How design process for the Base of the Pyramid differs from that for the Top of the Pyramid

Jagtap, Santosh; Larsson, Andreas; Hiort, Viktor; Olander, Elin; Warell, Anders; Khadilkar, Pramod

Published in:
Design Studies

DOI:
10.1016/j.destud.2014.02.007

2014

To cite this article: Jagtap, S., Larsson, A., Hiort, V., Olander, E., Warell, A. & Khadilkar, P. (2014). How design process for the Base of the Pyramid differs from that for the Top of the Pyramid. *Design Studies*, 35 (5): p. 527-558.

How Design Process for the Base of the Pyramid Differs from that for the Top of the Pyramid

Santosh Jagtap and *Andreas Larsson*, Department of Design Sciences, Faculty of Engineering, Lund University, P.O. Box 118, SE-221 00 Lund, Sweden

Viktor Hiort, Product and Production Development, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

Elin Olander and Anders Warell, Department of Design Sciences, Faculty of Engineering, Lund University, Sweden

Pramod Khadilkar, Centre for Product Design and Manufacturing, Indian Institute of Science, Bangalore, India

Abstract

The base (BOP) and the top (TOP) of the world income pyramid represent the poor people and the people from developed countries, respectively. The design of products for the BOP is an important ingredient of the poverty reduction approach that combines business development with poverty alleviation. However, the current understanding of the design for the BOP is limited. This study, using a protocol analysis, compared design processes for the BOP and TOP markets. The results indicate the difference between the design processes for these markets in terms of the design strategy employed by the designers (i.e. problem driven, solution driven strategy), their requirements handling behaviour, and their information behaviour.

Keywords: base of the pyramid; design process; design activity; design behaviour; protocol analysis

The world income pyramid can be divided into three segments (see Figure 1). The top of this pyramid, called the Top of the Pyramid (TOP), includes people from developed countries (Prahalad and Hart, 2002). The middle segment consists of the rising middle class from developing countries. The base of this pyramid, generally called the 'Base of the Pyramid' (BOP), consists of poor people. About two-fifths of the world population can be categorized as poor. Their income is less than 2 dollars per day (Karnani, 2011). About a fifth of the world population is classified as extremely poor with income of less than 1.25 dollars per day.

Figure 1 The world income pyramid (Prahalad and Hart, 2002)

Poverty is a trap because children born to poor parents are likely to grow up to be poor adults. Mahatma Gandhi often said - poverty is the worst form of violence. It is important to alleviate poverty. There are ways (i.e. approaches) to alleviate poverty (e.g. microcredit, granting formal property rights to the poor, etc.). In recent years, a poverty reduction approach that combines business development with poverty alleviation has received attention (Prahalad, 2004). Private sector firms continually search for new business opportunities. Saturated markets and a highly competitive business landscape motivate companies to search for new markets to increase profits. This has led companies to pay greater attention to opportunities at the BOP (Nakata, 2012; London and Hart, 2010). While companies are beginning to address the product needs of the BOP, there is limited practical and theoretical knowledge to support them (Nakata, 2012).

In the approach of combining business development and poverty alleviation, the poor at the BOP are considered as producers and consumers of products. Design of products is an important ingredient of this market-based approach. Furthermore, some universities have begun to offer courses and/or design projects in the area of the design for the BOP[1].

The research in the BOP domain has been carried out by several authors from different disciplines (Prahalad, 2004; UNDP, 2008; Whitney and Kelkar, 2004). While design research is important in understanding and improving design practice and education (Blessing and Chakrabarti, 2009), design researchers have given little attention to the field of the design for the BOP. Most of the design research has been carried out in the context of developed countries and relatively affluent markets (Viswanathan and Sridharan, 2012; Jagtap and Larsson, 2013; Jagtap et al., 2013). There has been little empirical examination of the design for the BOP, and this limits our ability to develop tools and methods for improving current practice and education of design for the BOP. It is therefore important to develop an understanding of design for the BOP.

This study aims at exploring the differences between the design processes for the BOP and TOP markets, where designing for the TOP is a baseline. The sharp contrast between the BOP and the TOP makes the distinctions clear. The intent of the study was not to determine the differences between the outcomes of these design processes. Rather, it was to empirically explore the differences between these design processes. The design processes are compared using the widely employed technique of verbal protocol analysis in the area of design research. In a laboratory setting, four designers individually solved a design problem for the BOP, and four other designers individually solved the same problem for the TOP. The collected data was encoded and analysed. Encoded results of the protocol analysis show the differences between the design processes for the BOP and TOP markets.

1 Background literature

1.1 BOP Markets and Product Design

The BoP includes poor people. About two-fifths of the world population can be categorized as poor. Their income is less than 2 dollars per day. Their income is irregular and unpredictable, and these people live in rural villages, urban slums, or shantytowns. Usually, these people have little or no formal education, and they are hard to reach via the conventional means of communication and distribution channels. The World Bank conducted a study called 'Voices of the Poor' involving 20000 poor women and men from 23 countries to explore their perspective regarding poverty, wellbeing, and illbeing (Narayan et al. 2000). This study identified that the poor face different problems such as: hunger, violation of dignity, powerlessness, insecurity, state corruption, unemployment, poor health, gender inequality, etc.

Poverty is multifaceted, and has three intertwined characteristics as follows (Karnani 2011): (1) lack of income and resources required to satisfy basic necessities such as food, shelter, clothing, and fuel, (2) lack of access to basic services such as public health, education, safe drinking water, sanitation, infrastructure, and security; and (3) social, cultural, and political exclusion.

It is important to alleviate poverty. The United Nations Millennium Development project (2005) notes, "Poor and hungry societies are much more likely than high-income societies to fall into conflict over scarce vital resources, such as watering holes and arable land…Many world leaders in recent years have rightly stressed the powerful relationship between poverty reduction and global security". Poverty is a trap - children born to poor parents are likely to grow up to be poor adults.

In recent years, a poverty reduction approach, popularised by the late C.K. Prahalad, has received attention (Prahalad 2004). This approach proposes solutions involving business development combined with poverty alleviation. According to Prahalad and Hart (2002), the most visible and prolific writers in the area of the BoP, this business strategy is important in, "…lifting billions of people out of poverty and desperation, averting the social decay, political chaos, terrorism, and environmental meltdown that is certain to continue if the gap between rich and poor countries continues to widen". Furthermore, saturated markets and a highly competitive business landscape motivate companies to pay greater attention to opportunities at the BOP (Nakata, 2012; London and Hart, 2010).

The International Finance Corporation together with the World Resources Institute measured the size of BOP markets (IFC, 2007). The potential purchasing power of the BOP is five trillion US dollars. Furthermore, the products originally developed for the BOP can be adapted for the markets in developed countries, and this is called 'reverse innovation' (Immelt et al, 2009). For example, GE developed an ECG device for rural India and an ultrasound machine for rural China. These products are now being sold in the United States.

In the market-based approach of combining business development and poverty alleviation, the poor at the BOP are considered as producers and consumers of products. Design of products is an important ingredient of this approach. Designing and developing products for the BOP require addressing constraints in the BOP. These constraints are significantly different from those in developed country markets. Regardless of the location of a BOP market, the constraints in the design and development of products for the BOP are the following (UNDP, 2008).
(1) Market information: In the design of products for the BOP, there is an important role of information regarding the BOP, for example, what the poor need, what capabilities the poor can offer, etc. In the product design for the BOP, businesses often lack detailed information about the BOP markets.

(2) Regulatory environment: The regulatory frameworks are under- or un-developed in the BOP. In addition, enforcement of the existing rules is inadequate. Complying with the bureaucracy in developing countries can be time consuming and monetarily expensive.

(3) Physical infrastructure: This constraint considers the inadequate infrastructure (e.g. roads, electricity, water and sanitation, hospitals, etc.) in the BOP. In developed countries, the logistics system that is necessary for accessing consumers, selling to them, and servicing products exists, and only minor changes may be required for specific products. In the BOP, the existence of a logistics infrastructure cannot be assumed.

(4) Knowledge and skills: The poor, generally, are illiterate and do not possess knowledge and skills regarding the availability of products, usage of products, etc. In the design of products for the BOP, the skill levels of the poor must be taken into account.

(5) Access to financial services: The poor lack access to credits, insurance products, and banking services. This puts limits to the purchases made by them. In addition, they cannot protect their meagre assets from events such as illness, drought, etc. In the design for the BOP, the designers must take into account the price-performance relationship.

Companies need to change their business assumptions, models, and practices in order to address these constraints (Viswanathan and Sridharan, 2012). While companies are beginning to address the product needs of the BOP, there is limited practical and theoretical knowledge to support them (Nakata, 2012). There has been little empirical examination of the design for the BOP, and there is an urgent need to develop an understanding of this area. This study aims at exploring the differences between the design processes for the BOP and TOP markets.

1.2 Design problem solving

There is a plethora of design process models (Cross, 1994; Pahl and Beitz, 1996). At a high level of abstraction, these models share common characteristics such as: progression from abstract to concrete, presence of feedback and iteration, presence of decision and evaluation points, etc. (McMahon, 2012). Chakrabarti et al. (2004) found that the main ingredients of the design process are: *requirements* (i.e. problems), *solutions*, *information,* and *strategy* (i.e. plan of action to progress through the design process).

Research in design has been undertaken by using a variety of methods such as verbal protocol analysis, questionnaires, ethnographic studies, observation, etc. Some characteristics of the design process have been widely observed. It is commonly accepted that the design process is iterative in nature. In the design process, the requirements and solutions co-evolve (Suwa et al. 2000). Designers develop both requirements and solutions in parallel (Dorst and Cross, 2001). Suwa et al. (2000) investigated the process of how different requirements are generated through unexpected discoveries during the design process. In their study, they found that sketches help in the identification of requirements. They call this requirements identification as 'invention' of design issues or design requirements. Chakrabarti et al. (2004) observed that the process of requirement identification is closely related to solution generation. Designers tend to use solutions to develop their understanding of the problem because a problem cannot be fully understood in isolation from solutions (Cross, 2006).

Based on the analysis of the activities of designers, Nidamarthi (1999) found that the designers tend to use tentative solutions to enhance the understanding of the initial requirements. He also observed that these solution-generated requirements (i.e. solution-specific requirements) played an important role in the problem solving process. He noted that the designers addressed increasingly more solution-specific requirements as the design progressed further. Restrepo and Christiaans (2003), based on their empirical studies of designers, have characterised requirements depending on their specificity. In their study, they found that two groups of designers generated broad requirements that did not belong to a specific solution. In contrary, two other groups were very specific; for example, with reference to a solution, one of these groups wrote, "The click mechanism should be safe for hands and fingers". Chakrabarti et al. (2004) and Fricke (1999) also have distinguished between solution-neutral and solution-specific requirements.

In design research, there has been interest in investigating design strategies used by designers. Kruger and Cross's (2006) empirical study of designers found that most designers employ either a problem driven or a solution driven design strategy, with each of these strategies being equally prevalent. In a problem driven strategy, the designer focuses closely on the problem at hand. The designer emphasises on defining the problem, and finding a solution as soon as possible. In a solution driven strategy, the designer focuses on generating solutions. The designer emphasises on generating solutions, and little time is spent on defining the problem. Christiaans and Restrepo (2001) also observed these problem driven and solution driven strategies.

In the field of design research, several authors note the significance of the role of information in design activities (Pahl and Beitz, 1996; Jagtap and Johnson, 2010). Design is an information-intensive activity. The findings of the empirical research conducted by Marsh (1997) in an aerospace industry suggest that, on average, 24% of designers' time is spent in acquiring and providing information. Furthermore, several studies, carried out in laboratory settings with experienced designers or students, note the importance of information in the design process (Kuffner and Ullman, 1991; Eris, 2002).

2 The protocol study

2.1 Experimental design

In order to address the aim of exploring how the design process for the BOP differs from that for the TOP, we carried out protocol studies using the think-aloud method. Chai and Xiao (2012), based on their analysis of citations and co-citations from the journal ‘Design Studies’, found that the protocol analysis is a popular research method among design researchers.

A design activity can be influenced by factors such as the designers involved, their level of experience with the problem, the problem itself, etc. In a comparative analysis, an ideal experiment would involve varying only one factor while keeping the remaining factors constant, and then compare the results due to the variation in that factor. However, when the same designer participates in several experiments to solve the same or similar design problem, the designer’s experience with the problem unavoidably varies. In this context, López-Mesa et al (2009) state, “In fact, no experiment arrangement for comparative analysis allows to having just one of the mentioned factors as variable, while the others are kept fixed”.

In our study, the experimental arrangement was as follows. In total, eight designers participated in the experiments. These designers were divided into two groups, namely BOP and TOP groups/sessions. Each designer worked on one design problem individually. While the eight designers solved the same design problem, the designers in the BOP sessions solved it *for* the BOP and the designers in the TOP sessions solved it *for* the TOP. Although the sample size in our study is small (i.e. four protocols in each of the BOP and TOP sessions), the experiments provided sufficient data for our empirical exploratory study. This sample size is adequate for a think aloud protocol study, and is in accordance with other studies, for example studies of Kruger and Cross, (2006), Kim et al. (2008), Rahimian and Ibrahim (2011), and Goldschmidt and Rodgers (2013).

2.2 Participants

In our study there are two types of markets (i.e. BOP and TOP). It is therefore necessary that the participants in the BOP sessions (i.e. BOP designers) and the participants in the TOP sessions (i.e. TOP designers) are required to have good understanding of the general characteristics of the BOP and TOP markets, respectively. In our experiments, this criterion was fulfilled by ensuring that the designers in the BOP sessions had experience of working on university-based design projects for the BOP, and that the designers in the TOP sessions had experience of working on university-based design projects for the TOP. All these designers were Masters students in ‘Industrial Design’ or ‘Product Design’. Each designer from the BOP and TOP sessions was provided two movie tickets as compensation for their time.

The average age of the designers in the BOP sessions was 25.5 years, and that in the TOP sessions was 26 years. Three females and one male were included in the BOP group and two females and two males in the TOP group. In the BOP group, one designer was from China, one was from India, one was from Vietnam, and one was from Sweden. In the TOP group, two designers were from Sweden, one was from South Korea, and one was from Canada.

All the designers in the BOP and TOP sessions come from fairly similar strata of the world income pyramid (e.g. none of the designers, from the BOP and TOP sessions, come from the BOP strata). The BOP and TOP designers were from the middle to upper middle class strata of the society. Furthermore, as mentioned above, all these eight designers are Masters students in ‘Industrial Design’ or ‘Product Design’. The main difference between the designers in the BOP and TOP sessions is that they have experience of working on university-based design projects for the BOP and the TOP, respectively; and we have already explained why it is necessary to have this experience. We therefore believe that excepting this difference in experience of working on university-based design projects, the designers in the BOP and TOP sessions are fairly similar. It is therefore likely that the differences in the design processes for the BOP and TOP markets are mainly due to the differences in these markets. There can be some differences in these design processes due to the difference in the BOP and TOP designers' degree of familiarity with the respective contexts (i.e. contexts of BOP and TOP markets). We have discussed these issues later in Section 5. Our experimental arrangement was pragmatic, and the findings gained through this research are useful in terms of their implications for design practice and design education. These implications are discussed in Section 5.

2.3 Procedure

While the think-aloud method is useful in revealing the subjects' thinking process, the subject may neither be familiar nor comfortable with speaking his/her thoughts as he/she works through the problem. It is therefore important to train the subjects to become familiar and comfortable with the method. In our experiments, before the subjects started working on the design problem, they were trained in speaking their thoughts with a warm-up task. The following steps were followed with each of the eight designers: (1) explanation of the experimental procedure (15 minutes), (2) warm-up task (30 minutes), and (3) solving the design problem (maximum 90 minutes). While, the third step of solving the design problem was allocated 90 minutes, the designers, on average, finished this step within 60 minutes. As an information source, a researcher was present during the entire experiment. The designers were allowed to ask questions to the researcher. When a designer paused the process of speaking his/her thoughts for a longer period of time, the researcher reminded him/her to think aloud. The data consisted of: (1) video and audio recordings, and (2) written materials and sketches produced during the process.

2.4 Design problem

In our experiments, to formulate the design problem, we considered different criteria. The design problem must be suitable for the above-mentioned Masters students. The problem also needs to be applicable for the BOP and TOP markets. This is an important consideration because some problems may be applicable for the BOP, but may not be applicable for the TOP. For example, while there is a presence of problems regarding access to clean drinking water in the BOP, these problems are not present in the TOP as there is access to clean drinking water. Based on these considerations, we created the design problem as shown in Figure 2. In this figure, in the case of the BOP sessions, *(---)* was replaced by 'a cluster of BOP communities in a developing country' and *(xxx)* by 'the cluster of BoP communities'. In the TOP sessions, *(---)* was replaced by 'a city in a developed country' and *(xxx)* by 'the city in the developed country'. The BOP and TOP designers were asked to consider general characteristics of the BOP and a developed country, respectively. The formulated problem is new to the designers and it does not require much technical knowledge to solve. Furthermore, the problem is relatively open to different types of solutions, and is not very large for capturing and analysing the protocols. After the experiments, all the designers expressed that the problem was interesting and new to them.

Figure 2 Design problem used in the experiments

2.5 Analysis

The audio recordings were transcribed, and parsed into segments using the previous guidelines of Ericsson and Simon's (1993) verbal protocol analysis. The transcripts were divided into segments, with each segment corresponding to a single thought, expression, or idea. Content cues (e.g. shift in a topic, new point about the topic) and noncontent cues (e.g. pauses, phrases) helped in dividing the transcripts into segments. We looked at both content and noncontent cues and applied those that resulted into the finer-grained segmentation. The segmentation of transcripts was based on the videos of the processes and the associated written materials and sketches.

The structured analysis of protocols involves the application of a coding scheme. In design research, several coding schemes have been used in protocol studies. Our coding scheme consisted of four major categories ('requirement', 'solution', 'information', and 'strategy'), borrowed from the coding schemes successfully implemented and developed by Chakrabarti et al (2004), Kruger and Cross (2006), and our own sub-categories. For example, under the major category 'requirement', in the sub-category 'activities', we added activities, namely 'evaluate', 'select/reject', and 'assume'. These activities were added because we observed them in the data. Similarly, under the major category 'information', we added activities - 'access' and 'assume'; and under the category 'solution', we added the activity 'select/reject'. The four major categories are: 'requirement', 'solution', 'information', and 'strategy'. The reason for using the coding scheme with these categories is that these categories were considered to be appropriate for our empirical exploratory study as they covered a broad range of aspects of the design process.

As shown in Table 1, for the segments that were classified under the 'requirement' category, we coded the applicable activity (i.e. identify, evaluate, repeat, interpret, ask, select/reject), type of requirement (i.e. solution-specific or solution-neutral), and the topics of requirement (e.g. materials, geometry, etc.). Some topics of requirements were borrowed from Pahl and Beitz (1996) and Dwarakanath and Blessing (1996), and some topics evolved during the coding process. In our study, the list of requirement-topics is the following: geometry, materials, installation, energy/power, costs, supply chain, logistics, safety, weight, forces, production, maintenance, users, ergonomics, aesthetics, information provision, food/water, healthcare, weather, hygiene, furniture, geographic location, and other. Some topics (e.g. food/water, healthcare, weather, hygiene, etc.) are specific to the design problem used in the experiments (see Figure 2).

For the segments classified under the 'solution' category, we coded the activity associated with the solution (i.e. generate, evaluate, repeat, select/reject). In the case of segments classified into the 'information' category, we coded the activity associated with information (i.e. access, ask, evaluate, repeat, assume, interpret). The category 'strategy' takes into account the planning aspects of the design process.

Table 1 Coding scheme

We measured the reliability of the coding process by calculating the percentage agreement between two coders. Due to resource limitations, two out of the eight protocols (i.e. two transcripts) were coded by the researcher and one coder. These two transcripts, one from each of the BOP and TOP sessions, were randomly selected. Prior to this coding, the coder was explained the coding scheme, using examples. The average inter-coder reliability was 87% (86.2% for the BOP transcript and 87.8% for the TOP transcript).

3 Results

As the sample size in our study is small (four designers in each of the BOP and TOP sessions), we have explored the structures of designers' behaviour using descriptive statistics and visually through graphs. This is in line with the studies of Fricke (1999), Günther and Ehrlenspiel (1999), and Kruger and Cross (2006).

3.1 Overview

Table 2 shows the number of segments, total time, and time per segment in the case of BOP and TOP sessions. The average number of segments is slightly higher in the BoP session as compared to that in the TOP sessions (227 and 218). However, the standard deviation of the total number of segments is higher in the BOP sessions as compared to that in the TOP sessions (103 and 55). This suggests that the distribution of the total number of segments is widespread from the mean value in the BOP sessions. Average total time (62 and 61 minutes) and time per segment (17.8 and 16.9 seconds) have approximately the same values in the BOP and TOP sessions. This suggests that in the BOP and TOP sessions, the number of segments in a given category indicates the amount of time a designer devoted to that category.

Table 2 Number of segments and duration of segments

3.2 Design strategies

Figure 3 shows the number of segments and percentage of segments under the major categories - requirement, solution, information, and strategy - for each of the designers in BOP and TOP sessions. The percentage of segments in this figure is based on the total number of segments. For example, in the case of the designer BOP-1, the total number of segments is 119, and 32.8% of these 119 segments is classified into the category 'requirement'. Figure 3 (b) graphically shows the average percentage of segments for different categories in the case of BOP and TOP sessions. In this figure, the average percentage of segments is based on the average percentage of segments of each of the designers under respective category. For example, in Figure 3 (b), average percentage of segments under the category 'requirement' (37.5%) for the BOP session is based on the average percentage of segments under 'requirement' category of each of the designers in the BOP sessions - that is - (32.8% + 39.5% + 39.0% + 38.8%)/4 = 37.5%. Figure 3 (b) shows that the average percentage of segments under the category 'strategy' is about the same for the BOP and TOP sessions (8.8% and 8.2%). This indicates that the BOP and TOP designers have spent approximately the same amount of time in planning activities. The higher number of segments under the category 'information' in the case of the BOP sessions as compared to the TOP sessions (12.5% and 8.2%) suggests that the BOP designers spent more time in dealing with information as compared to the TOP designers.

Figure 3 Number of segments and average percentage of segments for major categories (Ave. - Average; Seg. - Number of segments; standard deviation values are presented in brackets)

As shown in Figure 3, the average percentage of segments under the category 'requirement' is considerably higher in the BOP sessions as compared to the TOP sessions (37.5% and 31.0%). In contrast, the average percentage of segments under the category 'solution' is greater in the TOP sessions as compared to the BOP sessions (56.0% and 41.7%). This suggests that the designers in the BOP sessions have spent more time with requirements as compared to the designers in the TOP sessions, and that the designers in the TOP sessions have spent more time in dealing with solutions as compared to the BOP designers. This indicates that the designers in the BOP sessions have used a problem driven strategy, whereas the designers in the TOP session have used a solution driven strategy.

We created scatterplots of major categories (i.e. requirement, solution, information, and strategy) for each of the designers in the BOP and TOP sessions (see Figure 4). In Figure 4, the vertical axis of each scatterplot represents the percentage of the total number of segments, and the horizontal axis represents the major categories (1 - Requirement, 2 - Solution, 3 -

Information, 4 - strategy). For all designers in the BOP and TOP sessions, the most frequent activities are associated mainly with the categories 'requirement' and 'solution'. We can note a pattern of activities in these two categories in the case of BOP and TOP sessions by drawing ellipses as shown in Figure 4. In the case of BOP session: (1) the upward slope of these ellipses is small in the case of the designers BOP-1 and BOP-3, (2) the ellipse is flat as can be seen in the case of the designer BOP-4, and (3) the ellipse is downward sloping as seen in the case of the designer BOP-2. In contrast, in the TOP sessions, the upward slopes of the ellipses are sharp in the case of the designers TOP-2, TOP-3, and TOP-4. In the case of the designer TOP-1, the upward slope of the ellipse is small. These findings support the abovementioned interpretation that the designers in the BOP sessions have exhibited a problem driven strategy and the designers in the TOP sessions have exhibited a solution driven strategy. The scatterplots also show that in the case of seven out of the eight designers, the ellipses are upward sloping. This means that these seven designers spent more time in dealing with solutions than with requirements. This finding suggests the general solution oriented nature of design thinking.

Figure 4 Scatterplots of major categories (i.e. requirement, solution, information, and strategy) for the BOP and TOP designers (Vertical axis: Percentage of total number of segments; Horizontal axis: 1 - Requirement, 2 - Solution, 3 - Information, 4 - Strategy)

These problem driven and solution driven strategies in the BOP and TOP sessions can also be verified by computing the solution to problem (S-R) ratio (i.e. the ratio of average percentage of segments under the 'solution' category to the average percentage of segments under the 'requirement' category). For the designers in the BOP session, these ratios are 1.4 (BOP-1), 0.8 (BOP-2), 1.3 (BOP-3), and 1 (BOP-4). In contrast to these small S-R ratios, the S-R ratios in the case of the TOP designers are relatively higher: 1.3 (TOP-1), 3 (TOP-2), 1.9 (TOP-3), 1.7 (TOP-4). The average S-R ratio in the TOP sessions is 1.96 (s = 0.7), which is higher than the average S-R ratio of 1.12 (s = 0.3) in the BOP sessions. Note that the standard deviation values of S-R ratios in the BOP and TOP sessions are small (0.3 and 0.7 for the BOP and TOP sessions, respectively). While the standard deviation values of S-R ratios and those presented in Figure 3 indicate some individual differences between the designers in each of the BOP and TOP sessions, we observed consistent patterns regarding the strategies exhibited in the BOP and TOP sessions. Our examination of the data (i.e. transcripts, video and audio recordings, sketches, etc.) of each of the designers in the BOP and TOP sessions helped us to observe these patterns, which are explained in the sections that follow.

3.2.1 Strategy in the BOP sessions

After carefully reading the assignment, the BOP designers focused their attention on understanding the problem and on defining the requirements. They focused on understanding the design task without references to solutions. The problem was highly defined with numerous requirements, and these requirements were solution-neutral. In this process, they considered the context of the problem - that is - BOP context (e.g. "BOP has to be taken closely into consideration"). In addition to the context of the problem, the BOP designers considered requirements mentioned in the assignment (e.g. installation time of less than 2 hours, different types of weather conditions, etc.). They also took into account the interaction between the requirements given in the assignment and the context of the problem. The use of information was focused on understanding the problem-context and on defining requirements.

A highly defined problem was the result of their focus on understanding the problem-context and on defining requirements. Consequently, there was little scope for alternative solutions - that is - their solutions were constrained by the highly defined problem. In generating solutions, the BOP designers reminded themselves that they were designing for the BOP.

Throughout the process, three of the four BOP designers periodically dealt with solution-neutral requirements and also with the problem-context. One designer did not deal with solution-neutral requirements towards the end of the process. The BOP designers evaluated solutions with reference to requirements from the assignment and from the BOP context. They explicitly checked if the solution was suitable for the BOP. Furthermore, the BOP designers planned the design task mainly to deal with requirements.

3.2.2 Strategy in the TOP sessions

After reading the assignment, the TOP designers dealt with some basic requirements. In this process, two of the four TOP designers only mentioned the context of the problem (i.e. TOP context). Other two designers did not refer to the context at all. The TOP designers did not consider the interaction between the requirements given in the assignment and the problem-context. The problem was ill-defined. They generated solutions based on the ill-defined problem. They used information to deal with solutions.

They spent more time in generating solutions. They generated a number of solutions, and eliminated some solutions. The criteria for evaluation of solutions were not related to the context of the problem.

After eliminating some solutions, they worked on a single solution for longer periods of time with intermittent dealing with solution-specific requirements. They did not return to understand the requirements given in the assignment and the context of the problem. The TOP designers planned the process mainly to deal with solutions. Overall, the TOP designers approached the given design problem by using solutions rather than using problem analysis.

3.3 Requirement

3.3.1 Activities

The designers in the BOP sessions have spent more time in activities associated with requirements as compared to the designers in the TOP sessions (see Figure 3). The BOP designers exhibited the problem driven strategy, whereas the TOP designers used the solution driven strategy. Figure 5 shows the average number of segments and average percentage of segments for the activities under the category ‘requirement’ in the BOP and TOP sessions. This average percentage of segments is based on the average percentage of segments of each of the designers under respective activity. The coloured bars under the column ‘Average %’ in this figure are drawn by using the conditional formatting facility of the Microsoft Excel. The horizontal length of these bars represents the value of the average percentage of segments.

The occurrence percentages of segments in the activities, namely ‘interpret’, ‘ask’, ‘select/reject’, and ‘assume’ are small in both BOP and TOP sessions (see Figure 5). The average percentage of segments under the activity ‘identify’ is substantially higher in the TOP sessions as compared to the BOP sessions (72.8% and 51.3%). This indicates that the percentage of the total time associated with requirements is higher in ‘identify’ activity in the TOP sessions than the BOP session. However, the average number of segments under this ‘identify’ activity is approximately the same for the BOP and TOP sessions (44 and 45.8) (Figure 5). This suggests that the number of requirements identified in the BOP and TOP sessions is about the same. The average percentage of segments under the activity ‘evaluate’ is considerably higher in the BOP sessions as compared to the TOP sessions (18.8% and 11.1%). This finding indicates that the designers in the BOP sessions were engaged more in the evaluation of requirements than the designers in the TOP sessions. The occurrence percentage of segments in the activity ‘repeat’ is higher in the BOP sessions than the TOP sessions (27.6%

and 17.3%). This implies that the designers in the BOP sessions frequently remembered the requirements as compared to the designers in the TOP sessions.

Figure 5 Activities associated with requirements (Ave. Seg. - average number of segments; SD - standard deviation)

3.3.2 Specificity

Figure 6 shows the average percentage of segments classified according to the specificity of requirements (i.e. solution-specific and solution-neutral requirements) in the case of the BOP and TOP sessions. There are considerable differences between the occurrence percentages of these two types of requirements in the BOP and TOP sessions. The average percentage of segments associated with the *solution-specific requirements* (SRs) is higher in the TOP sessions as compared to that in the BOP sessions (48.0% and 32.2%). In contrary, the average percentage of segments associated with the *solution-neutral requirements* (NRs) is higher in the BOP sessions as compared to that in the TOP sessions (67.8% and 53.1%).

Figure 6 also shows that, in the BOP sessions, there is a substantial difference between the average percentage of segments classified into SRs and NRs. The designers in the BOP sessions dealt more with the NRs than with the SRs (67.8% and 32.2%). The BOP designers' emphasis on the NRs can be attributed to their problem driven strategy. While the designers in the TOP sessions dealt more with the NRs than with the SRs (53.1% and 48.0%), the difference between the average percentage of segments under these two types of requirements is small in the TOP sessions (53.1% and 48.0%) as compared to that in the BOP sessions (67.8% and 32.2%). This can be attributed to the solution driven strategy of the TOP designers.

Figure 6 Solution-specific and solution-neutral requirements (standard deviation values are presented in brackets)

3.3.3 Topics of requirements

Figure 7 shows the average percentage of segments classified under different topics of requirements in the BOP and TOP sessions. The BOP and TOP designers predominantly dealt with requirements regarding geometry and installation. As compared to the TOP designers, the BOP designers dealt more with requirements from the topics, namely materials (12.5% and 6.7%), users (13.3% and 6.5%), energy/power (6.3% and 4.3%), and costs (3.6% and 1.7%). As compared to the TOP designers, the BOP designers paid little attention to the requirements regarding aesthetics (0.4% and 5.6%), ergonomics (4% and 10.5%), information provision (0.4% and 2.6%), supply chain/logistics (2% and 7.3%), healthcare (8.6% and 13.8%), and hygiene (5.4% and 12.4%). The designers from both BOP and TOP sessions have not considered maintenance requirements. While the TOP designers have considered the requirements regarding forces and production, the BOP designers have not considered requirements from these topics.

The above findings suggest that, as compared to the TOP designers, the BOP designers dealt more or less with requirements from some topics. This can be attributed to the obvious differences between the TOP and BOP markets (e.g. the poor physical infrastructure in the BOP markets, low income of the BOP people, etc.). Furthermore, the differences in the occurrence percentages of requirements from different topics indicate the degree of importance the designers have placed on these topics. For example, the findings suggest that, as compared to the TOP designers, the BOP designers have placed more importance on the requirements regarding materials, energy/power, costs, etc. and less importance on the requirements regarding aesthetics, ergonomics, information provision, hygiene, etc.

Figure 7 Topics of requirements (standard deviation values are presented in brackets)

3.4 Solution

Figure 8 shows the average number of segments and average percentage of segments that are classified into the activities associated with solutions in the BOP and TOP sessions. This average percentage of segments is based on the average percentage of segments of each of the designers under respective activity. The occurrence percentages of segments in the activities 'generate' (56.9% and 54.9%) and 'select/reject' (1.7 and 0.9%) is slightly higher in the TOP sessions. The BOP designers dealt slightly more with the 'evaluate' (32.3% and 31.4%) and 'repeat' (16.5% and 14.7%) activities. Overall, the average percentage of segments for a given activity associated with solutions is about the same in both TOP and BOP sessions.

Figure 8 Activities associated with solutions (Ave. Segments - average number of segments; SD - standard deviation)

3.5 Information

The BOP sessions were more information intensive than the TOP sessions (see Figure 3). Figure 9 shows the average number of segments and average percentage of segments for different activities associated with information in the BOP and TOP sessions. This average percentage of segments is based on the average percentage of segments of each of the designers under respective activity. The occurrence percentages of segments in the activities 'access' (55.7% and 22.9%), 'ask' (20.4% and 14.6%), and 'repeat' (7.7% and 5.5%) are higher in the BOP sessions than the TOP sessions. On the other hand, the designers in the TOP sessions assumed substantially more information than the designers in the BOP sessions (39.8% and 7.1%). The TOP designers evaluated more information than the BOP designers (19.1% and 13%).

The BOP designers assumed less information and asked for more information (7.1% and 20.4%). This implies that, in the BOP sessions, asking for information was preferred over assuming the information. This also suggests that the BOP designers were not confident in assuming the information. On the other hand, in the TOP sessions, assuming information was preferred over asking for information (39.8% and 14.6%). This finding suggests that the TOP designers were confident in assuming the information.

Figure 9 Activities associated with information (Ave. Segments - average number of segments; SD - standard deviation)

3.6 Distribution of major categories

Figure 10 shows the distribution of major categories (i.e. requirements solution, information, and strategy) along the timeline. Figure 10 (a) shows this distribution for each of the designers in the BOP and TOP sessions. In this figure, a coloured bar on the timeline indicates that the designer spent time in that category. For each designer, the timeline of the design process was divided into four equal parts, namely quarters Q1, Q2, Q3, and Q4. We counted the number of segments for different categories in each of these quarters. Figure 10 (b) shows the average percentage of segments for the major categories in each of the quarters in the case of the BOP and TOP sessions. This figure also includes information on *solution-specific requirements* (SRs) and *solution-neutral requirements* (NRs). The average percentage in this figure is based on the average percentage of segments of each of the designers under the respective major categories. For example, in the BOP sessions, 41.1% under the 'requirement' category in Q1 is based on the average percentage of segments under the category 'requirement' of each of the designers in Q1.

Figure 10 Distribution of major activities (Ave. - average; SD - standard deviation)

From Figure 10, the following observations can be made. Throughout the process, the occurrence percentage of SRs is higher in the TOP sessions than in the BOP sessions, except for Q2. In Q2, the occurrence percentage of SRs is slightly higher in the BOP sessions than in the TOP sessions (10.5% and 9.7%). In Q1, the occurrence percentage of SRs is considerably higher in the TOP session than in the BOP session (7.2% and 1.9%). This indicates that the TOP designers engaged in activities associated with solutions from the beginning of the process (i.e. in Q1). This is also clear from the higher occurrence percentage of solution-related activities in Q1 in the TOP sessions than in the BOP sessions (10.1% and 7.2%). These findings can be attributed to the solution driven strategy of the TOP designers.

Figure 10 shows that, in the TOP and BOP sessions, from Q1 to Q4, there is a gradual decrease in the occurrence percentage of segments associated with NRs. However, there are some differences between these two sessions regarding the occurrence percentages of these NRs along the timeline. The designers in the TOP sessions considered the NRs mainly in the early phases of the process (i.e. in quarters Q1 and Q2). On the contrary, the designers in the BOP sessions dealt with these requirements throughout the process as can be seen from the average percentage of segments in Q3 (6.6%) and Q4 (2%).

The designers in the TOP sessions predominantly dealt with information in the beginning of the process (i.e. in Q1) (see Figure 10). The BOP designers dealt with information throughout the process. As compared to the TOP designers, the BOP designers were engaged more in activities associated with information in the later phases of the process - Q4 (10.8% and 4.4%). This suggests that the BOP sessions were more information intensive throughout the process than the TOP sessions. The distribution of the occurrence percentage of segments associated with the category 'strategy' indicates that the BOP designers were engaged in planning activities throughout the process.

3.7 Transitions

We counted the number of transitions between major categories for each of the designers in the BOP and TOP sessions. Figure 11 shows the average number and average percentage of transitions in the BOP and TOP sessions. A transition occurs when a protocol segment of one major category is immediately followed by a segment of another major category. The calculation of average percentage of transitions, shown in Figure 11, is explained as follows. For a given designer, we first calculated average percentage of transitions based on the total number of transitions of that designer. Using these average percentages of transitions for each of the designers in a session (i.e. BOP and TOP), we calculated average percentage of transitions for that session. For example, a transition from the category 'requirement' to the category 'solution' was made 18.9% of the time in the BOP sessions, and 22% of the time in the TOP sessions (see Figure 11). The average number of transitions (i.e. total number of transitions per designer) is slightly higher in the BOP sessions than in the TOP sessions (91.3 and 84.5).

As shown in Figure 11, the average percentage of strategy-to-requirement transitions is higher in the BOP sessions than in the TOP sessions (11.3% and 5.4%). This indicates that, as compared to the TOP designers, the BOP designers planned to deal more with requirements. On the other hand, the occurrence percentage of strategy-to-solution transitions is higher in the TOP sessions as compared to the BOP sessions (9.5% and 4.2%). This suggests that, as compared to the BOP designers, the TOP designers planned to deal more with solutions.

In both BOP and TOP sessions, the predominant transitions are requirement-to-solution (18.9% and 22%) and solution-to-requirement (15.8% and 21.7%). The average percentage of transitions between requirements and solutions is higher in the TOP sessions (22% + 21.7% = 43.7%) than in the BOP sessions (18.9% + 15.8% = 34.7%). This indicates that the degree of co-evolution of requirements and solutions is higher in the TOP sessions. In order to better understand the details of this co-evolution, we counted the transitions between solutions and requirements based on the specificity of requirements (i.e. SRs and NRs). For example, we divided solution-to-requirement transitions into solution-to-SR and solution-to-NR transitions. The result is shown in Figure 12. For instance, the average percentage of solution-to-requirement transitions (21.7%) in the TOP sessions was divided into solution-to-SR transitions (19.6%) and solution-to-NR transitions (2.1%). Figure 12 also shows transitions of SRs and NRs with information and strategy.

Figure 11 Average number and average percentage of transitions (Req - requirement, Sol - solution, Info - information, Str - strategy; Ave. - average; SD - standard deviation)

Figure 12 Transitions associated with solution-specific and solution-neutral requirements (SR: solution-specific requirement, NR: solution-neutral requirement, standard deviation values are presented in brackets)

In both BOP and TOP sessions, the transitions between solutions and SRs are higher than those between solutions and NRs. This is due to the fact that SRs are mainly associated with solutions, and therefore transitions between SRs and solutions will be higher than those between NRs and solutions. However, the average percentage of transitions between solutions and SRs is considerably higher in the TOP sessions (19.6% +19.9% = 39.5%) than in the BOP sessions (13.8% + 12.7% = 26.5%). This implies that the degree of co-evolution between solutions and SRs is higher in the TOP sessions than in the BOP sessions.

The average percentage of transitions between solutions and NRs is higher in the BOP sessions (3.1% + 5.1% = 8.2%) than in the TOP sessions (2.1% + 2.1% = 4.2%). This shows that while the co-evolution between solutions and SRs is higher in the TOP sessions, the co-evolution between solutions and NRs is higher in the BOP sessions. Figure 12 shows that, in both BOP and TOP sessions, the average percentage of transitions between other major categories (i.e. information and strategy) and NRs is higher than those between these major categories and SRs. This can be attributed to the fact that SRs are mainly associated with solutions than are NRs. It is therefore likely that the major part of transitions between SRs and the major categories - solution, information and strategy - will be associated with solutions than with information and strategy. The occurrence percentages of transitions between the major categories - information and strategy - and SRs and NRs are higher in the BOP sessions than in the TOP (see Figure 12).

This suggests that the designers in the BOP sessions actively dealt with requirements than the designers in the TOP sessions.

4 Summary of findings and discussion

This research, using a protocol analysis, presents empirical results of how the design process for the BOP differs from that for the TOP. The intent of the study was to empirically explore the differences between these design processes. In order to study these differences, we compared the designers who solved a design problem for the BOP with the designers who solved the same problem for the TOP. While there are some individual differences among the participants in each of the BOP and TOP sessions as indicated by the standard deviation values presented in the findings, we can note trends that distinguish between the BOP and TOP sessions. In this section, we discuss our research findings collectively to show these trends.

The designers in the BOP sessions used the problem driven strategy, whereas those in the TOP sessions used the solution driven strategy. This interpretation is based on the result that the BOP designers spent more time in dealing with requirements as compared to the TOP designers who spent more time in dealing with solutions. These strategies in the BOP and TOP sessions are further supported by the values of S-R ratios in these sessions. The average S-R ratio in the TOP session is higher than that in the BOP session. In addition, our examination of the data (i.e. transcripts, sketches, etc.) of each of the designers in the BOP and TOP sessions allowed us to observe consistent patterns regarding the strategies exhibited in the BOP and TOP sessions. The findings of this examination, explained in Sections 4.2.1 and 4.2.2, show that the BOP designers focused their attention on understanding the problem and on defining the requirements. In the BOP sessions, the problem was highly defined. In contrary, in the TOP sessions, the problem was ill-defined. The TOP designers approached the design problem by using solutions rather than using problem analysis.

The transition behaviour of the BOP and TOP designers showed that the BOP designers planned more to deal with requirements, whereas the TOP designers planned more to deal with solutions. Compared to the TOP designers, the BOP designers actively dealt with requirements as indicated by the higher occurrence percentage of transitions between the major categories - information, strategy - and requirements. These results of the transition behaviour also suggest the problem driven and solution driven strategies used in the BOP and TOP sessions, respectively.

Compared to the TOP designers, the BOP designers were engaged more with the evaluation of requirements, and also repeated requirements more frequently than the TOP designers. These findings plus the finding that the BOP designers spent more time in dealing with requirements than the TOP designers indicate that the unfamiliarity with the design task was higher in the BOP sessions than in the TOP sessions. This interpretation is further supported by the findings of Jin and Chusilp’s (2006) protocol analysis that the unfamiliarity with a design problem requires more time in problem understanding. Creating products for an unfamiliar context requires designers to develop a deep understanding of the problems (Rodríguez et al., 2006). In both BOP and TOP sessions, excepting the type of the market, the design problem was the same. This suggests that the major source of the unfamiliarity in the BOP sessions was the context of the market (i.e. BOP market).

Compared to the TOP designers, the BOP designers predominantly handled NRs than SRs. This finding that the BOP designers dealt more with NRs can be due to their problem driven strategy. While the TOP designers handled NRs in the beginning of the process, the BOP designers handled NRs throughout the process with an emphasis in the early phases. The BOP designers’ emphasis on NRs is further supported by the observation that the coevolution between solutions and NRs is higher in the BOP sessions. In contrast, the coevolution between solutions and SRs is higher in the TOP sessions. NRs are not specific to a solution, and the higher handling of NRs suggests that a designer is engaged more in the clarification of the design objectives that the final design solution needs to meet. These above findings that the BOP designers placed an emphasis on NRs, they dealt with NRs throughout the process, and the higher degree of coevolution between solutions and NRs indicate that the BOP designers engaged more in the clarification of the objectives than the TOP designers. A possible reason for these findings can be the higher degree of unfamiliarity with the design task in the BOP sessions than in the TOP sessions. Despite their experience of working on university-based design projects for the BOP, the BOP designers engaged more with the clarification of the objectives rather than with the solution-specific requirements. This can be attributed to the fact that the BOP designers were from the middle to upper middle class strata of the society, and that they did not experience the context of the poverty/BOP. Consequently, the BOP designers had less direct knowledge of the BOP. In contrast, the TOP designers' degree of familiarity with the TOP was relatively higher as they come from middle to upper middle class strata of the society.

The analysis of the requirements' topics revealed the differences between the BOP and TOP sessions in terms of different types of requirements considered in these sessions. As compared to the TOP designers, the BOP designers have placed more importance on the requirements regarding materials, energy/power, costs, etc. and less importance on the requirements from the topics aesthetics, ergonomics, information provision, hygiene, etc. These differences can be because of the obvious differences between the BOP and TOP markets. For example, the physical infrastructure (e.g. electricity networks) in the BOP markets can be poor or absent, the income of the BOP people is meagre; and therefore requirements regarding energy/power, costs, etc. are crucial in the BOP.

The TOP designers have paid attention to the requirements regarding aesthetics, ergonomics, information provisions, hygiene, and supply chain/logistics. The BOP designers have not paid enough attention to these requirements despite the problem driven strategy used by them and the importance of these requirements in the BOP. For example, the BoP people, in general, are semiliterate or illiterate, and therefore the requirements regarding information provision are important in the BOP. Also, the BOP people can have preferences regarding aesthetic qualities of products. Furthermore, the requirements regarding supply chain/logistics are important in the BOP.

We propose the following reasons for the BOP designers' less attention to the requirements regarding aesthetics, ergonomics, information provision, supply chain/logistics, etc. The BOP designers placed more importance on some requirements (e.g. materials, energy/power, costs, etc.) or they were overwhelmed by these requirements; and they thus perceived other requirements as less important. Another reason can be that the BOP designers had less direct knowledge of the BOP as they were from different strata of the society other than the BOP. Consequently, there was higher degree of unfamiliarity with the design task in the BOP sessions despite the BOP designers' experience of working on university-based BOP design projects. Furthermore, the designers might tend to think that the BOP people mainly have basic survival needs, and they might tend to give little attention to their other needs (e.g. their preference regarding aesthetic qualities of products). However, the BOP people can have other needs besides the basic survival needs. Van Kempen (2005) studied the status consumption by the poor in developing countries. His experiments in Bolivia revealed that the poor people consumed status products before satisfying their physiological needs.

The higher average percentage of segments under the 'information' category in the BOP sessions indicates that the BOP designers spent more time in handling information than the TOP designers, and that the BOP sessions were more information intensive than the TOP session. The BOP designers assumed less information and asked for more information. This suggests that, in the BOP sessions, asking for information was preferred over assuming the information, and that the BOP designers were not confident in assuming the information. In contrary, in the TOP sessions, assuming information was preferred over asking for information. This finding suggests that the TOP designers were confident in assuming the information. Furthermore, the BOP designers repeated more information than the TOP designers. Our abovementioned interpretation that the unfamiliarity with the design task was higher in the BOP sessions than in the TOP sessions is further reinforced by the above findings of the information behaviour of the BOP designers and Hertzum et al.'s (2000) finding that when faced with unfamiliar issues designers prefer to ask for information. The higher degree of unfamiliarity with the design task in the BOP sessions can be due to the fact that the BOP designers were from strata of the society other than the BOP.

The findings of this research can be useful in design practice and education. The BOP designers paid less attention to the requirements regarding aesthetics, ergonomics, etc. The requirements, which are given less attention, do not get fulfilled (Nidamarthi et al, 2001). There are examples of 'real life' BOP design projects where the requirements regarding aesthetics and ergonomics were not taken into account, and that caused in the unacceptance of the products by the BOP people. These 'real life' projects are from different sectors such as healthcare and access to clean drinking water (Lockwood, 2011; Starr, 2010). These examples of 'real life' BOP design projects and the findings of our research suggest that there appears to be a tendency not to pay enough attention to the requirements regarding aesthetics and ergonomics in the design of products for the BOP despite the importance of these requirements in the acceptability of products by the BOP people. A potential implication of these findings is that designers need to overcome the above tendency, and that they ought to consider such requirements in the design of products for the BOP.

A variety of problems with varying task environments is useful in developing different design skills (Cardella et al., 2002; Atman et al, 2005). The differences in the design processes in the BOP and TOP sessions suggest that solving design problems for the BOP can help students to practice and improve a different set of skills. This implies that students should be given opportunities to work on BOP design projects. Working on BOP design projects can be useful in developing skills required to design products for unfamiliar contexts. In addition, such BOP design projects can enhance skills of handling information-intensive design tasks.

The findings of this research can also help design teachers involved in the supervision of students' BOP design projects. Our research findings showed that the BOP designers spent more time in dealing with requirements, and that the unfamiliarity with the design task was higher in the BOP sessions despite the fact that the designers in the BOP sessions had prior experience of working on university-based BOP design projects. In a design school, it is highly unlikely to have a student, who is born and raised in the BOP - that is - who has experienced the BOP-context and has direct knowledge of the BOP. In general, a design student from a developed or a developing country, without any prior experience of working on a BOP design project, is likely to be unfamiliar with the BOP as it is probable that he/she will not have experienced the BOP context in his/her life. This implies that the BOP design projects may take longer in dealing with requirements than the design projects for familiar contexts, and this aspect needs to be taken into account in the supervision of students' BOP design projects. This also can apply to 'real life' BOP design projects that are carried out by companies.

There are some limitations to this research. These are the following: (1) the results are based on the design task that is not a genuine 'real life' design task, (2) the design task in this study is artificial task that is performed specifically for this study with limited amount of time, (3) the designers were on-camera and knew that they were being recorded, and (4) the designers worked individually in contrast to genuine design projects that are, in general, carried out by a team. Furthermore, the process of thinking aloud while solving a design problem may affect the design process. While the sample size in our study is small (i.e. four designers in each of the BOP and TOP sessions), the experiment provided sufficient data to observe overall trends and observations. We believe that it is important to validate the results of this research in studies of real design projects using ethnographic methodologies. Collecting and analysing data from a range of real design projects in the BOP using ethnographic methods may increase our understanding of the design for the BOP. We also believe that more extensive design research in the field of the BOP is warranted. In our experiments, the BOP designers and the TOP designers solved the design problem for the BOP markets and the TOP markets, respectively. This means that the people from these markets were considered as consumers of products. It would be interesting to study design process when the BOP people are considered as producers of products, and this can be an area of further design research in the field of the BOP.

5 Conclusions

This study employed protocol analysis to empirically explore the differences between the design processes for the BOP and TOP markets. As an exploratory study, we observed differences between these design processes. The differences suggest that the market-context (e.g. BOP, TOP) can potentially influence the design process. Through the results of our experiments, we found that the designers in the BOP sessions used the problem driven strategy and those in the TOP sessions used the solution driven strategy. The observed differences between the handling of NRs and SRs in the BOP and TOP sessions indicate that the BOP designers were engaged more in the clarification of the design objectives.

The differences between the information behaviour of the designers in the BOP and TOP sessions imply that the BOP sessions were more information intensive. The findings regarding the differences between the requirements handling behaviour and the information behaviour of the BOP and TOP designers indicate that the unfamiliarity with the design task was higher in the BOP sessions than in the TOP sessions. In general, a design student or a professional designer without any prior experience of working on a BOP design project is likely to be unfamiliar with the BOP. This is because he/she will not have experienced the BOP context in his/her life. Therefore, he/she might have to deal with higher degree of unfamiliarity with the design task for the BOP.

We also observed differences between the topics of requirements in the BOP and TOP sessions. The BOP designers placed more importance on requirements regarding materials, energy/power, costs, etc., and less importance on requirements regarding aesthetics, ergonomics, information provision, etc. There might be a tendency to think that the BOP people mainly have basic survival needs. Designers ought to overcome such a tendency, and they ought to consider BOP people’s other needs besides the basic survival needs.

The observed differences in the design processes for the BOP and TOP markets suggest that solving design problems for the BOP can help students to practice and improve a different set of skills required to design products for unfamiliar contexts. We believe that in tackling the wicked problem of poverty through the approach of business development combined with poverty alleviation, we need an extensive further research in the field of the design for the BOP.

[1]Some universities and institutes have begun to offer courses and/or design projects in the area of the design for the BOP. The following list, which is not comprehensive, presents some examples of these universities and institutes.

- Centre for Product Design and Manufacturing, Indian Institute of Science, Bangalore, India

- Design for Extreme Affordability course at the Stanford University, USA
- D-Lab, Massachusetts Institute of Technology, USA
- Faculty of Industrial Design Engineering, Delft University of Technology, The Netherlands
- IIT Institute of Design, Illinois Institute of Technology, USA

References

Atman, C. J., M. E. Cardella, et al. (2005). "Comparing freshman and senior engineering design processes: an in-depth follow-up study." Design Studies 26(4): 325-357.

Blessing, L. T. M. and A. Chakrabarti (2009). DRM, a Design Research Methodology. London Springer-Verlag London Limited.

Cardella, M., C. Atman, et al. (2002). Engineering Student Design Processes: Looking at Evaluation Practices across Problems. Proceedings of the American Society of Engineering Education Annual Conference, Montreal, QE.

Chai, K.-H. and X. Xiao (2012). "Understanding design research: A bibliometric analysis of Design Studies (1996–2010)." Design Studies 33(1): 24-43.

Chakrabarti, A., S. Morgenstern, et al. (2004). "Identification and application of requirements and their impact on the design process: a protocol study." Research in Engineering Design 15(1): 22-39.

Christiaans, H. and J. Restrepo (2001). Information Processing in Design: a theoretical and empirical perspective. Design Research in the Netherlands 2000. H. Achten, B. de Vries and J. Hennessey. Eindhoven University of Technology The Netherlands.

Cross, N. (1994). Engineering Design Methods: Strategies for Product Design. Chichester, UK., John Wiley and Sons.

Cross, N. (2006). Designerly Ways of Knowing. London, Springer-Verlag.

Dorst, K. and N. Cross (2001). "Creativity in the design process: co-evolution of problem–solution." Design Studies 22(5): 425-437.

Dwarakanath, S. and L. Blessing (1996). Ingredients of the Design Process: a Comparison Between Group and Individual Work. Analysing Design Activity. N. Cross, H. Christiaans and K. Dorst. Chichester, UK,, John Wiley & Sons Ltd.

Ericsson, K. A. and H. A. Simon (1993). Protocol Analysis, Revised Edition: Verbal Reports as Data, MIT Press.

Eris, O. (2002). Perceiving, comprehending, and measuring design activity through the questions asked while designing. Stanford Stanford University.

Fricke, G. (1999). "Successful approaches in dealing with differently precise design problems." Design Studies 20(5): 417-429.

Goldschmidt, G. and P. A. Rodgers (2013). "The design thinking approaches of three different groups of designers based on self-reports." Design Studies.

Günther, J. and K. Ehrlenspiel (1999). "Comparing designers from practice and designers with systematic design education." Design Studies 20(5): 439-451.

Hertzum, M. and A. M. Pejtersen (2000). "The information-seeking practices of engineers: searching for documents as well as for people." Information Processing & Management 36(5): 761-778.

IFC (2007). Market Movers: Lessons From a Frontier of Innovation. Washington, D.C.

Immelt, J. R., V. Govindarajan, et al. (2009). How GE Is Disrupting Itself. Harward Business Review.

Jagtap, S. and A. Johnson (2010). "Requirements and use of in-service information in an engineering redesign task: Case studies from the aerospace industry." Journal of the American Society for Information Science and Technology 61(12): 2442–2460.

Jagtap, S. and A. Larsson (2013). Design of Product Service Systems at the Base of the Pyramid. International Conference on Research into Design (ICoRD '13), Chennai, India.
Jagtap, S., A. Larsson, et al. (2013). "Design and Development of Products and Services at the Base of the Pyramid: A Review of Issues and Solutions." International Journal of Sustainable Society (IJSSoc) 5(3).
Jin, Y. and P. Chusilp (2006). "Study of mental iteration in different design situations." Design Studies 27(1): 25-55.
Karnani, A. (2011). Fighting Poverty Together: Rethinking Strategies for Business, Governments, and Civil Society to Reduce Poverty, Palgrave Macmillan.
Kim, M. J. and M. L. Maher (2008). "The impact of tangible user interfaces on spatial cognition during collaborative design." Design Studies 29(3): 222-253.
Kruger, C. and N. Cross (2006). "Solution driven versus problem driven design: strategies and outcomes." Design Studies 27(5): 527-548.
Kuffner, T. A. and D. G. Ullman (1991). "The information requests of mechanical design engineers." Design Studies 12(1): 42-50.
Lockwood, A. (2011). Selling condoms in the Congo, TED talk.
London, T. and S. L. Hart (2010). Next Generation Business Strategies for the Base of the Pyramid: New Approaches for Building Mutual Value, FT Press.
López-Mesa, B., E. Mulet, et al. (2009). "Effects of additional stimuli on idea-finding in design teams." Journal of Engineering Design 22(1): 31-54.
Marsh, J. R. (1997). The Capture and Utilisation of Experience in Engineering Design, University of Cambridge, U.K.
McMahon, C. A. (2012). "Reflections on diversity in design research." Journal of Engineering Design 23(8): 563-576.
Nakata, C. (2012). "From the Special Issue Editor: Creating New Products and Services for and with the Base of the Pyramid." Journal of Product Innovation Management 29(1): 3-5.
Narayan, D., R. Chambers, et al. (2000). Voices of the poor: crying out for change, The World Bank - Poverty Division (PRMPO).
Nidamarthi, S. (1999). Understanding and Supporting Requirement Satisfaction in the Design Process. Engineering Department. Cambridge, University of Cambridge.
Nidamarti, S., A. Chakrabarti, et al. (2001). Improving requirement satisfaction ability of the designer. Proceedings of the 13th International Conference on Engineering Design (ICED'01), Professional Engineering Publishing Ltd.
Pahl, G. and W. Beitz (1996). Engineering Design. London, Springer-Verlag.
Prahalad, C. K. (2004). The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits. Upper Saddle River: Nj, Wharton School Publishing.
Prahalad, C. K. and S. L. Hart (2002). The Fortune at the Bottom of the Pyramid. strategy+business.
Project, U. M. (2005). Investing in Development: A Practical Plan to Achieve the Millennium Development Goals. Overview.
Rahimian, F. P. and R. Ibrahim (2011). "Impacts of VR 3D sketching on novice designers' spatial cognition in collaborative conceptual architectural design." Design Studies 32(3): 255-291.
Rodríguez, J., J. C. Diehl, et al. (2006). "Gaining insight into unfamiliar contexts: A design toolbox as input for using role-play techniques." Interacting with Computers 18(5): 956-976.
Starr, K. (2010). Design for (Real) Social Impact, IIT Design Research Conference
Suwa, M., J. Gero, et al. (2000). "Unexpected discoveries and S-invention of design requirements: important vehicles for a design process." Design Studies 21(6): 539-567.
UNDP. (2008). "Creating Value for All: Strategies for Doing Business with the Poor." from http://www.growinginclusivemarkets.org/reports.

Van Kempen, L. (2009). Status Consumption and Poverty in Developing Countries, VDM Publishing.

Viswanathan, M. and S. Sridharan (2012). "Product Development for the BoP: Insights on Concept and Prototype Development from University-Based Student Projects in India." Journal of Product Innovation Management 29(1): 52-69.

Whitney, P. and A. Kelkar (2004). "Designing for the Base of the Pyramid." Design Management Review 15(4).

FIGURES

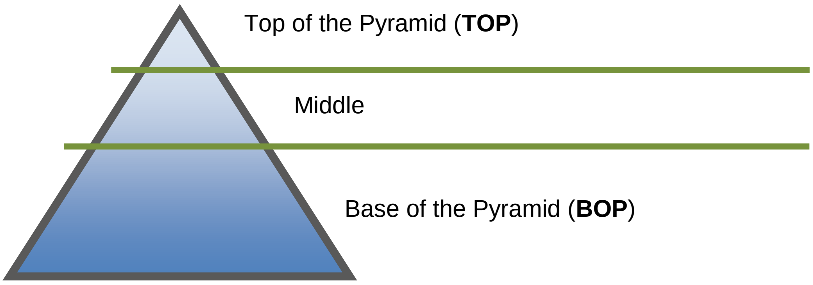


Figure 1 The world income pyramid (Prahalad and Hart, 2002)

A highly contagious and deadly disease called 'anthrax-d5' is spreading across (---). This disease is transmitted only through contaminated food and water. A person infected with this disease needs to be hospitalized in order to save his/her life. The spread of this disease is such that the existing healthcare infrastructure (i.e. available number of hospitals) is inadequate to hospitalize and treat the large number of infected people. There is an urgent need to erect a number of temporary shelters that can be used as hospitals. For (xxx), where the 'anthrax-d5' is spreading at an enormous rate, design such a temporary shelter that can be used to hospitalize 5 infected people (per shelter). Each shelter also needs to accommodate basic healthcare facilities and healthcare staff consisting of 1 nurse. The time to install this shelter must be less than 2 hours. The shelter also needs to withstand different types of weather conditions.

Figure 2 Design problem used in the experiments

(a)

			Requirement	Solution	Information	Strategy
BOP	1	Seg.	39	55	18	9
		%	32.8	46.2	15.1	7.6
	2	Seg.	133	102	71	32
		%	39.5	30.3	21.1	9.5
	3	Seg.	64	82	7	11
		%	39.0	50.0	4.3	6.7
	4	Seg.	112	117	27	33
		%	38.8	40.5	9.3	11.4
TOP	1	Seg.	70	90	12	8
		%	43.8	56.3	7.5	5.0
	2	Seg.	39	117	22	15
		%	20.4	61.3	11.5	7.9
	3	Seg.	88	167	12	20
		%	30.7	58.2	4.2	7.0
	4	Seg.	68	113	22	30
		%	29.2	48.5	9.4	12.9
Ave.	**BOP**	**Seg.**	**87.0 (43.1)**	**89.0 (26.8)**	**30.8 (28.1)**	**21.3 (13.0)**
		%	**37.5 (3.2)**	**41.7 (8.6)**	**12.5 (7.3)**	**8.8 (2.1)**
	TOP	**Seg.**	**66.3 (20.3)**	**121.8 (32.4)**	**17.0 (5.8)**	**18.3 (9.3)**
		%	**31.0 (9.6)**	**56.0 (5.4)**	**8.2 (3.1)**	**8.2 (3.4)**

(b)

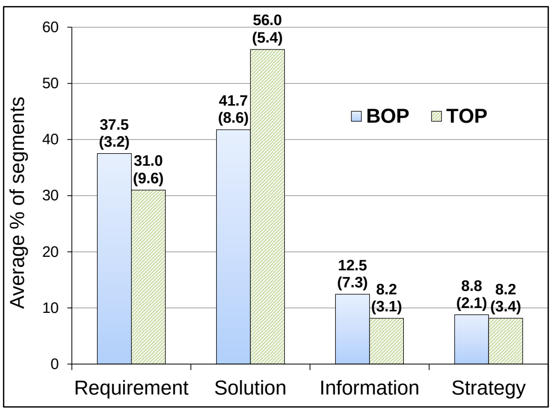


Figure 3 Number of segments and average percentage of segments for major categories (Ave. - Average; Seg. - Number of segments; standard deviation values are presented in brackets)

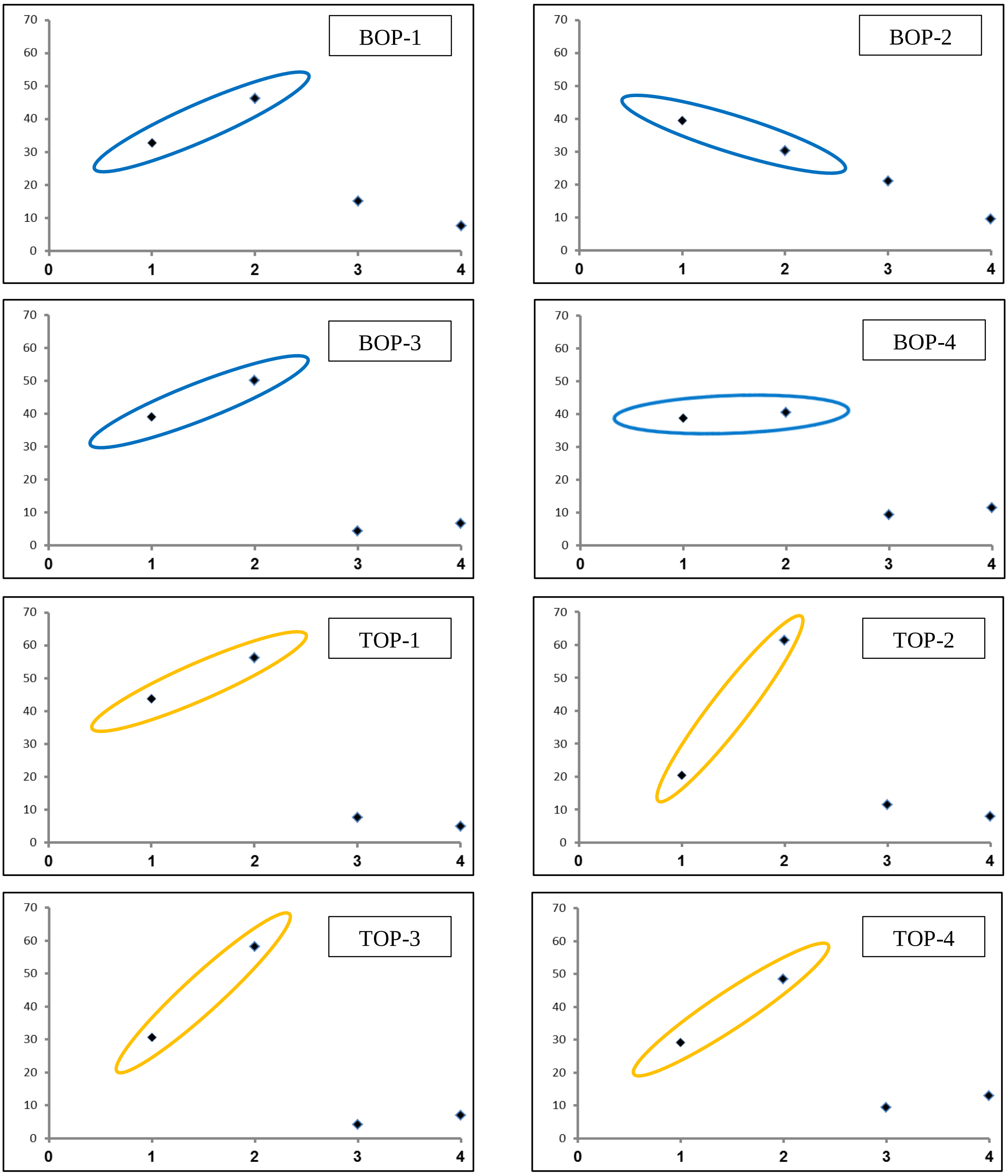


Figure 4 Scatterplots of major categories (i.e. requirement, solution, information, and strategy) for the BOP and TOP designers (Vertical axis: Percentage of total number of segments; Horizontal axis: 1 - Requirement, 2 - Solution, 3 - Information, 4 - Strategy)

	BOP				TOP			
Activity	Ave. Seg.	Ave. Seg. SD	Average %	Ave. % SD	Ave. Seg.	Ave. Seg. SD	Average %	Ave. % SD
Identify	44.0	22.8	51.3	7.2	45.8	6.9	72.8	17.6
Evaluate	20.0	17.6	18.8	11.4	7.8	3.8	11.1	2.8
Repeat	22.0	7.0	27.6	6.5	13.0	9.8	17.3	11.8
Interpret	1.8	1.5	2.6	2.6	3.0	4.7	4.6	6.6
Ask	0.5	0.6	0.6	0.7	0.0	0.0	0.0	0.0
Select/reject	1.0	1.2	0.8	1.0	0.8	1.0	0.9	1.1
Assume	3.8	2.2	4.6	2.6	4.5	7.7	6.4	11.0

Figure 5 Activities associated with requirements (Ave. Seg. - average number of segments; SD - standard deviation)

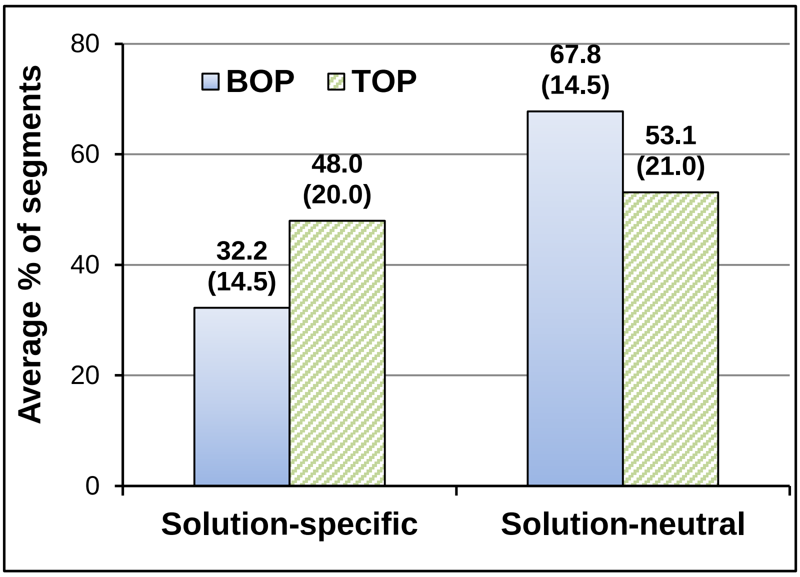


Figure 6 Solution-specific and solution-neutral requirements (standard deviation values are presented in brackets)

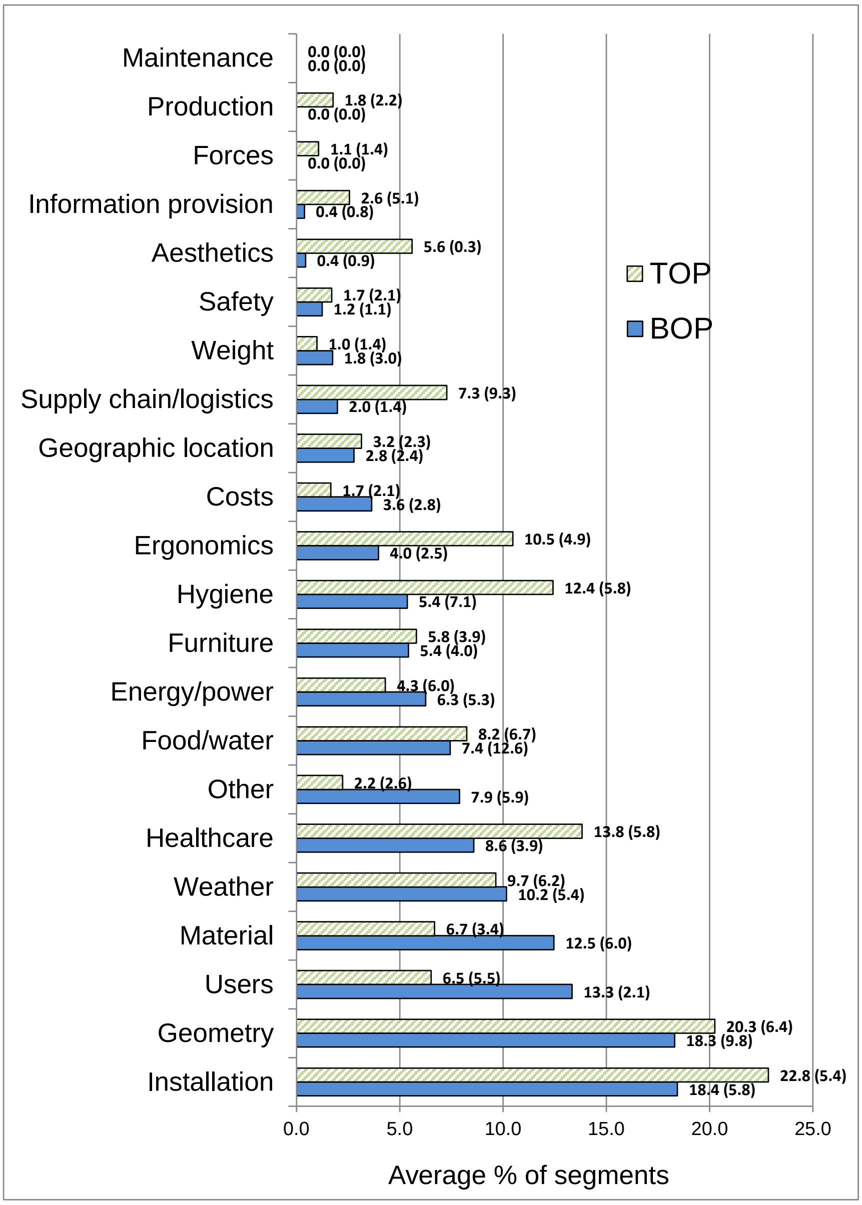


Figure 7 Topics of requirements (standard deviation values are presented in brackets)

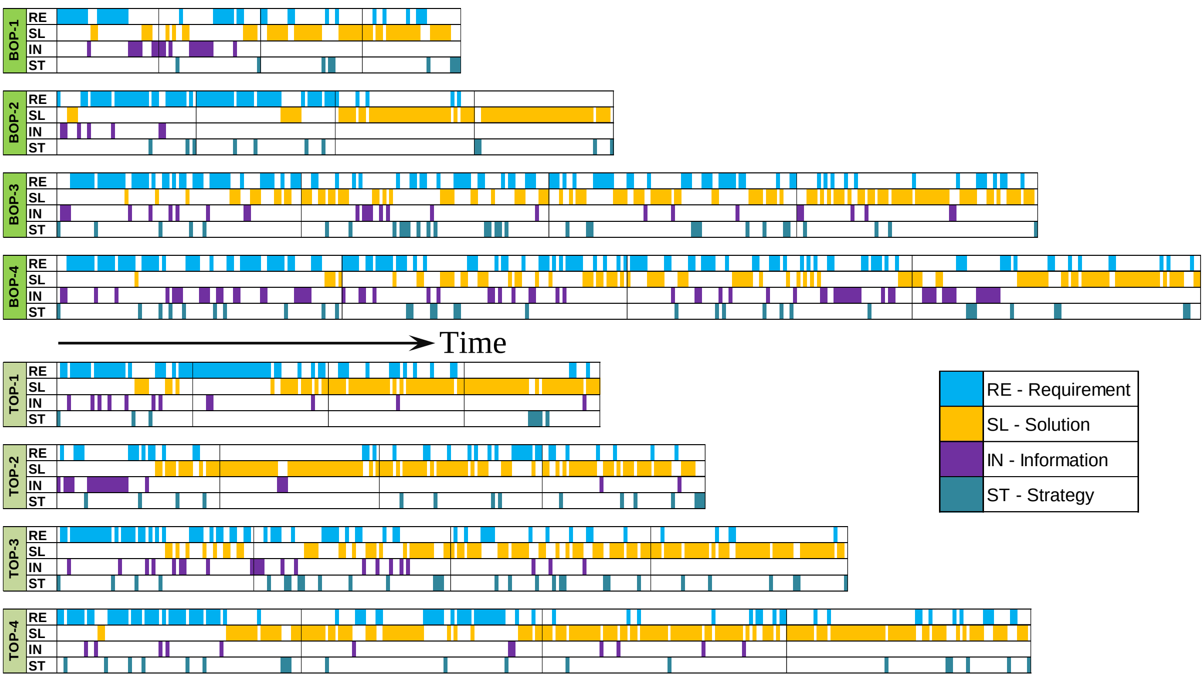
	BOP				TOP			
Activity	Ave. Seg.	Ave. Seg. SD	Average %	Ave. % SD	Ave. Seg.	Ave. Seg. SD	Average %	Ave. % SD
Generate	47.3	10.3	54.9	10.3	69.0	20.3	56.9	10.9
Evaluate	29.8	14.2	32.3	7.9	37.0	5.9	31.4	7.3
Repeat	14.5	10.0	16.5	9.7	18.8	11.0	14.7	6.6
Select/reject	0.8	1.0	0.9	1.2	2.0	1.2	1.7	1.2

Figure 8 Activities associated with solutions (Ave. Segments - average number of segments; SD - standard deviation)

	BOP				TOP			
Activity	Ave. Seg.	Ave. Seg. SD	Average %	Ave. % SD	Ave. Seg.	Ave. Seg. SD	Average %	Ave. % SD
Access	11.8	4.6	55.7	28.1	4.0	2.2	22.9	7.0
Ask	9.0	12.9	20.4	14.4	3.0	3.2	14.6	13.7
Evaluate	4.3	4.6	13.0	2.2	2.8	2.2	19.1	17.1
Repeat	4.0	6.7	7.7	9.6	1.0	0.8	5.5	4.2
Assume	3.0	3.6	7.1	8.9	6.3	3.5	39.8	30.2
Interpret	0.0	0.0	0.0	0.0	0.8	1.0	4.4	5.0

Figure 9 Activities associated with information (Ave. Segments - average number of segments; SD - standard deviation)

(a) Distribution of major categories in the case of each of the designers



(b) Average percentage of segments along the timeline (Q1 to Q4)

		Q1		Q2		Q3		Q4	
		Average %	Ave. % SD	Average %	Ave. % SD	Average %	Ave. % SD	Average %	Ave. % SD
SR	BOP	1.9	2.5	10.5	11.7	11.9	4.7	8.0	6.3
	TOP	7.2	4.8	9.7	9.5	21.1	13.5	10.0	5.9
NR	BOP	39.2	6.7	19.9	17.1	6.6	7.0	2.0	2.4
	TOP	35.2	9.2	16.4	14.7	0.7	1.5	0.9	1.7
Req.	BOP	41.1	4.8	30.4	12.4	18.5	8.6	10.0	6.8
	TOP	41.3	7.9	26.1	14.3	21.8	13.1	10.8	6.1
Sol.	BOP	7.2	3.5	17.6	8.3	33.1	9.5	42.1	3.5
	TOP	10.1	2.2	22.3	9.2	32.3	5.5	35.3	6.7
Info.	BOP	51.7	32.4	27.6	25.5	9.8	13.3	10.8	12.5
	TOP	54.5	17.2	27.3	13.3	13.8	14.2	4.4	5.0
Str.	BOP	18.4	14.1	30.7	10.3	21.4	15.1	29.5	14.1
	TOP	30.6	13.8	12.9	17.3	16.7	14.1	39.8	18.7

Figure 10 Distribution of major activities (Ave. - average; SD - standard deviation)

Transition	BOP				TOP			
	Ave. No.	Ave. No. SD	Ave. %	Ave. % SD	Ave. No.	Ave. No. SD	Ave. %	Ave. % SD
Req to Sol	17.3	12.0	18.9	3.6	18.0	4.7	22.0	5.5
Req to Info	8.8	7.3	9.4	2.6	6.8	3.1	8.1	3.2
Req to Str	7.8	4.3	9.6	5.4	4.8	2.9	5.2	2.4
Sol to Req	15.0	11.0	15.8	2.4	17.8	2.5	21.7	3.6
Sol to Info	4.5	3.1	5.2	2.5	3.5	2.4	3.8	1.9
Sol to Str	6.3	4.0	7.8	3.0	8.5	3.1	9.9	2.6
Info to Req	9.5	9.3	8.8	4.9	6.3	1.7	7.8	3.5
Info to Sol	4.5	2.6	5.7	3.8	4.0	1.8	4.5	1.0
Info to Str	2.0	2.8	1.4	1.9	1.0	2.0	0.9	1.9
Str to Req	8.8	4.0	11.3	4.4	5.0	3.6	5.4	3.0
Str to Sol	4.0	3.2	4.2	1.4	8.3	4.2	9.5	3.2
Str to Info	3.0	4.2	2.0	2.8	0.8	0.5	1.0	0.7

Figure 11 Average number and average percentage of transitions (Req - requirement, Sol - solution, Info - information, Str - strategy; Ave. - average; SD - standard deviation)

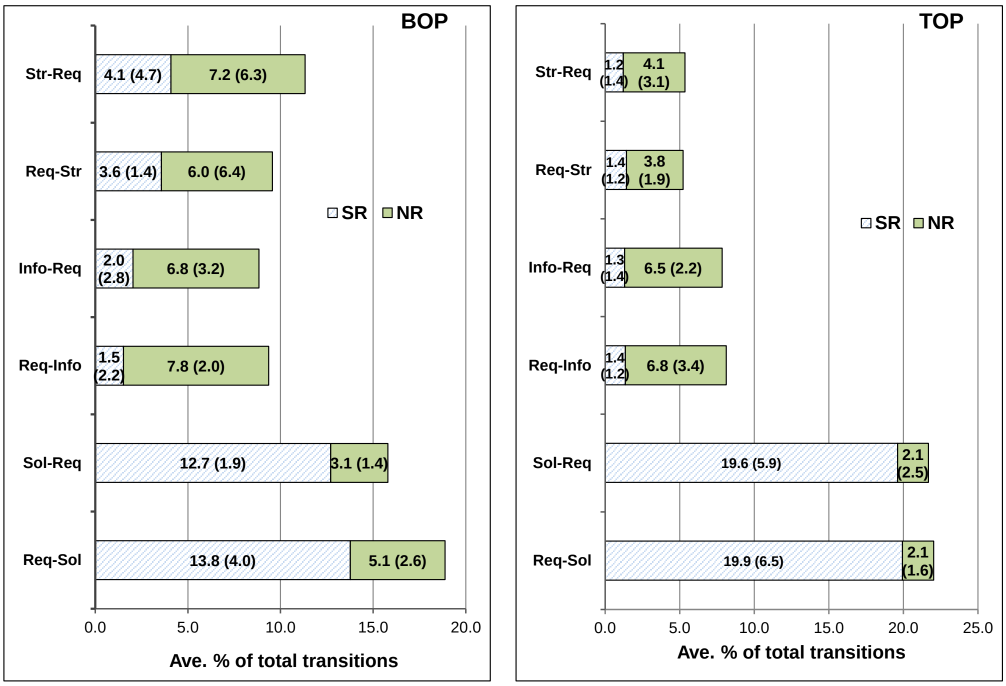


Figure 12 Transitions associated with solution-specific and solution-neutral requirements (SR: solution-specific requirement, NR: solution-neutral requirement, standard deviation values are presented in brackets)

TABLES

Category	Description (example)
Requirement	
Activity	
Identify	Designer identifies or modifies a requirement for the first time in the protocol ("That needs to include these healthcare facilities.")
Evaluate	Designer evaluates or analyses a requirement ("That is the most important requirement to manage food and water.")
Repeat	Designer repeats or remembers a requirement (The designer repeated the following requirement, "Time to install must be less than two hours.")
Interpret	Designer expresses a requirement in a different form ("This means that it has to be lightweight.")
Ask	Designer asks about a requirement to the researcher ("Does the shelter needs to have a bed for nurse to rest?")
Select/reject	Designer selects or rejects a requirement ("I am not considering this stormy condition in the weather.")
Assume	Designer assumes a requirement ("I am assuming this should be having toilets and sanitary areas.")
Req. type	
Solution-specific	A requirement that is specific to any of the designer' solutions (The designer, in relation to a specific solution, dealt with the following requirement, "The outside of it should be of leak-proof material to protect from rain.")
Solution-neutral	A requirement that is not specific to any of the designer' solutions ("The solution needs to be as cost-efficient as possible.")
Req. topic	Categorization of a requirement based on its topic (e.g. materials, geometry, etc.)
Solution	
Activity	
Generate	Designer generates, modifies or details a solution ("Let's put cloth on inside of this roof.")
Evaluate	Designer evaluates or analyses a solution ("So, this is efficient to erect really fast.")
Repeat	Designer repeats a solution or parts of a solution generated earlier (The designer repeated the part of a solution, "This is made from bamboo.")
Select/reject	Designer selects or rejects a solution ("I am not going with this inflatable concept.")
Information	
Activity	
Access	Designer accesses/collects information ("Developed countries have such facilities.")
Ask	Designer asks the researcher for information ("Does anthrax spread from person to person?")
Evaluate	Designer evaluates or analyses information ("This is actually not accurate information of this kind of inflatable material.")
Repeat	Designer repeats or remembers information (The designer remembered the information, "The disease is transmitted through contaminated food and water.")
Assume	Designer assumes information ("Let me assume that these people can move on their own.")
Interpret	Designer expresses information in a different from ("So, this also means the disease is going to kill people.")
Strategy	A plan of action for proceeding through the design process ("I will start by just taking some notes about what this task is.")

Table 1 Coding scheme

		Total number of segments	Total time in minutes	Time per segment in seconds
Average (Std. dev.)	BOP	227 (103)	62 (17)	17.8 (4.8)
	TOP	218 (55)	61 (21)	16.9 (5.5)

Table 2 Number of segments and duration of segments