What Decision Factors Will Affect Design For Base Of The Pyramid (DfBoP)?
--- *An Experience Research Based On Case Study From IDE/TU*

Jiang Jiehui and Prabhu Kandachar*

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 an analysis research based on 24 case studies from IDE/TU, and the aim is to conclude design decision factors for BoP.**

Key words— **Design for Base of the Pyramid (DfBoP), design feature, design factor, design model, the faculty of Industrial Design Engineering, Delft University of Technology (IDE/TU)**

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. *Purpose of this paper*

As similar as other innovative design researches, DfBoP research is initialized through design cases. Some fundamental research questions such as "Is DfBoP feasible?" and "Will industrial partners (companies) have interests to invest for BoP?" have been answered in the past five years. Several successful cases have been set up in IDE/TU such as "Lifestraw" or "Woodstove" and some previous researches have been done through observation:

Kandachar and Halme [6] found that all cases are started with the needs of the users as a starting point for BoP product and innovations. Kandachar [7,8] 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 1:

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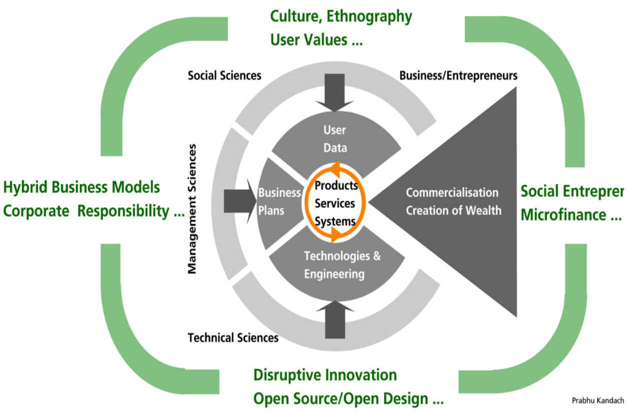

Figure 1: Schematic of the design process as practiced at IDE/TU and the need for innovations at several fronts to meet the unmet needs of the BoP community.

The observation result has been simplified by Diehl [9,10] with "4As" design principles as follows:

- Availability – Unlike developed market, a product or service for China rural healthcare should affect users through different channels. One hypothesis is portable device, and it can work for China rural anytime and anywhere.
- Affordability – The design for rural healthcare should be low cost and sustainable because target group is in low incomes. There is no a comparison standard for price reduction but at least 80 percent of the cost of a compared product in western is necessary. The common design tool is to use advanced technologies such as Information and Communication Technology (ICT), nanotechnology (New package material) and biotechnology.
- Awareness- Health awareness level of China rural should be considered before a design, and it's perfect if the design will help build awareness and education. However this is a big challenge for all stakeholders.
- Acceptability- Social-culture is another important factor for designers. The designer may think of the taboo of target group, and then aesthetics.

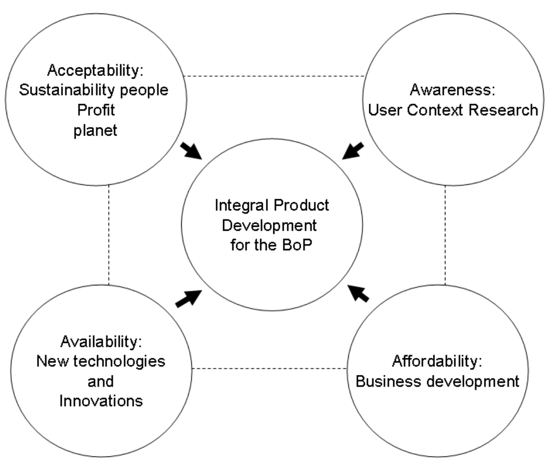

Figure 2: An integral product development approach for the DfBoP by Diehl, which includes four characters: Availability, Affordability, Awareness and Acceptability

Figure 2 shows Diehl's design approach and this approach has been proven successfully through design case in rural Cambodia (Kamworks & Angkor light projects) [11].

However, above researches are remaining at "Strategy research step", which means all research results lack of the meaning of statistic and they are difficult to be implemented into further design practices. There are two misperceptions still existing: on the one hand, the difference between BoP and common design is not obvious. Some research questions such as "What's the relationship and difference between BoP design and common product development?" have not been answered yet; on the other hand, some internal design factors for design researchers are not clarified. "Chaos phenomena" appears at every step of a BoP design and the designers are always surrounded by research questions such as "What kind of factors will appear in BoP design?" or "When will this factor affect my design?" Compared with other common designs, the fuzzy possibility is higher and as a result, it lacks of systemic quality control approaches like Design for Six Sigma (DFSS) (Or explain like this: we don't know whether DFSS is efficient for BoP design.) So the design risk has been zoomed out. This paper is about one of them and the aim of the article is to answer the research question "What decision factors will affect Design for Base of the Pyramid (DfBoP)?"

II. Methodology

A. *Research Approach*

We choose case study as the research methodology in this paper, and there are totally five steps used to achieve the goal:

1. We chose 24 typical DfBoP cases from IDE/TU, which covers all BoP design fields.
2. Qualitative research: decision factors will be found through individual cases.
3. Quantitative research: independent variables of decision factors will be found through case analysis.
4. Statistic research: all independent variables of decision factors will be statistic in terms of research activities from designer's experiences.
5. Analysis research: the results of statistic will be concluded as experience formula

As a result, all outputs of this research are completely experience models, and there is still a distance to implement the research result into "artifact step" right now because the research on individual difference elimination has not been finished.

B. *Participant cases*

24 DfBoP cases from all cases in IDE/TU have been chosen, and all of them are organized as master graduation projects, which are about 30 academic weeks (6 months). The students (design groups) will finish different sub-cycles of a product development process according to different needs from our industrial partners (MNCs, NGOs and local companies). These commercial interests can be concluded as three main steps:

Feasible step: In this step there is not concrete product, but partners have interests in certain BoP field in certain developing countries, such as Intel Healthcare has investing interests on "Diabetes monitoring" in India while Philips lighting has interests on "Lighting" for all over the world. The outputs of the design are product concepts, even just proposed solutions. This kind of design is also called "Strategy design", which is with some proven design knowledge and skills from department of Strategy Product Design. (SPD)

Pilot step: In this step the design is based on current products or technologies, and partners have interests to invest their products from high-end markets to middle and low-end markets, or from one developing country to other developing countries, such as "Lifestraw" project for the Danish company Vestergaard Frandsen in Ghana and "Adoptable Woodstove" project for Philips Domestic Appliances in India and China. This kind of design is called "Integrated design", which is with design knowledge and skills from department of Integrated Product Design (IPD).

Business step: In this step the design is based on a successful previous product development and partners have interests to discovery new business models, such as "Online Microfinance: into (context)" project for Microsoft in South Africa. This kind of design is called "Design for interaction", which is with design knowledge and skills from department of Design for Interaction (DFI).

All cases will be divided into above three steps and they can be found at Table 1.

C. *Qualitative research*

We used two kinds of research methodologies to explore decision factors as qualitative research: cross cases comparison and user evaluation analysis.

Cross cases comparison means we choose two similar DfBoP cases and compare their difference, these differences will be considered as decision factors by designers.

User evaluation analysis means we analyze user's evaluation in the DfBoP and confirm some decision factors.

Finally, we found that all decision factors are involved into four aspects:

1. Social factors

Some social factors such as culture and life habit will affect

Table 1: Design cases from IDE/TU, which cover all DfBoP fields: education, health, food & nutrition, water, energy, housing, materials, connectivity, designing & tools and entrepreneurship

Company	Title	Date	Education	Health	Food/nutrition	Water	Energy	Housing	Material	Connectivity	Design/tools	Entrepreneur	Feasible	Pilot	Business	Country
Helps International	Improving the climate of cooking area	2006/06		+	+		+	+					+	+		Guatemala
NPSP Composieten	Natural Fibers in doors and windows	2005/10						+	+					+	+	India
Ecofys/Kamworks	Solar lighting	2005/10					+						+	+		Cambodia
Vestegaard Fransen	Personal water purifier	2006/04	+	+		+							+	+	+	Ghana
Bosch/Siemens	Product service system for plant oil stove	2006/07		+	+		+							+	+	Philippines
INBAR	Human powered splitting tool	2006/06					+		+			+	+	+		India
Impact	Support tool for village doctors	2006/09	+	+						+				+	+	China
Philips healthcare	Screening device for oral cancer	2005/11		+										+		India
Philips Research	Design of a malaria diagnosis	2006/08		+									+			India
Philips Apptech	Adoptable woodstove	2006/04		+	+		+					+	+	+		India
Movendi/ MAK-D	Tricycle for disabled entrepreneurs	2006/07		+								+		+	+	Ghana
EYE, Padan	Reeling machine for silk farmer	2006/11							+			+	+	+	+	India
Philips Apptech	Safe drinking water	2006/4		+		+								+		India
Philips Design	Contextualizing products	2006/2		+							+		+			India
Philips healthcare	Creating market insight	2005/12		+						+	+				+	India
Micorsoft	Online Microfinance	2006/02								+	+	+			+	Africa
Philips Appetch	Adoptability of the U-Specs	2005/10	+	+							+			+		India
TU	Water supply in slums	2006/04		+		+		+				+		+		Brazil
ECOFYS	Rural Energy system	2008/04	+				+	+				+	+	+		Africa
Phillips Apptech	Cooking in rural China	2007/06		+			+				+		+	+		China
Phillips Apptech	Safe drinking water for China	2007/06		+		+			+				+	+		China
Intel healthcare	Mother health	2008/06	+	+						+		+	+			India
Intel healthcare	Child health	2008/06		+						+		+	+			India
Intel healthcare	Interface for diabetes monitor	2008/06	+	+						+		+	+	+		India

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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. One example is "Woodstove" project.

At 2006, we designed a DfBoP product "woodstove" for rural India, which is very popular by local women. At 2007, we transferred this design into rural China, but we found local women don't like it at all. There is no difference between products itself. The material is same, size is same, cost is same and even color is same. But the feedbacks from questionnaires are completely opposite. Through comparison, we got the answer "Cooking habit and dish size" at last as Figure 3.

Once we improved the size of the product, we got positive feedbacks from Chinese women.

Figure 3: Cooking habit is different in rural India and China, India women like cooking by sitting while Chinese women like cooking by standing, and the dish size is different

2. 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." And it really happened in DfBoP, for instance, in the case "Screening device for oral cancer", the design is based on the technology "Light Inducing Fluorescence (LIF)" and design task is to create a pre-program user interface for rural doctors; in the case "Personal water purifier" the biochemical filter technology has been used to create 99.999% pure water; while in case "Online Microfinance" the Information and Communication Technology (ICT) is used to optimize the microloans business model.

Figure 4: Local mothers in rural Bangalore are choosing preferred product, the main difference are about technical factors. And they will result purchasing decisions.

On the other hand, it's an interesting phenomena that technical factors will be considered in user's evaluation even though they have not very clear understanding about what kind of advanced technology we use in DfBoP. We have done a user experiment to test technical factors about "safe drinking water" in rural Bangalore, India as Figure 4.

In this experiment, we designed three kinds of products, which can filter same level drinking water. Product 1(left) and 2 (middle) are used same filter technology but different materials, and product 2 and 3(right) are used same materials but different filter technology. The experiment result is that "almost all of potential users make the same decision". As a result, technical factors are proven related with DfBoP.

3. 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", as mentioned in introduction of this paper.

An example, called "Tricycle for disabled" in Ghana is a typical successful case from "market factors" as Figure 5.

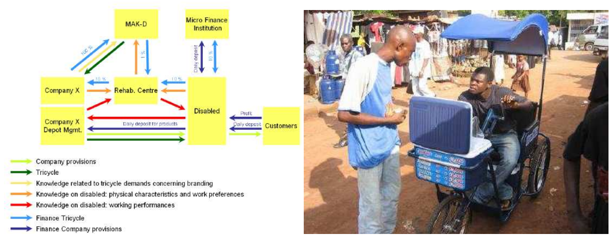

Figure 5: The final application of tricycle for disables in Africa is "Ice cream sale" (right), which is a successful design case through setting up successful business model (left)

4. Organization factors

Through observing the cases, we found that organization factors like government support, Non Government Organization (NGO) support are also important in concrete cases. However, 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, e,g design cases for rural China healthcare.

D. Quantitative research

To find the meaning of statistic of above four aspects, Quantitative researches about research activities have been done in this paper. Quantitative steps are as follows:

1. We proposed that all design processes are divided into six months, which covers feasible, pilot and business steps averagely.
2. We conclude key factors of each aspect; all key factors appear in more than two different DfBoP cases at least.
3. We stat research activities (sometimes these activities are called research through design) in each key factor, which refer the factor of influence of each key factor in a DfBoP case.
4. The maximal efficient times of each key factor are three, according to "1 in 3" design principle.

To describe above steps clearly, a DfBoP case "Mother health" will be considered as example.

1. This case starts from initial of feasible step and end at first-fourth of pilot step. So it has been statistic as fifth-twelfth in a six months calendar.
2. Through conclusion, we found six key factors are considered by designers: Culture, User awareness, Life style (Social), incomes (market), business model (Market), and Government support and local partner support (Organization). All of key factors can be proven in other DfBoP cases.
3. We make a table to statistic designer's research activities through their research report and contact with designer directly. (table 2)
4. The research activities for each factor are not more than 3.

Table 2: The statistic result of research activities in "Mother health" project in rural India, and the result are looked as experience information for DfBoP as well

Activity	**Activity description**	**Key factors (time)**
Trends & Developments: Aravind Eye Hospital	Identify design trends and developments from a hospital	Partner (5/12)
Observational research: Delivery Room	Identifying problems, needs in user situations	Life style (3/12)
Focus group: opportunity exploration	Identify trends, developments from team of Manjunatha Maiya, BoP chair Manipal and earlier student connections	Partner (3/12)
Mother and Child / Household / Community level	Identify issues, problems and needs in MCH	Culture (1/12) Incomes(1/12) Awareness (1/12)
Design of strategic directions	Design of strategies for new solution development	Business model (1/12)
Evaluation of Strategic Options	Select the best strategic options + collect suggestions for improvements	Business model (5/12)
Continuation: Supporting Successive Attempts	Stimulate parties to continue with the results of our project towards concrete solutions	Partner (3/12)
Customers and Policymakers	Identifying issues, problems and needs through interviews from Government	Government (1/12)

Quantitative results of DfBoP cases can be found at table 3.

E. Statistic research

The statistic result is based on quantitative results, and the result is efficient because all designers have similar research background, knowledge construction and design skills. To achieve a more visualized statistic result, we shift all research activities into a standard 12 units coordinate. Finally we fit four carves as Figure 6:

F. Analysis research

According to research experiences, there exists a balance among all design factors at anytime in a design process by Roozenburg and Eekels [12], this balance can be described as follow mathematic formula:

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

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 according to hypothesis:

$$\int_{T_i}^{T_{i+1}} L(s)+L(m)+L(t)+L(o) = \tau + \int_{T_{i-1}}^{T_i} L(s)+L(m)+L(t)+L(o) \qquad (2)$$

Where τ refers the standard error.

To prove the accuracy of (2), we use a tool Matlab to

Table 3: Quantitative result of research activities 3 2 1 0

Title	Social factors				Market factors				Technical factors			Organization factors		
	Culture	Awareness	Life style	User habit	Expenditure	Incomes	Business model	Sale	Advanced technology	Low cost	Material	Policy	Government	Other partner
Improving the climate of cooking area	1	2	1	1	0	1	1	0	2	1	1	0	0	0
Natural Fibers in doors and windows	0	0	1	1	1	0	1	0	3	1	2	0	0	0
Solar lighting	1	1	2	1	1	1	1	0	3	1	2	0	0	0
Personal water purifier	2	2	2	3	1	1	1	0	0	1	1	0	0	0
Product service system for plant oil stove	0	0	0	1	0	0	2	1	0	1	0	0	0	0
Human powered splitting tool	1	0	1	0	0	1	1	0	0	0	3	0	0	1
Support tool for village doctors	1	2	0	0	0	0	1	0	0	1	0	1	1	1
Screening device for oral cancer	1	1	1	0	0	0	1	0	0	1	0	0	1	1
Design of a malaria diagnosis	1	0	1	1	0	0	0	0	1	1	0	0	1	0
Adoptable woodstove	1	1	1	2	1	1	2	1	0	0	0	0	1	1
Tricycle for disabled entrepreneurs	1	0	1	1	0	0	3	0	0	1	0	0	0	1
Reeling machine for silk farmer	1	0	0	1	0	0	1	0	1	1	3	0	0	0
Safe drinking water	1	1	1	1	1	0	1	0	0	1	1	0	1	1
Contextualizing products	1	1	1	1	0	0	0	0	0	0	0	0	0	0
Creating market insight	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Online Microfinance	1	0	0	1	0	1	3	1	1	0	0	0	0	1
Adoptability of the U-Specs	0	0	1	1	1	0	1	0	0	1	0	0	0	0
Water supply in slums	1	0	1	0	0	0	1	0	1	1	0	0	0	0
Rural Energy system	0	0	1	0	1	0	2	0	1	1	0	0	0	0
Cooking in rural China	1	0	1	2	0	1	0	0	0	0	0	0	1	0
Safe drinking water for China	1	0	1	2	1	1	0	0	0	0	2	0	0	0
Mother health	1	1	1	0	0	1	2	0	0	0	0	0	1	3
Child health	1	1	1	0	0	1	0	0	0	0	0	0	1	2
Interface for diabetes monitor	1	0	1	1	0	0	1	0	0	1	0	0	0	0

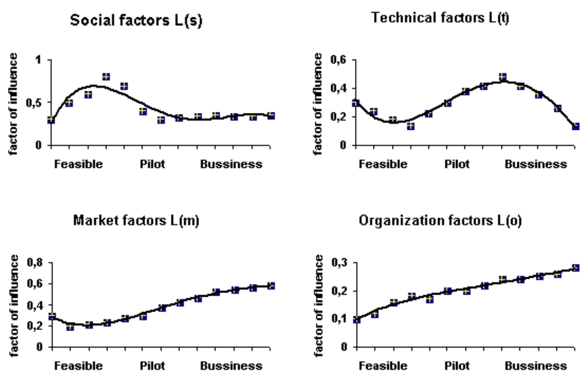

Figure 6: Statistic results about factor of influence for four different factors in BoP design cases, which can be fit as a carve L(x) = N(x)/24, where N is the total number of research activities in a certain time.

calculate τ.

III. Result

Through calculate, we found τ = [-0.18, 0.2] in this research, while average error rate of τ for (2) is 6.4%. And the result of this research can be found in Figure 7.

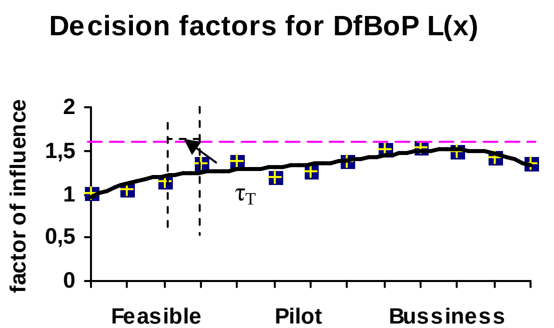

Figure 7: Decision factor for DfBoP carve, which fits (2)

As a whole, this research is efficient because the τ is not very huge. It refers missing decision factors in this research and the formula can be improved through more cases.

VI. Conclusion and Discussion

The research question "What decision factors will affect DfBoP" has been discussed in this paper. The authors proved that Social factors, Market factors, Technical factors and Organization factors are main decision factors through case study. All DfBoP cases are from student projects in IDE/TU since 2003.

The research process of this article includes qualitative research, quantitative research, statistic and analysis. Finally, we found that DfBoP fits design features as common design such as Roozenburg and Eekels. All research results are based on experience research, so the conclusion can't be used for practice immediately.

There are still a lot of research questions to be answered for DfBoP right now, like "What are design features for DfBoP?" or "What is analysis process for DfBoP?" Even for current question "What decision factors?", the research should be going on because individual difference will be focused for special design fields such as health or Energy. And these researches will be set up in future.

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