needs while dealing with local constraints. By optimizing the local jugaad logics, MNE and SME would be able to build a model of reverse globalization (Gupta, 2011). However, many challenges remain in going from grassroot innovations, valid within local specificities to more generalized frugal design:

- Understanding the multiple dimensions of the socio-technical system the innovation will fit into. Various exploratory tools are available to understand local contexts, needs, aspirations and behaviors (Sanders, 2000): interviews, observation, participation, and so on. However understanding the needs of the targeted population may be crucial, but it does not ensure success of the project in term of scale-up (Lecomte et al., 2012), and therefore sustainability. Design has to embrace the entire spectrum of the human nature (Faste, 2001). The point is going beyond user-centered design to system-centered design, from involving users to involving communities. Inclusive and participative designs aim at taking inputs from a wider user community; projects are very successful locally, but struggle to scale-up.
- Understanding the main functions of the future technology, to guide the decision making process on features: this just enough approach requires careful trade-offs, planned during the

early phases of product development, to bind the multiple objectives of lowering costs and increasing utility and quality.

- Overcome the representation filter: authors also point out the difficulty to design for others, and indeed the difficulty to design for a collection of other people, with their subtle variations. We would naturally add that cultural differences make another difficulty. (Usunier, 1998) says that as the researcher (or designer) has a different background culture to the local field and informant, therefore basic differences have to be clear from the beginning of the design process. Designers, like everyone, have a tendency to project their own experience to other users, projecting their values and their expectations (Redstrom, 2006). At better, they make stereotypes, the "socially constructed representations of categories of people" (Hinton, 2000), which allow them to take their marks, but could link to misunderstanding the key concepts of the local context.

To overcome the challenges of frugal design, to help organizing, representing and hierarchizing data collected from the field, we suggest using the Persona tool as a mediation and representation support for the designers.

1.4. How to make it practical: Use of Personas?

Persona are figurative and actionable images of the end-users (Cooper, 1999). Firstly described as "hypothetical archetypes of actual users" (Cooper, 1999), they are fictional people, but their behavior is described with realism, with a lot amount of details: names, preferences, activities, family members, achievement, and so on (Grudin & Pruitt, 2002). "The special aspect of a persona description is that you do not look at the entire person, but use the area of focus or domain you are working within as a lens to highlight the relevant attitudes and the specific context associated with the area of work" (Nielsen, 2013). Based on the Theory of Mind, which states that human can extrapolate from a mental state of other humans their behavior, designers can generate new knowledge from the persona, completing the possible scenarios (Grudin & Pruitt, 2002).

Depending on the literature, several benefits can be found. The most quoted ones are the following:

- Personas transform qualitative data from ethnography into manipulable tool by designers (Cooper, 1999; Nielsen, 2013), it is the only tool that helps designers to actually use qualitative data during design. It especially forces designers to consider social and political aspects of design, difficult to manipulate while designing (Grudin & Pruitt, 2002).
- Persona help to make trade-offs (Floyd, Cameron Jones, & Twidale, 2008), which is one of the major challenges when designing frugal products.
- Personas help to clarify and explicit assumptions (Grudin & Pruitt, 2002), and therefore can support local and grassroot knowledge
- Personas create a focus on target users by identifying their key attributes (Floyd et al., 2008; Grudin & Pruitt, 2002), which can help to design for multiple end-users.

According to the literature, Persona seems to be appropriate tools to support grassroot innovators for conducting frugal design. They can be used as intermediary objects (Boujut, 2003; Vinck, 2011) by designers to support representation of users or potential users (Floyd et al., 2008). More and more companies are using Personas to support the Customer Values and to represent every stakeholder of the value chain. We have explored a specific field study to identify what would be the dimensions and characteristics that persona should carry in order to support this mediation and translation from field observation to designers.

2. Methodology

2.1. Why prosthetics? The choices of our field study

Why did we choose prosthetics among other fields to tackle these questions? The choice of the product and focus was made from our opportunity to study different product and design, in different design processes, in different countries. From high-tech prosthetics to low-cost prosthetics, the nature of the product itself is also particular and informant as it is an embodied product that should be included in all particular activities and dimension of all users while at the same time many regulations and standards define what it should be. The appropriation of the product is a key point. This choice corresponds to the recommendation of Yin, as the case is supposed to be "unusually revelatory, extreme exemplars or opportunities for unusual research access" (Yin, 2009).

Moreover, prosthetics are shown to be a great field of study for understanding frugal innovative adaptation, as it answers to essential needs with an objective of low-cost and high quality, and in a context of replicability. Prosthetics are complex products, with a strong relation to its user (amputee) and the environment the user lives in. Authors emphasize the need to understand and adapt the technologies to local conditions and culture (Cummings, 1996; Meanley, 1995; Sethi, 1989; Vossberg, 1985). Usability and ergonomics of the devices have to be locally adapted to maintenance problems, culture acceptability and use differences (Pearlman et al., 2009; Sethi, 1989). The developed technology should be less cumbersome, less time-consuming and less expensive (Juma and Yee-Cheong, 2005). Therefore transfer of prosthesis from North to South cannot be a long-term solution, and there is a need to take into account local specificities (Meanley, 1995).

A lot of examples show how prosthetics are mines of information for local adaptation and innovation. The Jaipur foot story demonstrates how the prosthesis could be successfully replicated in all over India, based on a generic local adapted model. The amazing Jaipur knee innovation, overcoming the issue of squatting and knee-bending in India, could therefore not economically succeed, but local manufacturers have seized the concept of polycentric joint to copy and adapted it with local material. Therefore, as pointed out in the introduction, design process has to be taken in a broad sense. "Design encompasses all the activities involved in conceptualizing, framing, implementing, commission and ultimately modifying complex systems (Freeman & Hart, 2004). Talking about design includes human activities for realizing their purpose of adapting the products to the final purpose (Buchanan, 2001). In our study, it is about adapting prosthetics to end-users through different dimensions, such as early design phases for new product development, but also manufacturing processes, evolution and modification through development and uses. The transformation of the product has to be though in a continuous way, and re-design way appear anytime at the product goes along its life circle.

Finally, the prosthetics, as in health care sector, tackle the issues of global standardization and local adaptation, showing the tensions and the trade-offs between the global nature of a product, and its specificities.

2.2. An itinerant ethnographic research

This study was conducted as a descriptive and exploratory field study that can be classify as qualitative study following Eisenhart and Graebner: "Qualitative research is highly descriptive, emphasizes the social construction of reality, and focuses on revealing how extant theory operates in particular examples". (p 28) (Eisenhardt & Graebner, 2007). By using ethnography research, we explore the socio-technical settings of a particular context, providing useful perspectives to

conceptualize practices and actors into a design process (Akrich, 1992). (Willis, 2007) describes ethnography as 'an umbrella term for fieldwork, interviewing, and other means of gathering data in authentic (…) environments". Ethnography is thus a "study at first hand" (Hammersley, 2006), that describes local processes of innovation and structuration, and gather "experiential, presentational, propositional, and practical knowing" (Guba & Lincoln, 2005).

As it was obviously not possible to follow continuously the whole process of prosthetic design – the design of prosthetics may take from two weeks to two months, and involves medical secret of the patient - we chose to visit itinerantly several rehabilitation centers in Vietnam. During two months, we visited six centers in five different cities (Ha Noi, Ba Vi, Da Nang, Ho Chi Minh City, and Can Thò), as well as one center in Vientiane (Laos). Each time, we stayed several hours to several days, to be deeply immersed in the community (Flick, 2002). We interviewed over twenty (20) people working on the medical field such as prosthesists, technicians, doctors, directors of hospital, physiotherapists, as well as patients (prosthetics users), with the help of local translators. These numerous informants from different hierarchical positions and geographical areas allowed us to ensure retrospective sense-making of the case studies observed. Most of the interviews were recorded, translated, and transcribed into written documents (see table 1 below for the list of interviews).

Center	Interviews	Observations and materials
Ha Noi (VietCot)	Collective interview with a doctor, a student and the secretary (recorded) Students	Prosthesis manufacturing (videos and photos) Patient rehabilitation (photos) Technical documents
Ba Vi	Chief technician (recorded)	EB-1 foot manufacturing (videos and photos) No prosthesis manufacturing in progress (production stopped) Visit of the center (recorded) Technical documents
Da Nang	Director (recorded) Chief doctor (recorded) Chief prosthesist (recorded) Chief physiotherapist Two patients (recorded)	Prosthesis manufacturing (videos and photos)(recorded) Patients rehabilitation (photos) Final evaluation of the patients before coming out Posters and technical documents
HCM City	Director (recorded) Chief prosthesist	Orthesis manufacturing (videos and photos) Handicapped children rehabilitation
HCM City	Doctor Chief of the training room A patient	Prosthesis manufacturing (videos and photos) Training room
Can Tho	Director (recorded) Chief prosthesist (recorded) Three patients	No prosthesis manufacturing in progress (production stopped) Orthesis manufacturing (videos and photos) Technical documents
(Vientiane)	*(Chief prosthesist)*	*(Prosthesis manufacturing (photos))*

Table 1
Methods and data gathered in rehabilitation and manufacturing centers in Vietnam and Laos

As ethnography research involves multiple sources of data (Flick, 2002), we gathered a rich variety of data sources, interviews, archival data, when possible technical documents, observations, photos and videos at different moment of the design, manufacturing, and fitting process, and concerning different components (feet, leg, knee). We completed our study with interviews with three western (European and American) prosthetics designers, to better understand the process and the challenges. One

interview was conducted with an expert working in a US NGO, one with an US engineer that designed a new knee, and a last one with a French P&O owning a prosthetics company.

2.3. Multiple stories, one ethnographic frame

As the centers were very different, we did not observe the same elements from one to another: some centers were manufacturing their own components, some were only importing them; some centers had several departments and kept their patient all along the process, others just take care of the prosthetics fitting process, and so on. Because of this diversity, comparative study was not possible. However, we have chosen the six Vietnamese centers (the one in Laos brings only additional arguments) relatively to their common background:

- **Governmental supervision and organizational structure**: all visited centers are under the supervision of the MoLISA (Ministry Labor, Invalids and Social Affairs) and ruled by the National Health Policy. The unprecedented rapid growth of the number of diabetes persons, the increasing aged population, and the changing social structure that link indubitably to vehicle and industrial accidents, make the amputee population in the center of health preoccupation. The Ministry of Invalids was created in 1940, and merged with the Ministry of labor and Social Affairs in 1987 to create the MoLISA, responsible for social and vocational rehabilitation, job placement and social welfare. In total, 14 centers out of 23 rehabilitation centers are under the supervision of MoLISA. Its active partnership with the WHO has conducted to a multi-level and systemic approach of health care, thus rehabilitation takes place at several levels: physical, social, educational and economical.
  A turning point regarding disabled persons has been made with the Vietnamese Ordinance in November 1998, which stated that the disabled persons have equal rights and opportunities in all living sectors. Further along, the constitution of 1980, rewritten in 1992, and with its final version in 1998, states that *« war invalids, sick soldiers family of fallen soldiers and revolutionary martyrs will enjoy preferential treatment in state policies. War invalids will enjoy favorable conditions for their physical rehabilitation, shall be given employment suites to their states of health and assistance insecuring stable living conditions »* (Constitution de 1998, article 67 (Fundamental rights and duties of the citizen »). This article makes war and post-war landmines amputees financially protected for a social and economic rehabilitation. To allow other poor patients to access to health care, a number of formal institutions help in providing financial services, such as the Vietnam Bank Agriculture & Rural Development (VBARD), the Vietnam Bank of the Poor (VBP), the People's Credit Funds (PCFs) Cooperation, the Rural Shareholders Banks (RSHBs) or informal institutions.

- **International standards**: all centers follow, during design, manufacturing, and prosthesis fitting, the international standards proposed by the International Society for Orthotics and Prosthetics (ISPO). ISPO and its members have launched several studies in developing countries have contributed to define appropriate prosthesis technologies for developing countries. One of the most important challenges is the quality of the product or device, meaning that "medical devices are produced properly and used judiciously and safely" (WHO, 1995). This echoes the article 20 of the United Nation Convention of the Rights, saying that countries have to provide a choice of high-quality, affordable health devices.
  Following several studies, ISPO and WHO have developed quality standards for developing countries (WHO Technical Report Series No 100), which are 1) Simplicity, ease of

construction and possibility to repair; 2) Durability, 3) Adaptability to local conditions of living and occupation, and 4) Inexpensiveness of primary cost and repair.

- **The Vietnamese Training Centre for Orthopaedic Technologists (VIETCOT):** all prosthesists (commonly named P&O - Prosthesist and Orthotists), Vietnamese and Laos, come from the same international training school. Officially named governmental institute of national education, and partner with the international committee ISPO, the VIETCOT training center follows the structure and the standardization the context provides. Since its creation in 1997, more than fifty professional orthopaedic technologists were trained from different countries in Asia. VIETCOT is under the direction of the German Agency for Technical Cooperation (GTZ).

This multiple field-studies is to be assimilated to a rich ethnographic study composed of plentiful point of views, feedbacks, experiences and competencies. The myriad of qualitative data gives us multiple views of the re-design and appropriation process, during manufacturing, assembling, fitting and use. The ethnography studies build a patchwork of stories that – joined end to end - compose a coherent whole to understand how local P&O professionals design frugal prosthetics. Our semi-directive interviews and observations followed a wide-open structure to include individual experience, center history, and manufacturing processes, as well as interaction between the different professions and their link to the final user. By doing so, we try to get closer to a « post interactionist » ethnography, containing several dimensions to open our research to a wider, biographical, organizational and historical temporality.

3. Results: a multiple re-design process through different dimensions

3.1. Diagnostic of the patient: between procedure and intuition

"First, when comes the patient, the OP [Orthotics Prosthesist] looks at his gait, qualities and defaults, stronger and weaker muscles, form of the stump, and so on... in order to decide with solution will be appropriate. For example, if the muscle is strong enough to support the prosthetics, it will be a full-contact socket. If the stump is too small or the muscles too weak, we will use an open-ended socket with a belt, either to the chest or to the waist" [2]. This quotation from a teacher at VIETCOT resumes the procedure the patient follows when arriving in the rehabilitation center. The VIETCOT center provides a questionnaire that has to be filled by the prosthesist and the doctor when a new patient comes. Part of the procedure concerns biomechanical and anatomical assessment, but a whole page is dedicated to a functional analysis of daily activities (endurance per day, type of work, etc.) and surrounding environment (type of transportation). Based on this assessment, the prosthesist altogether with the doctor, determines the Expected Functional Level the client is expected to reach with the new prosthesis. The functional level "help to define a range of prosthetic components that may be beneficial to serve the functional needs identified". For example, at the functional level 0, the patient "will not have the ability or potential to ambulate or transfer safely with or without assistance and a prosthesis will not enhance their quality of life or mobility". At the highest level, the functional level 4, the amputee "has the ability or potential for prosthetic ambulation that exceeds basic ambulant skills, exhibiting high impact, stress, or energy levels, which is "typical of the prosthetic demands of the child, active adult or athlete". The result of this categorization is the choice of a prosthetic that corresponds to the user needs. An amputee level 0 would have a "limited and unlimited household ambulator", and on the other extremity, a patient level 4 will have "a highly active and sturdy, impact-resistant components. A fluid (or computer-) controlled knee mechanism is indicated to cope with the

quickly changing speeds and loading situations." (All quotes are from the VIETCOT Training Manuel, p 40-41]. Between these extreme functional levesl are found a range of alternatives.

As this diagnostic is the only one taught during training lessons, we would have expected to see this procedure in every visited center. However it happened that all cases were different. Like for manufacturing technics, ancient or actual partnerships play a role in the diagnostic approach: if some centers had the VIETCOT procedure, other funded by NGOs had their own diagnostic procedure. For example, the Red Cross has adapted the questionnaire to be simpler, with only check boxes that allow the prosthesist to follow step by step the procedure. It has also a more detailed questionnaire about functional activities of the patient, in order to help choosing the right prosthesis.

Nevertheless, the subjectivity and experience of the prosthesis come along in the final decision. Observations from the field have shown that the prosthesis look at his patient and from a simple glance he already knows with type of prosthesis he will choose. We watch a patient coming in Can Tho center: the man was around his fifties, coming to change his old artificial leg which was so used it was falling apart. The P&O talked to him while showing him another patient wearing a wooden leg, as if he was proposing this solution for replacement. In this case, no questionnaire was proposed at the venue, although measurement and gait analysis were surely done at one point. Therefore, it is possible that this intuitive approach do not give enough 'voice' to the final user: in Da Nang, a P&O explained to us why the prosthetics a patient had fit him well, because of the form of his stump, and his activities in a shop. While the P&O was talking, the patient was repeating his leg was really too heavy, and he had difficulties to walk with. For the American P&O who worked 15 years in Vietnam, *"many times the amputees community themselves, especially in developing countries, are not consulted enough, are not studied enough about the features of the product that they want"* [11]. Another approach was more technical, studying the old leg (when existing) to understand the habit of the patient. A partially registered conversation between a prosthesist and a patient in Can Tho reveals the interest the P&O had in the old leg, where it broke, and what were the daily activities of the amputee. In Ha Noi, the patient was a young child, and prosthesists took time to analyze his old leg and its weakest points, while the boy was remaining totally silent during 1h. Analyzing *"failures of the original [product]"* seems to be classical for understanding the habits of the user; the American P&O had this approach for designing a more suitable foot: *"... we understand the... the failure of the original foot very well. I t was a little bit more difficult to understand the performance of the foot [...]we had to analyze the flexibility of the toes, that means we put force on the toe, and bend the rubber of the toe, and we would measure the force vs the reflection of the toe*" [11]; "*And for those people living on the hills side, going up and down the road, that is a very difficult challenge. That actually created... we found out about that, because many of those amputees, instead of using an ankle joint, they will actually cut the length of the foot"* [11].

Those examples illustrate the multiple dimensions the P&O has to deal with when fitting a patient. First, the end-user is a patient to be rehabilitated, with a medical approach. The residual limb is taken as a "physical object, made up of an inner core (bone) surrounded by a cellular structure (muscles), wrapped up with a protective container (skin)" [Vietcot manual]. The general side-effects can be complex, such as a change of the center of mass support, change from physiological weight transfer surfaces to non-physiological ones, loss of feedbacks and control loops, loss of joint stabilization, need to re-learn the process of standing and walking, and need to switch from unconscious automated control and motion pattern to highly conscious and new patterns of stability-control and motion. Therefore, the choice of the prosthesis will be made relatively to the state of the patient in order to "*decide which solution will be appropriate"* [2]. Secondly, the amputation has also psychological, physiological, and social repercussions, and has to involve a social approach. From the questionnaire,

his own perception of the user and sometimes interviews, the P&O analyzes the situation to understand what the needs of the user are. And finally, one must not forget that the patient is also a client as he buys the product and the service. The old man was maybe complaining about the weight of his leg because all other patients had more 'high-tech' hydraulic knees, a solution he could maybe not afford. The glance of the P&O took from the new patient may told him a lot about his living conditions, and the cheap components he would choose to be appropriate.

3.2. The prosthesis' choice: a modular process

Basically, the prosthesis is made of several components put together during alignment. For transfemoral amputees, an exo-skeletal artificial leg is composed of a socket, a knee, a sting, a stank and a foot, and a transtibial only of a socket and a stank with a foot. Each component can be brought separately. Based on the previous assessment, the PO, sometimes with the doctor, chooses the good components and the type of socket he will make.

A catalog of dozen of products can be found on the VIETCOT manual, from really sophisticated products (for example carbon foot) to very low-cost ones (such as bamboo pilon). When visiting the centers, we have asked about the proposed products, the reason why they proposed this product and to which type of patient. The answer was not always given, but yet we had a lot of results, summarized in the table 2 below.

Center	Products	Reasons (when explained)
Ba Vi	EB1 foot EB1 for highlanders EB2 foot	Manufacturing center of foot on site Close to mountainous regions Manufacturing center of foot on site
VIETCOT	All components available, mostly from OttoBock Not much a use of EB1 Full contact socket when possible	Training center; Partnership with Ottobock; Facilities for importation ? ?
Da Nang	Da nang foot 'High tech' components PP knees and prosthetics, adapted from existing products No full-contact socket	Manufacturing center on site Richer patient who can pay Manufacturing on site; existing products not convenient (has to be more standardized, and cheaper) Too hot, too humid, not convenient
HCMV 1	Large variety of imported products Mostly 'high tech'	Urban center Richer patient who can pay
HCMV 2	Components made in PP Very large offer: Da Nang foot EB1 foot Imported foot HCMV foot No full-contact socket Leather and steel frame	Cheaper but not durable under UV; manufacturing center on site Cosmetic seem to be appreciated Governmental partnership, but heavier More high tech for richer patients (more durable) Manufacturing on site, lighter (plastic ankle) ? Better fixation, specialists of leather

Can Tho	Foot imported (Ossür)	« Best foot », very expensive but very resistant
	Foot locally made (EB1 sole + wood)	Cheap, locally made, easy to repair
	Da Nang foot	?
	Saigon foot	?
	Foot locally made of wood and foam	For children and old people (light and cheap)
	Prosthesis made of PP	Classic prosthesis made with vacuum technic. More expensive
	Prosthesis made of PN	Only for transtibial amputees.
	Prosthesis made of wood	For healthy adults than work on the fields. Heavy, but solid
	Use of armature	Cheaper, easier to change when damaged

Table 2: Different offers for different reasons

Some of the products proposed are imported from Germany or England, and then assembled locally. Prosthesists can order products such as the polycentric knee joint which allow a nearly-natural swing phase (extending the leg), or even hydraulic knee shins, that provide adjustable extension (straightening) and flexion (bending) for stance control. Therefore, these types of products are considered *"only for the people who have money"* [9]. In the VIETCOT Manual Training book, these prosthesis are even categorized as "sophisticated" technology, with components of high complexity and function, which is *"appropriate in the Industrialized World, not appropriate for the general introduction to OP services in developing countries"*. The main reason is simply the cost of these products that exceed what local customers can afford to pay, or are willing to pay. Therefore, usual clients are wealthy urban persons that *"want to pay for that [imported components]"* [11], and also some richer veterans that spare the government funding with their own financial means to afford buying imported products (as seen in Da Nang).

Some manufacturing centers manufacture their own products: Ba Vi produces its own foot (EB1 & 2), as well as Da Nang and Ho Chi Minh 2. All centers, except Ha Noi and HCM1, manufacture knees, stank and alignment components, out of PP with hydraulic presses. Few details are changing from one center to another, as the machines are not really the same depending on the NGO that provided it. The cast-iron molds are made locally, so that centers can produce their own specificities. We could observe then that HCM2 center had a wider range of sizes for feet and knees than Da Nang. In Da Nang center, *"the knee didn't convince them, so they improved it"* [5] by changing the lock system: instead of having left and right knee with the lock on the inside for sit position, they have standardized the knee for later differentiation (two holes on each side of the knee). Although we don't know who have changed the system, this example shows anyway an adaptation of the design for manufacturing to simplify the process, and lower the costs.

In Ba Vi, the prosthesists worked three years with an American NGO on a new foot. The goal was to use locally available material (rubber) while keeping high performance. They are now producing the EB1 feet in big quantities and even export them. In a more crafty way, prosthesists from Can Tho have designed their own products for answering to local needs. *"When there are children or old persons that are very fragile, [the PO] have to design themselves the feet that fit to the patients"* [14]. So they made light foot made of foam for children and old patients, and a heavier but more solid foot with EB1 sole and wood. For healthy working men, they manufacture wooden endoskeletal legs which are said to be archaic by articles (ref), but still very solid [9]. In HCM2, the center produces feet that look like Da Nang ones, but with a brighter color and different composition.

Here is a transcription of the exchange we had with our translator describing four different feet in Can Tho:

PS - Light, this one is light
(…)
PS –Shock absorption?
Me – Yes
(…)
PS – This one is very heavy
(…)
PS – This one is very solid, when you cannot, when you… when you put your foot to the ground, like that (bouncing movement), yes, this.
(…)
PS – but this one is only light, there is no, like you say, the shock absorption. And this one, for 5 years, 10 years, it is good, but for 5 months, 1 year, not really. [9]

Every product fulfills one important function upon other. A foot which is solid will not be light. And a light foot would not be durable, and has bad shock absorption. In HCM2, the principal criteria for describing the feet were cosmetics, price and weight, and these three requirements were prioritized differently depending on the foot.

A frugal prosthesis appears to be diversified in several frugal products. Looking for the just-enough the frugal design is talking about brings us several just-enough depending on the product, its use and the activity. Through the field arise a segmentation of the patients in several big categories: urban and rural, rich and poor, field worker and citizens (see table 3 below). The diversity of patients and users is simplified, and the choice of the prosthetics seems to follow this identification.

Group of users	Specificities	Impact on the prosthesis choice
Veterans or civil servants	Funding from the government every 3 years for buying facilities	'Just-enough' technology
Private patients	Willing to pay for a prosthesis	More technology
Amputees that live in the cities Wealthier veterans	Walk on flat ropes Ride bicycles Wear shoes Want to look normal (don't want to be identified as amputees)	Good functions Very good cosmetic finishing Fit in shoes Have a normal gait
Amputees that live on rural areas	Work in the rice fields Have to lift weight Wear sandals Work for hours (10h/day)	Strong prosthesis Comfortable Cosmetic not so important (because of the mud)
Amputees that live on the mountains	Live on the hill side (not flat surfaces) Walk on ropes	Prosthesis with flexible ankle joint

Table 3: the segmentation of patients (constructed with interviews data)

3.3. The professional dimension of manufacturing practices: use of adaptive standard or adaptation of standards?

The first step of this adaptive design process is the measurement of the stump to design the interface between the skin and the prosthesis: the socket. There are several ways of manufacturing a socket, and several types of socket possible. A technic, the lamination resins, is taught at VIETCOT, but not

practiced in none of the visited centers, for several reasons: *"too much dust and it's dirty, and too difficult" [4]*. *"So before, they had an evolution, a slowly evolution if you want, before there was wood, and then lamination, and then they changed and came back to this one [vacuum]"* [5]. All sockets are then made in polypropylene (PP), with the vacuum technic, despite some reticence of using this material in the climatic conditions of Laos and Vietnam *("(...) but I have to decide, I wouldn't choose the PP. It's not good for our country, too much sun, too much water."*[16]), which degrades too fast the prosthesis *("PP is a plastic not resistant to UVs, and it is not good to wear the prosthesis outdoor"* [8]). Nevertheless, the PP material with vacuum technic is the best value for money known, which is nowadays used in all developing countries. Some prosthesists also mentioned the role of partnership on manufacturing technics, not only because of the machines available, but also because of the training the NGO gives. For example, the center of VIETCOT has a lot of technic available, due to its status of official government center, and its close partnership with Ottö Bock, a P&O global firm that donated all the machines. In Can Tho and Da Nang centers, both funded by the Red Cross, technics with other type of plastics were found (PN plastic), though not really used. Like in European P&O companies, there are slight differences between the profession, and to our opinion, it would not be a huge mistake to make the hypothesis that partnership and history of each center have an impact on manufacturing choices.

The manufacturing process described below is the common basis for all transfemoral and transtibial sockets made with vacuum technics, used in every center. To make a socket with vacuum technics, a negative plaster cast is made off the measurements, with the help of plaster bandages wrapped on the residual limb. Then the negative cast is poured with a plaster/water mix to be transferred on a positive cast, which will be the basis for the real prosthesis manufacturing. However, as observed, measurement is not enough as they do not represent the final residual limb under load bearing conditions. Observations show that the positive models are often "free-style"-modified without the patient in place, in order to optimized force transfer and enhance comfort. *"The more prosthesis you do, the more accurate you can be with experience. That's why students learn a lot from the experienced professor that have more than the theoretical background: they know/they feel how to do it, like artists" [2]*. In this manufacturing phase, the skills, experience and 'know-how' of the prosthesist are of major importance. Gestures are fast, self-confident. Videos show prosthesists manipulating drawings and measures very rapidly and without several attempts, then scrape and rub the plaster mold with a lot of precision, sometimes with poor tools.

Other interesting elements came out of the observation of this manufacturing process. A video of a Vietnamese prosthesist shows her trying to optimize the use of PP sheet during cosmetic phase by putting little piece together. This example is relevant of the negotiation that take place during manufacturing: while cosmetic is considered the most important process because *"it shows how professional the prosthesist is"* [1], and because end-users care a lot about aesthetics of the leg, economic constraints seem to be more important and put above cosmetic. Combining little pieces of PP forces the prosthesist that has to finely shape the leg, and rub off all irregularities from the joints, which take more time and work at the end. This phenomenon was observed in rural centers, where PP seems to be economically used, but not in urban places where the bins were full of unused PP, ready to be melted and used again. The manufacturing time was also a data that came out often from the interviews. A prosthesis is made usually in one week, if all the components are available. But depending on the number of demand, this time can vary from three days to two months. Surprisingly, the more people there are, the faster the manufacture is. The reason may be that the hospital cannot host everyone for a few days, so they have to be faster to send the amputees home. The time also varies from one patient to another too, during the same period – in Can Tho for example, a prosthesist

told us that they have to be quicker for poor people, because they cannot stay for a long time in the city, far from their family [9]. A patient confirms that he doesn't come often because the center is too far from his town – and work.

The individual adaptation of the prosthesis is also done during iterative modifications during fitting, to finely adjust every component to the physical characteristics of the patient (gait, posture…). When the socket is ready for fitting, every component of the prosthesis[1] is gathered and put together relatively to a static reference system: the alignment. Following the equilibrium principle (sum of forces equals zero), the prosthesist rectifies or adjust either the components alignment, or the components' design themselves. The prosthesis is then observed within its dynamic movement, and the physiological gait patterns are observed for any possible correction. As VIETCOT prosthesists said, poor socket design, poor understanding of the user's habits and poor prosthetic alignment can link to a non-optimal combination of forces and bending moments that will make the prosthesis difficult to use. One Vietnamese prosthesist stated: "*because the foot is standard and may not correspond to shoes habit of the user, for example if wearing heels or not, (...) the first step is to find the right angle of the foot/ground in order to have the top of the foot as flat as possible*", which can be done by putting a piece of wood beneath the heel [2]. The alignment is made using a table with tensioned strings for 3D positioning, or more often in its simplified version of a simple string used as a pendulum, which seems to be faster and more convenient.

The last step of the manufacturing and fitting process is a long period of training, necessary to get the user used to the new prosthesis, especially when the muscles have to be re-educated. Although the manufacturing time can vary, this training period of two or three days is uncompressible in order to test while practicing whether the prosthesis fits well the patient or not. Here we could observe a great variation in the rehabilitation team composition, depending on the availabilities of health professional, and the proximity of other departments such as surgery or physiotherapy: a prosthesist was always present, sometimes a doctor, sometimes a physical therapist, and sometimes the three of them.

Standard procedure and manufacturing processes leave space for individual fitting through measurement, individual assessment, and rehabilitation. Along all steps, individual variations are taking into account for adapting the prosthesis to the patient. The VIETCOT training courses and ISPO and ISO standards give an adaptive basis for standardized manufacturing process. Therefore, our observations show that the professional dimension also plays an important role to get close to the final user: the P&O professionals negotiate the standards with the existing constraints by developing a professional attitude consistent with the surrounding environment.

3.4. Re-design by users for adaptation

Some feedbacks from patients were captured and used to understand the effective use of their prosthesis. Two veterans were met in Can Tho. From their original foot delivered fifteen years ago, nothing was left. The fastener was replaced by a lace-up; the toes were cut and the foot transformed into a pilon; the ankle was reinforced with a piece of steel. Their prosthesis were entirely re-designed for their special needs: working 10 hours in the rice fields and carrying heavy weights on their shoulders. The American P&O told us about amputees living in the mountains who adapted their prosthesis by cutting the toes for climbing mountains: "*they would make a very short foot, and then they would rain or cut a radius under the toe area so they could roll over the toe very easily. So that*

[1] For reminding, the components are: Socket, knee, stank and foot for a trans-femoral amputee, and socket, stank with foot for a trans-tibial amputee

allow them – because the foot was very short – that allow them to bend the pilon and walk up the hill" [11]. In HCM1 and 2, P&O also pointed out the necessity of modularity for maintenance by low-income users. The patient may *"change little parts of the prosthesis"* when they have *"no money for changing the whole prosthesis"* [9].

The adaptation of the prosthesis doesn't stop at the end of manufacturing: the product design continues during use, and it is customized to fit into daily practices. For the French P&O interviewed, this is *"signs of a wrong design*" [15] that have to be listened.

4. Discussion and conclusion: toward the use of Persona for supporting ethnographic data for frugal design

4.1. Four dimensions for frugal design

Our analysis reveals four important dimensions in local adaptation and frugal redesign: the manufacturing knows-how, the context effect, the choice of the components and the characteristics of users.

Our study show the complexity of the mechanisms locally implemented to provide frugal prosthesis for Vietnamese amputees. Along the design and manufacturing chain, designers, technicians, P&O professional and end-users set up regulations strategies and "bricolage". The standard process of manufacturing and fitting an amputee leaves space for individual adaptation through measurements, diagnostic and components modularity. Therefore, our study shows that these standards are negotiated during professional practices to answer to constraints such as cost, machines availability and material availability. Professional acts replace the trade dimension at the core of the local adaptation issues; professional practices become actively involved in design processes. P&O assimilate in their skills and know-how all surrounding constraints to answer to the amputees' needs, combining medical, social and economic approaches.

The results show also the importance of the industrials and NGOs partnerships in manufacturing and design orientations. Manufacturing machines, procedures and training can be different from one center to another one. The field knowledge of NGOs is not to be underestimated in that years of partnership and experience in P&O domain could have brought them to develop more adapted practices to local realities. The example of the simplified diagnostic procedure developed by the Red Cross illustrates this fact. Manufacturing, professional acts and partnerships are important features of the redesigning chain to be re-inserted at the beginning of a new product development, in order to build a coherent whole. Our studies show a lot of information about the context, such as local knowledge and historical constraints.

Another important aspect of our results is the market segmentation that emerges from the field. The job of a P&O is to design and manufacture a prosthesis individually adapted, as well as to choose the right components of the prosthesis. Multiple of combinations are possible, given the diversity of cases and offers. However beyond this variability appear some simplification patterns: P&O implicitly built categories of users with few criteria (urban/rural, rich/poor, activity) for which a limited choice of prosthetics is available. Standards involve dealing with dozens of specifications, but observations of practices show that trades-offs are made between a limited number of specification, such as cost, durability, cosmetics and weight. This priorization of functions allows the P&O to provide a suitable prosthesis for one type of patient, while keeping low cost. It seems here that frugal strategies is to offer an array of "just-enough" products given the end user. Imported products seem to be limited, and a

real investment is made on local manufactured products, which may link to exportation (like the Ba Vi foot).

4.2. Construction of personas for integrating the multi-dimensions

These data collected from the field show a complex reality of natural adaptation from technic to human through several dimensions. Designing a frugal prosthesis takes into account design for manufacturing, design for cost, design for variety, but also a sort of "design for multiple adaptations". The prosthetic centers, especially rural ones, deal with the multi dimensions to end up to intermediary standards, results of stabilized trades-offs between manufacturing process, context constraints, modular products and final uses. However, a lot of these compromises are driven by tacit knowledge which questions the possibility of reproducing the results.

The main question we tried to answer is: how to scale up from these local intelligences, in terms of design methodologies and tools? We have proposed to look closer to the Persona tool, as the literature and case studies seem to defend its benefits.

- **Personas help to clarify and explicit assumptions** (Grudin & Pruitt, 2002). By this way, all the local embedded knowledge and professional acts that our study shows can be valorized into the design specifications.

- **Personas transform qualitative data from ethnography into manipulable tool by designers**, giving a meaning and an objective to the multi-dimensions of frugal design. By doing so, intangible knowledge and contextual elements are valorized into the design process. For example, telling which type of machine the Persona of a P&O technician is using will bring elements about the adaptation he will make to the prosthetics.

- **Personas create a focus on target users by identifying their key attributes** (Floyd et al., 2008; Grudin & Pruitt, 2002). The case study show a number of stakeholders involve in the prosthesis design and manufacturing process. Making personas helps not to forget any important actor of this process, and allows identifying secondary personas such as partners, governments, or suppliers. Building personas also allows representing every stakeholder during design even if they are not physically present.

- **Persona help to make trade-offs** (Floyd et al., 2008), which is one of the major challenges when designing a low cost product such as a prosthesis. Our result show the importance of identifying the key feature of a frugal product, which involves high priorization of the other features given a particular use.

From the results described above, we can reinforce our initial hypothesis: Personas, taken as Intermediary Objects, should be useful tools to support grassroot innovators for guiding frugal design. Practically, personas should use ethnographic data to construct realistic context, and behavior, taking into account the multi-dimensions of local redesign and adaptive intelligences.

4.3. Conclusion

Personas appear to be a potential tool for gathering information on multiple end-users and inscribe the future product inside the socio-technical eco-system. As such, personas carries the representation of end users from the upstream (carrying intentions of involved designers) and downstream (evolving during design process) (Vinck, 2011). Persona can be also used to elicit implicit assumptions and

values of involved designers, and well as a support for a better definition and priorization of the requirements. These preliminary results require more investigation to implement the persona and validate value and usefulness for designers in frugal engineering processes. Some interviews with western designers in the prosthetic field particularly emphasize the difficult challenge of finding the right balance between "which design the patient liked, and which one we thought would be more durable". As the US designer says during an interview, "the trickier problems are getting the designers out there right". In case of collaboration between global institutions and local grassroot communities, the need for a mediation and representation of the effective end-users within its complex environment is crucial. By proposing a tool for fostering local intelligences to a more engineering process, thinking frugally, we provide the missing link between local and global.

The use of ethnography as a constructivism method involves deeply the researcher as both part of the study and the result. So do Personas used as intermediary objects. The Persona method can involve both researcher and local communities into the process of understanding and eliciting concepts for a better frugal design toward end-users, taken in their multiple dimensions. In this way, ethnographic research could be actively used into personas as a "transformative intellectual" (Guba & Lincoln, 2005). Ethnography is an approach in which local practices are questioned, reinvented and developed (Hooks, 1990). Therefore work still has to be continued for effectively transforming research methods into design methods, in a context of developing countries.

Over several of limitations of our work, we wanted to particularly draw the attention that our study talks about frugal products, but does not question whether or not local innovation are appropriate to the targeted population. Although studies make the assumption that local redesign and adaptation processes, there is no evidence that local designers or professionals know "better" for their own market, neither that they design "better" products. Our study simply says that frugal innovation could inspire from these local intelligences, taken as knowledge inspirations, shaped as personas, to guide the frugal design process. Thereby innovative and successful ideas can come from grassroots as well as from outsiders, broadening the source of knowledge, such as proposed in design thinking theories or inclusive design. In this vein, the practical use of personas still has to be defined for a better collaboration between grassroot and frugal, between communities and designers, between local and global. This study opens new academic and practical questions on how to design collaboratively frugal product for the developing world.

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