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Assessing the Benefits of Early Stage Design Research of Rural BoP-Focused Energy Solutions in Urban Settings

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Abstract: The benefits of user-centered design in design and testing for Base-of Pyramid (BoP) related products have been generally established. However, conducting extensive field tests in rural villages can be daunting. Besides the expense of conducting multiple field visits in remote locations, the process of transforming those design insights into a manufactured design change can take weeks, if not longer. These barriers can lead some firms to forego obtaining valuable user feedback during the initial design research process. Two case studies, based in Chennai, India, investigate the benefits of conducting rural BoP product tests in an urban environment. Findings suggest that design insights gained from the urban families are as informative as similar tests conducted in rural settings. This report also offers insights on selecting users, field-testing new BoP products, effective user-centered design frameworks, rapid prototype fabrication, as well as limitations to this approach.

Keyword: Base-of Pyramid (BoP), User-centered design (UCD), Urbanization, Prototyping, Urban testing, Design research, Chennai, Tamil Nadu, India

1 Introduction

The benefits of user-centered design (UCD) have been generally established. As a research method, UCD offers insights into user needs, desires and limitations through an evaluatory framework for the design experience of first-time product or service users. India, China and many African countries have become testing grounds for innovative UCD research on products, from water filtration devices to financial services, designed by public and private companies for the world's base-of-the-pyramid (BoP[1]) markets.

While the global BoP segment is diverse, most potential customers live in rural areas on less than $2 USD per day. In India alone, approximately 820 million people are spread across 630,000 rural villages, representing 71 percent of India's population [1].

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[1] *Base-of-the-pyramid, or Bottom-of-the-pyramid, is the socio-economic designation for the more than 4 billion people globally with annual per capita incomes below $1,500 USD (PPP).*

According to a leading thinker in the field, the disconnect lies in that "90 percent of the world's designers focus on solutions for the richest 10 percent of the world's customers rather than the other 90 percent who need it most."[2]

Design firms have emphasized the importance of UCD in creating usable and useful products for the BoP segment [3]. However, design research and prototyping has proven difficult, costly and time-consuming for firms not familiar with nuances of research in rural India. Consumer product firms, researchers and designers need a way to gain initial user insights, while keeping costs low and design on schedule.

Two case studies, conducted in the slums of Chennai, Tamil Nadu, India in 2009, investigate the extent to which urban areas can serve as early stage testing grounds for rural household energy products. Household energy products, specifically cooking technologies, were chosen based on five characteristics: they fulfill a need in urban areas unlike rural farming and irrigation products, they are utilized in the same ways in rural and urban poor settings, they are ubiquitous and easily accessible, and they are low-cost. The urban testing concept takes into account the rural-to-urban migration patterns that transfer people's rural cooking behaviour and cultural practices into urban centers, and maximizes the flexibility for researchers to meet diverse groups in one place.

The background section describes this area of research, outlining this study's objectives and methodology. The first case study "Conducting urban user testing on an existing improved cookstove" details the ability of researchers to gain valuable design insights on rural products by conducting product tests in urban locales. This case concludes with a comparison of urban user insights with those experienced by product designers in rural settings. The second case study "Designing, prototyping and conducting urban testing of cookstove regulator concepts[1]" describes how the urban testing concept can be applied to new product design and prototyping. Outcomes from these case studies are validated by the willingness of urban users to participate in these product tests, the quality of user insights, and the ability of researchers to regularly visit participants.

The paper concludes with a discussion on the main findings, implications for the ongoing research on early stage user involvement and the limitations. The case studies suggest that urban settings can facilitate early stage product design, prototyping and user testing for researchers, developers and companies designing for the rural BoP.

2 Background

2.1 BOP and Design

The growing emergence of the rural market in India's formal economy presents an opportunity for products designed around rural needs and desires **[4]**. Government initiatives, as well as the potential opportunity to obtain carbon credits, have focused the attention of entrepreneurial designers on the untapped rural BoP energy market. Although improved cookstoves have been in the market for over thirty years, only a few models have shown successful adoption or long-term viability [5, 6].

Regardless of whether or not a fortune is to be found at the base of the pyramid [7, 8] new government initiatives are calling for innovative clean energy products for the rural markets. In 2009, India launched the National Biomass Cookstoves Initiative (NCI) with the goal of spreading clean energy alternatives to all of India's households through the development of "the next-generation of household cookstoves, biomass-processing technologies, and deployment models" [9]. The central government aims to alleviate indoor air pollution by targeting the approximately 84 percent of the rural population that

[1] *Regulators are metallic vents that fit within existing chulhas. They behave similar to the steel grates used in improved biofuel cookstoves to improve combustion efficiency.*

use either firewood & chips or dung cake as their primary cooking fuel in *chulhas* (traditional cookstoves) [10].

In contrast to previous government initiatives for energy, NCI's approach emphasizes the end-user, specifying that "the starting point of the current exercise is the user. The solution on offer should, first and foremost, be easy to use and maintain and conform to local cooking habits across the country"[9]. Similarly, experts in the field of household energy consumption posit that "the success or failure of the introduction of a new improved cooking stove in a certain rural region will depend not only on its accessibility, affordability and efficiency and maintenance, but also on whether the stove design and functionality is well tailored to the local culture, tastes and cooking habits or behaviours related to food preparation of the people in that region"[11].

The importance of centering on users' needs and desires has become a major component in modern design thinking for the BoP through the use of UCD strategies of "deep listening" and "deep dialogue" [12]. Deep understanding is attained from heavy interaction with potential users in their environment and in-home testing of prototypes over an extended period of time [13]. However, the logistics, cost and time required for research of this intensity make extensive rural research a prohibitive endeavor. Product companies are required to locate rural villages in which to test, select households willing to test and provide user feedback, make multiple site visits to collect data, and develop actionable insights to modify existing prototypes and then repeat the process several times in several locations.

Companies need an easier strategy for gaining initial user insights. User-focused testing in urban households that maintain rural characteristics, such as cooking primarily with biomass or having no electricity, can contribute to this early stage design research on rural-focused energy products. The method allows designers to gain much needed usability insights from a more accessible segment of the target population.

2.2 Urbanization and Energy Use

Approximately 1.18 billion people live in India, of which, 29 percent reside in urban areas [1]. This figure is expected to rise as urbanization continues and more families are attracted to urban centers in search of work [14]. Many of these families will end up living in urban slums, which are currently home to 23 percent of India's urban population [1].

Many urban slum dwellers maintain cooking practices similar to their rural counterparts. Nearly one quarter (24 percent) of urban households in India use either firewood & chips or dung cake as their primary cooking fuel[1][10] in wood/biofuel-burning *chulha* stoves that are characteristic of rural India. In a Chennai slum, five types of biofuel stoves were counted along approximately 250 metres of road. They illustrate the diversity of rural stove types that can be found in urban areas.

Slums provide a valuable and efficient context for BoP design research across several verticals. For example, with seven percent of urban households using kerosene as their primary lighting fuel [10], there is opportunity to test new lighting solutions in urban

[1] *The types of firewood used by urban households can differ greatly from that of their rural counterparts. In Chennai, urban chulha users commonly collect rectangular scrap wood that is freely available as waste from lumber stores, construction sites and shops throughout the cities. This wood often contains nails and is occasionally treated or painted.*

slums. The urban poor who retain their rural practices can benefit not only from new technology, but also be involved in the design process.

3 Objective

The overall objective of this study is to test the hypothesis that product testing of rural-focused energy solutions in urban settings is viable. Urban settings offer regional diversity and easier accessibility for researchers to interact with the users on a regular basis with minimal interruptions of the user's daily routines. Urban testing saves researchers money, time and logistical efforts typically required for early-stage rural product design testing.

This hypothesis includes the following testable assumptions:

1. Urban households are able and willing to thoroughly test consumer energy products, and provide relevant user-feedback;
2. User insights can be easily attained on a regular basis;
3. User insights can quickly be turned into manufactured design changes at a low cost;
4. Select urban families will cook in a manner similar to rural counterparts;
5. Urban user product modifications and design feedback will also be similar to rural counterparts.

Urban settings provide designers with greater access to resources needed for quick product modifications compared to rural towns and villages.

4 Methodology

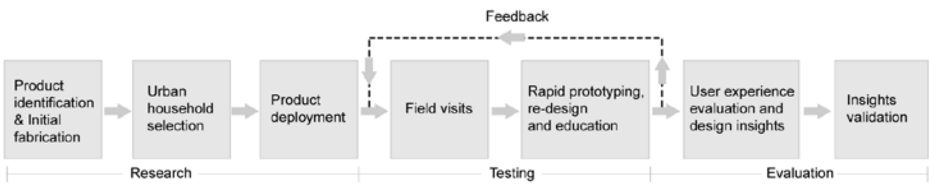

Figure 1 Process flow diagram

The hypothesis was tested in the urban slums of Chennai, Tamil Nadu using a three-step process: (i) Research (ii) Testing and (iii) Evaluation. The methodology was first to take an existing BoP-focused improved cookstove through a full product testing cycle, and then to take a product concept not yet on the market through a full design, prototyping and testing cycle.

The research phase for the first case study began with a leading improved cookstove from Prakti Design[1], and for the second case study with a *chulha* cookstove regulator insert prototype made with local resources. Families that regularly cooked traditional foods on wood-burning *chulhas* were identified in urban slums and their willingness to use (test) new products and be interviewed on a regular basis was confirmed. The last

[1] *www.praktidesign.com*

step in the research phase was to deploy the Prakti Design cookstove and the regulator insert prototype to households for testing.[1]

During the testing phase, weekly visits with the families were conducted to gain user insights through qualitative research methods (visual observation and interviews) and to clarify product use with instructions in Tamil language as needed. Observations from field visits were used to record product use, wear and the evolution of modifications made by the users. Interviews with users provided relevant feedback on usage, likes, dislikes and the incorporation of the product into daily routines.

Findings from the testing phase were evaluated using criteria based on a user experience framework devised by L. Alben [15]. Criteria included:

1. Look and feel of the product;
2. How well the user understands how to use the product;
3. How the user feels about the product while using it;
4. How well the product serves its purpose; and
5. How well the product fits into the whole context in which the user is using it.

Evaluation of the product and user experience based on these criteria uncovered insights for improved product design, instructions and potential marketing strategies. In the first case study, urban design insights were verified with Prakti Design to identify similarities and differences with their extensive rural field-testing.

5 Case study 1: Conducting Urban User Testing on an Existing Improved CookStove

5.1 Overview

An invasive product, an improved biofuel cookstove, was chosen for a six-week user test. A household was required to replace their existing wood-burning *chulha* with the Leo Double Pot stove from Prakti Design. The Leo stove is marketed as a highly efficient wood-burning cookstove which requires less fuel and produces less smoke than traditional *chulhas* through improved fuel combustion and heat transfer. During testing, a brand new stove was deployed and subject's usage was tracked twice a week for six weeks. After testing, Prakti Design compared the urban field test insights with their insights from extensive rural user research.

Similar to households in rural Tamil Nadu, the user household used an outdoor wood-burning (single-burner) *chulha* twice per day to cook traditional Tamil fare for her family. The food was strictly vegetarian, consisting primarily of rice and vegetables and the occasional pot of tea. Firewood was typically collected for free from discarded packing crates and from a nearby waste lumber pile.

The Leo stove was deployed in its box and given to the family for free. Basic instructions on the functionality of the stove were explained to a small crowd that had gathered. Authors observed the user boiling water on the stove for the first time to insure

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[1] *Families were given no incentive to participate in the study except for being allowed to keep the product they were testing if they wanted. All dialogue between the families and the researchers was in Tamil, the language of the state of Tamil Nadu. Two researchers were present for every household visit; one to ask user-centric questions, and the other to act as a behavioural observer and photographer.*

user understanding of the product. (In a rural market setting, this basic demonstration most likely would be given by the micro-entrepreneur selling the product.)

The participant used the stove regularly over the period of six weeks and often commented that she liked using it, mentioning in particular that igniting the fuel was intuitive, and the stove produced a steady flame for cooking meals.

Figure 2 Leo Double Pot stove by Prakti Design

Figure 3 User preparing dinner with the Leo stove

5.2 Key Findings

User Perception and Behaviour: This case study of the urban field test of the Prakti stove yielded four key insights about user perception and behaviour. First, the user consumed more firewood than was required for the stove to work efficiently. Second, ash from previous meals was regularly left inside the stove, reducing the stove's efficiency. Third, although it was a double-burner stove, the user preferred to use only one burner. Fourth, the user viewed smoke as a positive byproduct of biomass cooking.

During interviews, the user reasoned the excess firewood was needed because the new stove was taller than her traditional *chulha* and a larger fire was needed to reach the pot. The user behaviour of leaving ash in a traditional *chulha* after cooking is common in both rural and urban Indian kitchens and had transferred over to use of the new Prakti stove. The user primarily used only one of the two burners because her original *chulha* was a single-burner, and that was the cooking method she knew. Lastly, user perception was that smoke was an effective a mosquito repellant that kept her from being bitten while cooking.

These insights revealed the need for users to acquire a basic level of product education and behaviour modification. Potential design modifications to facilitate ash removal or limit the amount of fuel could help users use the product with more efficient outcomes. However, the view of smoke as a useful byproduct of cooking could inhibit proper use of improved, low smoke cookstoves.

User modifications: Short, frequent visits over a six-week period enabled the authors to identify and track user modifications that influenced the intended performance of the product. For example, this double-burner stove design required a cooking vessel to be placed snugly within the opening above the combustion chamber, allowing the maximum amount of heat and exhaust to exit out the second burner. After week one, the user had placed three stones around the primary burner to raise the pot and let the fire escape through the first burner. In week two, she purposefully broke the metal pins off of the exhaust plate from the secondary burner so she could place it over the primary burner. This resulted in flames exiting the primary burner in a fashion similar to her traditional single-burner *chulha*, but made the secondary burner obsolete.

Bi-weekly visits allowed for close observation of the evolution of user modifications as the Prakti double-burner stove was turned into essentially a single-burner stove.

Furthermore, brief, frequent visits allowed the user to become comfortable with the presence of researchers and engage with the product in a natural fashion, minimizing the Hawthorne Effect where participants modify their behaviour or perceptions because they know they are being studied.

Verification: Findings were presented to Prakti Design to compare the observed user behaviours with their extensive rural research, and determine whether urban testing provided design insights applicable to rural target customers. The insights and recommendations focused on two major findings (i) high behaviour modification expected from the users and (ii) reluctance in switching from single burner to double burner. Specific comparisons between the urban test results and Prakti Design's rural research were sought along the following:

- Did users use more firewood than necessary?
- Did users not remove the ash before cooking?
- Did users modify the vent over the primary burner, and to what extent?

Comparison revealed strikingly similar insights between the urban test and Prakti Design's rural research. Prakti acknowledged that they had observed similar user behaviour regarding excessive use of firewood in the stove which leads to blocked airflow and inefficient fuel combustion. Prakti also observed the common practice of leaving ash in the stoves and the reluctance of rural users to change that habit. Prakti researchers had witnessed some rural users modifying the double-burner stove so that it behaved more like a single-burner *chulha*, including breaking the pins from the secondary burner to place it over the primary burner. However, the urban test was the first record of the use of three stones to lift a pot around the primary burner. Prakti designers concurred that the urban user provided relevant and usable design insights on the Leo Double Pot stove.

6 Case study 2: Designing, Prototyping and Conducting Urban Testing of Cookstove Regulator Concepts

6.1 Overview

This case study tests design and rapid prototyping of new rural-focused cookstove concepts in urban sites. The authors designed a metal regulator insert that increases air flow and improves combustion inside existing *chulhas.* It was purposefully designed as a non-invasive product that requires minimal behaviour change to lower the barriers to market entry for clean cooking technology. As in the first case study, urban households demonstrated a willingness and ability to test consumer energy products. Urban spaces offered local resources to turn user insights quickly into manufactured design changes at a low cost. Initial urban prototype and test results of the low-cost stove regulator insert have strong implications for its rural deployment/market strategies.

Figure 4 Regulator after 8 weeks of use

Figure 5 *Chulha* with the regulator insert

During the research phase, ten slum households with traditional south Indian cooking practices allowed authors into their living spaces to take measurements of wood-burning *chulha* dimensions and volunteered to test cooking products. The regulator insert prototype design was fabricated from scrap iron at a local metal shop in accordance to the stove measurements. After a quality check, prototypes were deployed to six households. Among households, two engaged in commercial cooking activities and all six in domestic cooking; four cooked inside and two regularly cooked outdoors. A brief demonstration was given to each user on how to position the regulator insert within the *chulha* and to remove ash after each use. Households were requested to use the regulator insert during all cooking activities for an eight-week period. Weekly interview and observation sessions were conducted with each participant.

6.2 Key Findings

Resources for Prototyping: Of the three welding shops within a 1km radius of the urban testing site, the shop that offered the lowest prices (Rs.100 ($2 USD) per regulator) and willingness to build prototypes to exact specifications in half a day was selected. In contrast to rural villages with scarce resources for prototyping, the urban setting provided a range of fabricators and resources, including skilled trade shops for electronics, carpentry and plastics. These urban resources allow for quick, cost-effective prototyping, modifications and same-day deployment.

Users' first impressions: Initially, one tester, who sells food cooked on an outdoor *chulha,* had not used the regulator insert due to concerns that the new technology would change the taste of the food. After encouragement at two visits, the participant began to use the product regularly and did not report a change in the food taste or customer satisfaction. The frequent visits enabled the authors to quickly identify the non-tester and problem-solve the situation. The other five participants integrated the product into their cooking routines within the first week of testing and no other observations of non-use were reported. Participants used the regulators twice a day for about two hours/meal for the duration of the study.

Behaviour change: Regulator inserts allowed users to adopt clean cooking technology while maintaining traditional cooking practices. The main behaviour modification required of users was to remove the ash before each use instead of the typical 1-2 days to improve air flow under the device. Users pointed out that the size of the regulator insert limited the amount of firewood that could fit in the *chulha*. Frequent visits to the urban testing site allowed for some education about the ash removal and instant feedback about the firewood use.

Perceived benefits: Combined interviews and observation during weekly visits revealed insights into how to verify decreased smoke output from the energy-efficient stove and how poor families themselves measure indoor air pollutants. All four families that tested the regulator insert indoors reported that the regulator insert caused their *chulhas* to produce less smoke than traditional practices. Probing during interviews revealed that the testers observed physical indicators of smoke within the house: the wall behind the stove held less soot between cleanings and soot-covered cobwebs were less visible in the cooking space. Although air quality monitors would be required to verify accuracy, further studies on indoor air quality could incorporate household indicators and user participation. The trust established during frequent visits to participating households allowed the authors to engage in open-ended interviewing and uncover useful insights for future research and design.

7 Summary

These two case studies explored the effectiveness of UCD testing and prototyping of rural BoP products in an urban testing site, specifically an urban slum in which testers maintained rural cooking practices on traditional wood-burning *chulhas*.

In the urban location, prototyping was extremely time and cost efficient (Rs.100/2USD per regulator). Households willing and able to test invasive and disruptive products were available. Among testers in both case studies, participation was full and there were no drop-out reports. Participants actively engaged in the product testing and provided comprehensive insights into product use, user behaviour and satisfaction levels. The Prakti cookstove case study demonstrated that urban users are thoroughly willing to take ownership of the products to the point of making design modifications. Design insights drawn from rapid testing in urban areas was validated by analogous research by Prakti Design's rural research. Follow-up interviews with the households five months after the study revealed that four of the six regulators from the second case study were still being used on a daily basis without any instructions to continue use. The two in non-use had broken from excessive wear-and-tear and the participants asked for replacements.

Furthermore, testers provided their own qualitative indicators on fuel usage and indoor smoke that could be useful in future research on indoor air pollution and energy-efficient products. Even without specific design modification suggestions, tester feedback was actionable enough to allow for future design changes on the stove regulator.

8 Conclusion

It will always be necessary to conduct BoP product testing with a rural target audience. However, by engaging urban households in the initial testing of consumer energy products and using local manufacturers for fabrication, this study suggests that designers can rapidly research, test, design and deploy prototypes while saving valuable financial and human resources and time. As an initial design research method, urban testing alleviates many financial and logistical challenges researchers face in conducting rural testing. Urban spaces offer high density of potential participants and facilitate the rapid prototyping process through the utilization of local resources. Close proximity to testers allows for more touches and tracking of user modification that might have gone unnoticed with less contact. Frequent visits, facilitated by close proximity to participants, can improve user participation in testing. High user participation in the two case studies provides strong qualitative evidence for the UCD mandate of government schemes, like NCI, around energy-efficient cookstoves for the BoP.

This project's findings are limited by a small sample size and a single type of product. It remains to be seen if similar findings would be revealed with other consumer products, such as solar lighting solutions. The realities of life in urban slums undoubtedly influence participants, and even researchers, making it hard to transpose urban design insights to the entire rural Indian or world BoP population. Further research is urgently needed in other cities and countries to verify that this method of gaining design insights for rural BoP-focused products is a viable research and design strategy for the 'other 90 percent' of the world's population.

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