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Roadmap Research On Process In Design For Base Of The Pyramid (DfBoP)

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***Abstract*— Base of the Pyramid (BoP) is a 4 billion design target group, which is composed of people living on an income less than US$3 per day. Design for BoP is a new research topic and design practice started from 2003 in the faculty of Industrial Design Engineering, Delft University of Technology (IDE/TU). To explore some unknown research questions about it, a research project on "Product design for BoP" had been set up. This paper is a roadmap research based on case studies from IDE/TU, and the aim is to explore the roadmap of design process in DfBoP.**

Key words— **Design for Base of the Pyramid (DfBoP), design process, design parameters, design optimization and evaluation**

I. INTRODUCTION

A. Base of the Pyramid (BoP) and Design for Base of the Pyramid (DfBoP)

According to the World Bank (2005), there are 4 billion people living on an income less than US$3 per day and 1 billion living less than even US$1 per day. This part of the population is often called "Base-of-the-Pyramid" (BoP), referred by Prahalad and Hart [1]. Most of BoP is living in developing countries including Africa, India, China and Brazil, and so on.

Currently, most of the entrepreneurs, professional designers and design institutes are targeting the end-users in advanced markets as this group has a higher purchasing power of average more than US$10,000 per year. C.K Prahalad and Stuart Hart's work[1,2] in this area suggests that there is a fortune to be made for entrepreneurs in BoP initiatives, while at the same time great opportunities for the world's poor to escape from poverty. Prahalad's book 'The Fortune at the Bottom of the Pyramid' [2] proposes a framework for the active engagement of the private sector and suggests a basis for a profitable win-win engagement. He argues that all that is stopping business from designing products and services to meet the needs of the world's poor, and then efficiently manufacturing and distributing them is human ingenuity - innovation. The topic has unleashed an extensive and generally enthusiastic response from academics, businesses, NGOs and governments.

Recently, some Multi National Companies (MNC) such as HP, Intel, Philips and Microsoft have been aware of the design opportunities of this market, as well as some design institutes such as Delft University of Technology (TU), Illinois Institute of Technology (IIT), Berkley and Standford which are partnering with MNCs for BoP design. These design cases can be found through Prahalad and Hart [2], Brown and Hagel [3], Wilson and Wilson [4], Jamie and Niels [5].

The faculty of Industrial Design Engineering, Delft University of Technology (IDE/TU) starts design practice for BoP since 2003, and the design projects includes education, health, food & nutrition, water, energy, housing, materials, connectivity, designing & tools and entrepreneurship. These designs are usually called "Design for Base of the Pyramid (DfBoP)" and there are more than 50 cases were experienced until June, 2008.

B. Process in DfBoP (product development)

Until now, there are a lot of definitions about process such as Caulkin [6] "continuous and regular action or succession of actions, taking place or carried on in a definite manner, and leading to the accomplishment of some result; a continuous operation or series of operations." Keller et al [7] define the process as "a combination of inputs, actions and outputs." Anjard [8] further defines it as "a series of activities that takes an input, adds value to it and produces an output for a customer".

Process is also playing a very important role in design activities, which is often engineered by previous researchers like P-diagram by Taguchi [9] and NSIPOC-diagram by Yang Kai [10]. These diagrams can be proven effective initially in DfBoP through cases; one example for P-diagram is Safe drinking water project by Hsiao-Chun Lai (Figure 1)

Example: Safe drinking water project. Master student Hsiao-Chun Lai finished a DfBoP project to supply pure drinking water for rural China, which means water-filter technology is used in a special container.

The inputs, process, and outputs of this project are as follows:

Inputs: Water gravity filter, energy, pump system, etc

Process: Safe drinking water system

Outputs: Celebrashui, Tentea, etc

Design parameter X: Materialization design, shape design, etc

Noise factors Z: Drinking culture and beliefs, awareness, drinking pattern etc

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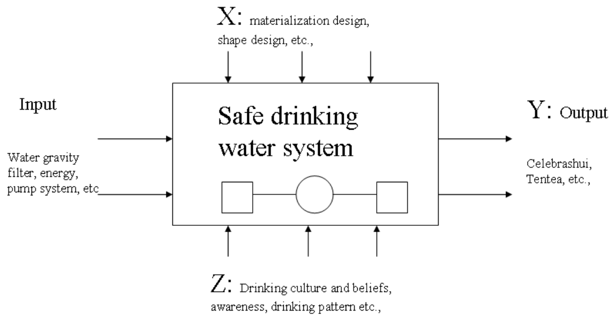

Figure 1 P- diagram of safe drinking water system.

Another example can be implemented in NSIPOC-diagram. Example 2: Woodstove project is a DfBoP project to supply new energy stove for rural India, which will help to decrease the indoor pollution (Figure 2).

The needs, suppliers, inputs, process, outputs and customer of this project are as follows:

Needs: Different needs in different stages, such as smoking pollution from wood burning indoor will result in health problems and that's why user may have interests in this kind of design; sustainable and low cost may improve the competition of this design, etc

Suppliers: Philips Design have business interests to transfer their existing woodstove products into a new design, which may be popular in rural India

Inputs: Philips has a previous stove and new low cost energy technology (LPG)

Process: Supervisors, student designers, local partners, company mentors and standards will be involve in the process

Outputs: A new product, named adoptable woodstove has been designed

Customers: Rural Indian women are the target customer.

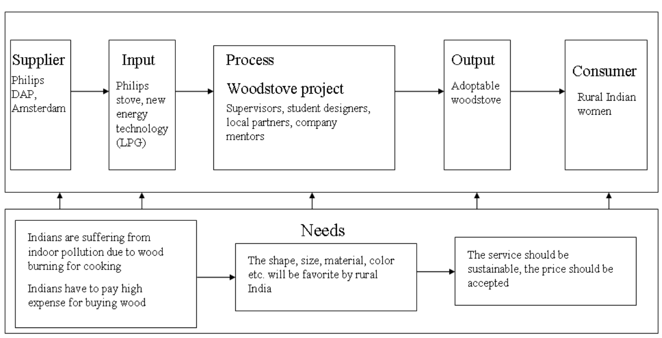

Figure 2: NSIPOC- diagram of woodstove, which needs have been considered as the fundamental of the process

The design process may be considered as a black box in Taguchi method, where X is a set of design parameters, or control factors; Y is the sets of outputs, usually a set of characteristics related to product performance or functions, or customer desired characteristics. Z is a set of "noise factors." Z will also influence Y but can't be sufficiently controlled. The output Y is usually a function of X and Z:

$$Y = f(X, Z) \tag{1}$$

Although current research model can be used for process research in DfBoP, some differences have been found through observation. The obvious one is the question "What is the detail difference between common product design process and DfBoP?" (Too many failure cases indicate that design for poor and design for rich is a little different.) IDE/TU explores this research through design practices:

Kandachar and Halme [11] found that all cases are started with the needs of the users as a starting point for BoP product and innovations. Kandachar [12,13] has observed that several innovations are taking place that need to be considered for an effective approach to serve the unmet needs of the BoP-community. These innovations include: on user side ethnographic tools, cultural probes, business innovations such as hybrid business models, corporate responsibility, technological innovations like disruptive innovations, open source designs, etc. Other innovations at the entrepreneurial side such as microfinance, social entrepreneurship need to be considered as well. A schematic of the design process and the several innovations needed are shown in figure 3:

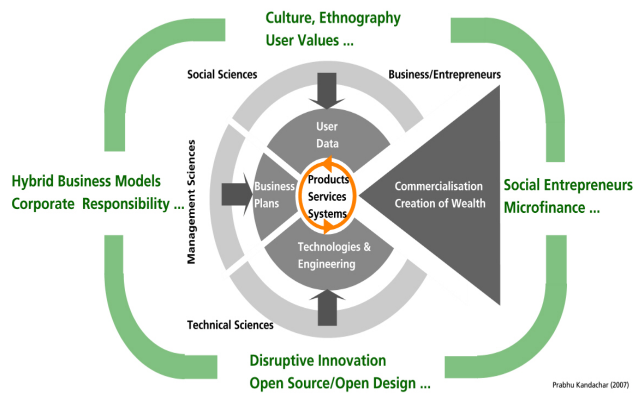

Figure 3: Schematic of the design process as practiced at IDE/TU and the need for innovations at several fronts to meet the unmet needs of the BoP community.

The research results pointed out that user needs are main research inputs while design factors such as culture, user values are main design parameters X (within P-diagram).

As a result, we consider design factors as research start and the research aim is to explore a research roadmap about process in DfBoP.

Three main research branches have been explored in this paper:

- Design for X: design parameters for DfBoP will be initially discussed.
- Process construction (DfBoP procedure): process model will be hypothesis according to design phases.
- Design evaluation: evaluation model and formula will be hypothesis.

II. Methodology

A. *Research Approach*

To achieve the final research aim, some different research methodologies have been used in different reasoning phases such as literature review, case study, and interviews. There is a logical order for approach in this research (Figure 4):

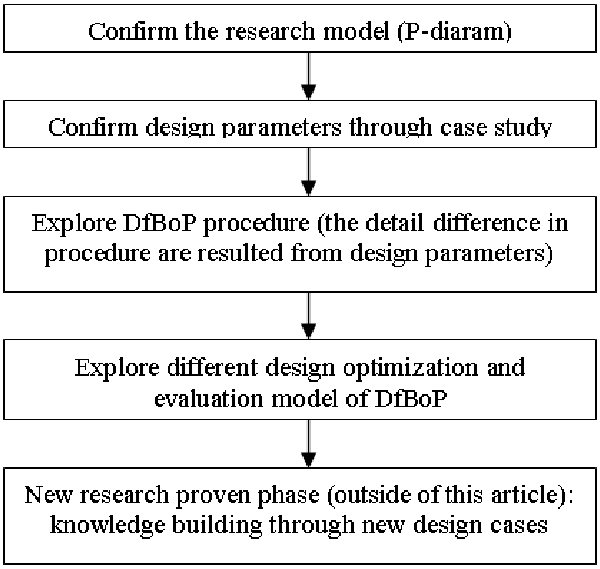

Figure 4: Logic reasoning phases of design process in DfBoP

24 design cases in IDE/TU from 2003 to 2007 have been collected, and all of them are organized as master graduation projects, which are about 30 academic weeks (6 months). These cases are chosen as quantitative researches. Also, some interviews with designers (students) and researchers (professors and design specialists) provide a lot of useful inputs to this research.

More descriptions about cases and statistics can be found in another research paper [14].

B. Design parameters of DfBoP

The previous research about decision factors in DfBoP by Jiang and Kandachar [14] showed that there are four kinds of decision factors work and affect each other in DfBoP.

- Social factors: Some social factors such as culture and life habit will affect DfBoP. Just like common product design, social factors play key roles in a design process and they decide users “Buy it or not buy it” directly.
- Technical factors: Some technical factors such as material also will affect DfBoP in this research. It is a popular point of view that “low cost advanced technology can be used for poverty.”
- Market factors: Some market factors such as user salary or expenditure will be considered in DfBoP. In fact, they will be decision factors because “DfBoP is also a business”
- Organization factors: Organization factors like government support, Non Government Organization (NGO) support are also important in concrete cases. Sometimes, they are always identified with different words in different project reports such as “Political factors”, “Policy factors” or “Network factors”. At most time, they are accessorial factors but they became chief indeed in certain cases.

In these four factors, totally 14 design properties have been located. (They can be considered as design parameters in Taguchi method). The schematic of properties can be found in figure 5.

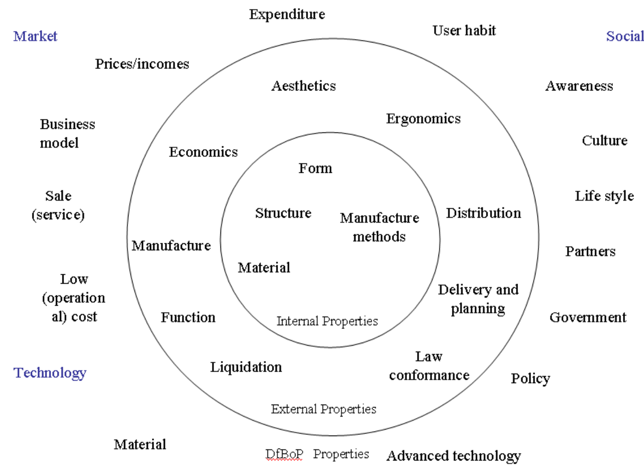

Figure 5: DfBoP properties (design parameters)

Detail factors are as follow description:

- Policy: the design should be under the development plan of government policy. (For example, design can’t be illegal or without current healthcare system)
- Partners: Partners are necessary in BoP design. In this research, partners are composed of 1) international partners such as Research Institutes, Non Government Organization (NGO) and Multi National Companies (MNC); 2) local partners such as local research institutes, local government and local companies.
- Government support: Sometimes government support is looked as design platform in other researches such as Rodrígueza [15], and that hypothesis is accepted by the author in this paper.
- Awareness: To understand awareness of local BoP is very important for a designer once start to design a product. (Especially for health design, designers have to know what kind of solutions is most accepted by local BoP: a disease prevention tool, a diagnosis tool, a treatment tool or multi-functional tool.)
- Culture: Local culture will be considered in integral product design in all cases, such as the user’s favorite in color.
- Life style: Similar with other common product development, life style will be initially considered in concept design, and then the design will easily accepted by the users.
- User habit: Sometimes user habit will be involved into culture or life style, but sometimes it will be considered alone such as “woodstove”
- Advanced technology: Advanced technologies like ICT, biotechnology or nanotechnology should be involved to achieve design functions.
- Low cost: Some improvements for low (operational) cost such as cheaper materials will be considered in a BoP design.

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- Material: Material is a complete technology factor will be considered in DfBoP, a local known material may mean low cost and prefer acceptances.
- Prices/incomes: The rate of design price/income is a very important market factor will be considered by designers, especially in developing countries.
- Expenditure: The same reason with prices/incomes.
- Business model: To create a win-win situation in a cooperative design, business model will be focused before setting up long time sustainable business projects.
- Sale (service): The sale service with the design is also important in a DfBoP, including sustainable maintain and repair.

The statistic results showed that the rate of each factor is as society (0.419), market (0.242), technology (0.231) and organization (0.108), while average error rate of statistic is 6.4%.

C. DfBoP procedure

Because of the difference of design parameters between DfBoP and common product development, DfBoP procedure should be particular in some aspects. In fact, through observation, we found that most components of DfBoP procedure can be preserved from an existing methodology such as Pahl [16] or Roozenburg [17], while small changes are needed.

There are two obvious differences between DfBoP and common design.

1. Needs play a unique role in the whole design progress, while user needs are considered as the design start. The woodstove example of proved that "Indoor air pollution" is the design motivation and then market needs from Philips DAP are created according to the motivation.
2. Compared with common product development, DfBoP procedure looks more repairable, which means the DfBoP procedure is a helix other than a straight line.

To demonstrate 1, we chose two design cases for the same design aim: "cooking" and use cross case comparison methodology. The procedure (core elements) is based on Roozenburg model, which is commonly used for students in IDE/TU. (Table 1)

Table 1: Comparison of "Cooking stove" example between DfBoP and common product development

	Common cooking stove	Woodstove
User needs	X	Decrease indoor air pollution
Market need	All user-end	Base of the Pyramid
Design task	Fast temperature raising, new energy, light and more portable	Improved product which help to solve air pollution and at low cost
Concept design	A lot of concepts such as open fire, Mud/Sawdust, VITA….	Three main different concept: fuel, semi-gasfied and LPG
Embodiment and detail design	Light and small, fast boiling, anti-wind and anti-rain…	Low pollution, low cost, simple operation…
Manufacture	No special	No special
User test	No special	User training
Product improvement	Material, color, type…	Material, color, type …
Product for sale		

Through comparison we found that most of differences happened in the start phase, especially for user needs. User needs are always found in DfBoP at the beginning while it doesn't appear in common product development at most time.

Difference 2 could be described by figure 6, which is based on estimate and rough statistics. (We divided all design activities into three phases: feasibility, pilot and prototype, and 12 steps according to Roozenburg methodology. We analysis all design activities in a time axis and got a rough result about activity order, but this part research won't be discussed in this paper)

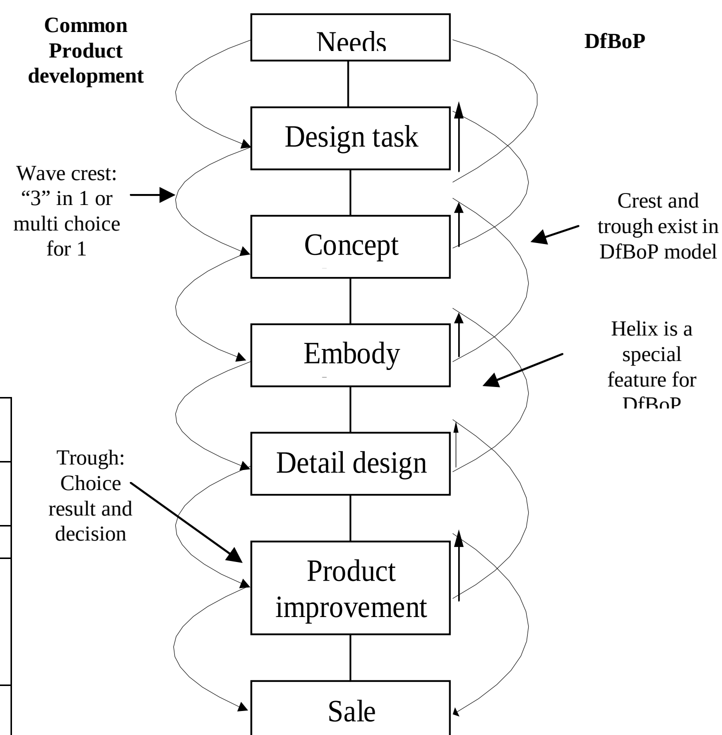

Figure 6: Design procedure estimate model of common product development and DfBoP

Helix wavelet of DfBoP is a doubtful phenomenon, which appeared in a lot of DfBoP cases in the past. However, recent cases showed that this phenomenon is random and until now we don’t know how to locate all design parameters in the Helix model, which means it’s still in initial step of hypothesis.

D. Evaluation and optimization model of DfBoP

The last obviously difference between common product development and DfBoP happened at process evaluation and optimization model. Due to does Helix phenomena exist, the evaluation of the process changed. Figure 7 provided an evaluation example of DfBoP project “woodstove” with Philips.

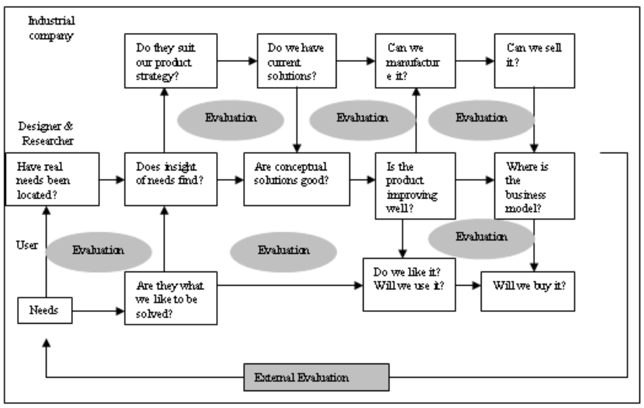

Figure 7: “Woodstove project” of Evaluation model of DfBoP process

Two features appeared in this example:

1. There are a lot of Sub-circles in this case, and they are not a straight line. This result suits for the helix model of DfBoP procedure.
2. It’s a cooperation model, which emphasis the interaction of industrial and users (Academic designers has been separated as one part in this case). Actually, DfBoP users have been involved into design process from needs phase until sale phase. It’s a very interesting phenomenon that most of DfBoP designers have lived in BoP community during their design activities in all DfBoP cases. (The longest time is half an hour, which means all design activities happened among BoP population)

Evaluation model is individual in each design case, but all cases suit above two features.

To achieve the design optimization, we set up a model through mathematics derivation:

Because four main factors (society, market, technology, organization) exist, the optimizations are based on these four factors as (2)

$$Y= D [M, S, T, O] \qquad (2)$$

Where Y means result of optimization, sometimes it means a guide of product/service; M means Market, S means Society, T means Technology and O means Organization; D means the optimization formula. Combined with formula (1), we got the formula (3)

$$F(X, Z) = D [M, S, T, O] \qquad (3)$$

The statistic result from cases showed that formula (4) is effective in DfBoP

$$\int_{T_i}^{T_{i+1}} \sum_{j=0}^{m} L(x_j) = \int_{T_{i-1}}^{T_i} \sum_{j=0}^{m} L(x_j) \qquad (4)$$

Where i, j, m refer random parameters, L refer the fitting carve of all design factors, x_j refers a design factor of all design.

This formula can be translated as another formula in this research:

$$\int_{T_i}^{T_{i+1}} L(s)+L(m)+L(t)+L(o) = \tau + \int_{T_{i-1}}^{T_i} L(s)+L(m)+L(t)+L(o) \qquad (5)$$

Where τ refers the standard error.

When we compared (3) and (5), we found that τ is equal to F (Z) in this paper.

One fixing model has been set up based on (5) as Figure 8.

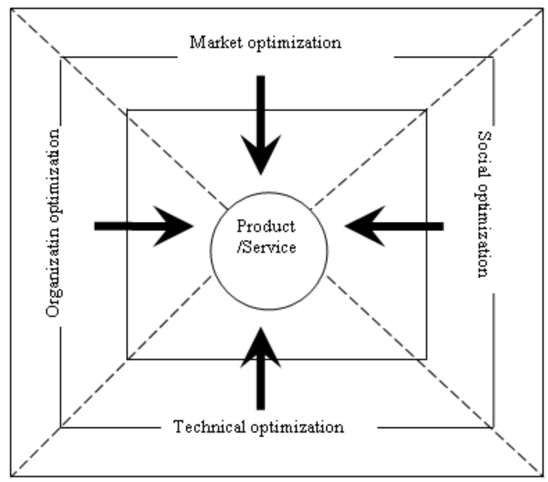

Figure 8: The initial optimization model is divided into three phases and social, market, technical and organization factors four aspects

III. Result, Conclusion and Discussion

This article is a roadmap research about DfBoP, focusing on design process. There are mainly three questions about the process have been discussed “Design for X, DfBoP procedure, evaluation and optimization model”. As the result, an improved Roozenbug model can indicate all research conclusions as Figure 9.

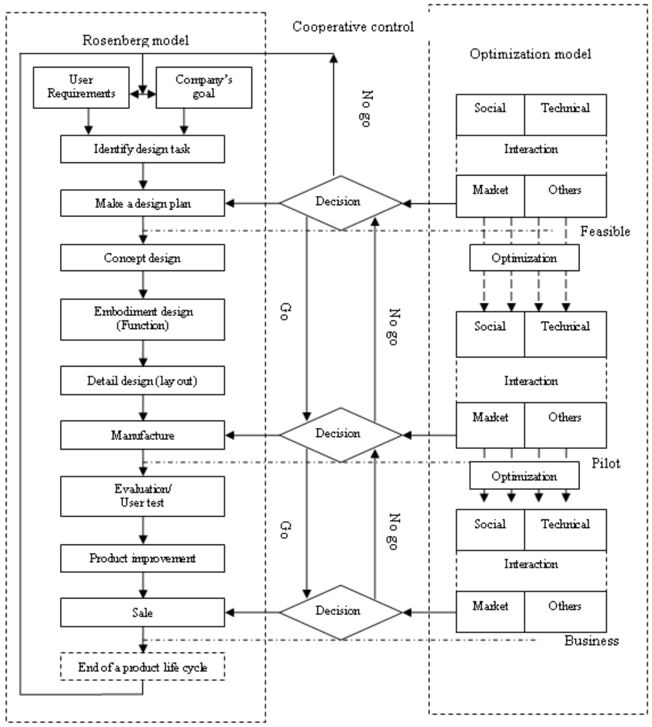

Figure 9: The improved Roozenburg model for BoP design process

However, more detail researches in this filed are undergoing in IDE/TU and more research results will be achieved through a lot different research projects.

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