Received: 28 September 2023 | Accepted: 12 December 2023

DOI: 10.1002/hcs2.80

ORIGINAL ARTICLE

HEALTH CARE SCIENCE

Learning from socially driven frugal innovation to design the future of healthcare: A case of mobile Primary Health Center

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Funding information
None

Abstract

Background and Aim: Despite their flaws, the low-cost but powerful economical solutions can ensure everyone has access to health. The main aim of this study is to extract characteristics of frugal innovation (FI) and social innovation (SI) for Primary Health Centers (PHCs) in low resource settings (LRS) for sustainable development. We will use the gained insights to design the mobile primary healthcare infrastructure using FI and SI strategies. There is a lack of methodology to design sustainable healthcare infrastructure for LRS. There is a gap in the literature about building sustainable infrastructure to provide basic healthcare facilities essential to the community. This article studies several factors necessary for designing sustainable infrastructure from the lens of FI, SI, and sustainability to develop a mobile healthcare infrastructure for last-mile people.

Methods: Started with purposive sampled case studies to find out factors and criteria that most affect the success for an innovation to be frugal, social, and sustainable. The established criteria were used to design, develop, and deploy the mobile Primary Health Center (mPHC). Moving forward, we tested the system designed with stakeholders to gather insights. At this stage we found the feedback loop from the stakeholders and the role of interdisciplinary discussions between experts, medical officers, nurses, patient, and other staff of PHCs during the design, development, deployment, and test stage to be useful in taking design decisions efficiently.

Results: The designed healthcare infrastructure of mPHC through the aspects of FI and SI proves to be efficient in providing key healthcare services to LRS.

Conclusion: Focusing on essential capabilities and optimizing performance with technology, methodologies, and processes reduces costs in an innovation. Focus on socially inclusive and rebalancing power disparities, overcome

Abbreviations: FI, frugal innovation; FIH, frugal innovation in healthcare; LMICs, low and middle-income countries; LRS, low resource settings; mPHC, mobile Primary Health Center; PHC, Primary Health Center; SI, social innovation.

societal challenges and improve human capabilities will create a sustainable and novel solution.

KEYWORDS

low resource settings, mobile Primary Health Center, sustainable development goal, frugal innovation, social innovation

1 | BACKGROUND AND MOTIVATION

In 2030, 39%–63% of the world's population, and even fewer in developing nations, are predicted to have access to essential health services. Only one-third to one-half of the world's population currently has this coverage [1]. Low and middle-income countries (LMICs) have limited access to healthcare due to resource limitations in their healthcare systems [2, 3], as well as financial barriers (such as user fees) for both public and private systems [4, 5]. The COVID-19 pandemic has increased pressure on healthcare systems worldwide, highlighting the urgent need for innovative and more affordable healthcare solutions [6]. Technological solutions are often not suitable for health needs in underdeveloped countries because they focus on health issues that are not prominent in undeveloped countries' populations or because they offer adequate remedies only when abundant resources are available [7–9].

It has been substantiated that tech solutions are insufficient for LRS; therefore, we need socially driven innovations [10]. Innovations usually occur in LRS when traditional solutions are unavailable and modern solutions are expensive. The foundation of frugal innovation (FI) is the idea of "doing more with less for more", that is, providing value with fewer resources for a more significant number of people [11]. Resource limitations were recognized as the main driving forces behind these inventions, including underdeveloped infrastructure, institutional gaps, illiteracy, and poor purchasing power [12, 13]. Cheap, durable under challenging conditions, simple to use and repair, and created from recycled and locally sourced materials are some characteristics of FI [14, 15]. FI enhances impoverished people's well-being in four areas: income production and security, education, infrastructure, and distribution [16]. It relies less on fancy labs and more on fundamental engineering abilities [17]. FI in healthcare is defined as an innovation process that efficiently uses resources to create valuable and effective healthcare-related products or services at reasonable prices [18]. In addition to the potential for low-cost innovations, FI in healthcare also incorporates more open platforms and the engagement and cooperation of various actors.

To assist the underprivileged groups, FI in healthcare comprises a wide range of continuously affordable solutions of a high enough performance level. Most FI studies, however, have focused on products, even though authors believe that FI can include products, services, processes, or business models [19]. The current inefficiencies in healthcare systems worldwide are inextricably linked to the demand for FI in healthcare. One-third to one-half of the world's population lacks access to high-quality healthcare services because of rising healthcare expenses, advanced medical technology, and their unavailability or inadequacy in situations with limited resources [20]. It is crucial to identify solutions to give universal access to high-quality healthcare services and address the existing inequities [21–23]. Access to appropriate and high-quality healthcare is a crucial concern for society. Further, there are no standard guidelines to design frugal products and moreover for healthcare innovation.

Application of FI to achieve higher-order goals such as being environmentally friendly, shaping customer behavior and making the product robust, lightweight, performance efficient, and so forth. can only be derived from involvement from users, providing accessibility, robustness, scalability, using local materials and green technology, concentrating on fundamental functions and optimizing performance (Table 1).

2 | METHODS

We have used the case study method of different companies' products to determine the factors responsible for their success from the lens of FI and social innovation (SI) characteristics. We used the case study method to gain a fundamental grasp of modern phenomena in practical settings [35]. Since our goal is to obtain insights into the aspects of FI, we used purposive sampling to select four cases for this analysis [36, 37].

The question in inquiry is: How can FI and SI guide design for sustainable communities and improve the lived experience of community members? We used qualitative and inductive approaches combining the case study method with the FI and SI characteristics for LRS.

TABLE 1 Aspects of FI from literature review.

References	Aspects of FI
Bianchi et al. [24]	Involvement of users as co-designers
Bhatti [25]	Increase accessibility
Tiwari and Herstatt [26]	Accessibility, Robustness, Scalability, Value proposition and reduce the usage of resources (both material and financial).
Bound and Thornton [27]	Implies producing goods that are better and not just more affordable. It holds for both services and goods. Low-priced does not equate to low-tech.
Basu et al. [28]	Robustness; lightweight; solutions suitable for mobile devices; human-centered design; simplification; new distribution models; adaptation; use of local resources; green technology; accessibility.
Brem and Wolfram [29]	Sophistication, sustainability, and emerging markets oriented.
Prabhu and Gupta [30]	Price sensitive customer. Principles to follow; involve and reaffirm, use flexible resources, develop long-term solutions, shape customer behavior, cocreate value with potential customers, and make creative allies.
Zeschky et al. [31]	Technical novelty and market innovation
Soni and Krishnan [32]	FI can be seen as a way of thinking or living, a method, and an outcome in the form of goods or services.
Simula and Hossain [33]	Resource scarcity; simplification; lean and environmentally friendly techniques
Weyrauch and Herstatt [34]	Sustainable cost reduction; Concentrate on fundamental functions; Optimized performance

Abbreviation: FI, frugal innovation.

Case studies were purposively sampled by the authors. We designed, developed, deployed a mobile Primary Health Center (mPHC) for LRS, and tested it with the users (verbal informed consent was obtained before the interview). We found several guiding actors in making a sustainable system based on user feedback. Finally, we gathered insights from all the different characteristics of FI and SI in making sustainable healthcare infrastructures. The core of the proposed design strategy is the user with actors and roles in making the goal of designing socially driven frugal infrastructure for sustainability.

3 | RESULTS AND DISCUSSION

3.1 | Case studies

3.1.1 | Defining FI

For any innovation to be deemed a FI, it is defined to have three prerequisites [34]: (a) significant cost reduction, (b) ideal performance level, and (c) concentration on essential functionalities. Thus, the following four purposive sampled case studies were analyzed considering these three essential qualifications to be called FI.

Table 2 shows the comparative analysis of case studies for FI fit based on the criteria laid down by Weyrauch and Herstatt [34]. All the case studies starting from Narayana Hrudayala, General Electric, Siemens and Vortex Engineering that there was a substantial lowering of cost per patient due to two main factors: One was to focus of core functionalities as Narayana did by treating five patients by one doctor due to assembly line technique; the other focus was to optimize the process which is done by using lean manufacturing by Narayana. In case of Siemens, the focus on core functionalities was fulfilled by designing the tools which can identify the sports related injuries quickly; and the focus on optimization by Siemens is done by scanning more patients daily thus less energy is used. Thus, it can state that two of the main factors for cost reduction in an innovation are to focus on core functionalities which is related to reducing the array of services to be provided to as minimum as one single service and to optimize performance level by using technology, methods and process.

3.1.2 | Defining SI

Khan and Melkas proposed characteristics of SI [38]: sustainable solution, novel solution beneficial for society, socially inclusive and rebalances power disparities, overcomes societal challenges and improves human capabilities and promotes well-being. Each case of FI was evaluated according to these five characteristics of SI. We applied the stated characteristics of SI to the above four case studies for further analysis:

TABLE 2 Comparative case study for FI fit.

	Criteria for FI		
	Substantial cost reduction	**Concentration on core functionalities**	**Optimized performance level**
Narayana Hrudayalaya (NH)	Compared to the United States (US), where the cost of heart surgery can range from US $20,000 to US$100,000, NH costs between US$2000 and US$5000.	Pay attention to critical functions. High surgical volume: NH surgeons conduct one to five operations daily, lowering the per-unit surgery cost. Using an asset-light strategy, inventory expenses are kept to a minimum. Additionally, fixed costs are shared with other hospitals. Minimizes building costs and leases equipment to cut costs.	Uses lean manufacturing and large production to deliver top-notch cardiac care. Thirteen percent of all patients receive free or inexpensive operations thanks to the money from paying customers.
General electric's MAC 400 electrocardiogram (ECG) machine	It costs a tenth of what it would in western markets, bringing the price of an ECG down to just $1 per patient.	Pay attention to critical functions that fit local conditions. When visiting patients in remote communities, small, battery-powered devices are simple to transport on motorcycles. Employs a rugged printer. Very simple for non-specialists to use.	Performance satisfies the needs of both rural patients and doctors. The need for easy-to-transport ECG equipment for doctors to use in remote areas is excellent. Performance satisfies the need for a speedy diagnosis of heart problems.
Siemens CT scanner (SOMATOM Spirit)	Lowers the cost of treatment by 30%. This scanner costs about US $60,000, considerably less than the various CT scanner variants, which can cost between US$1,000,000 and $2,500,000.	Pay attention to critical functions that fit local conditions. They are designed to identify frequent illnesses and sports-related injuries. Very simple for technicians and other less experienced healthcare professionals to use.	Users' needs are met by performance since they want straightforward fixes like simple diagnoses. More patients are scanned daily, less energy is used, and the radiation dose is reduced by up to 60%.
Vortex Engineering (Solar powered ATM)	The price of vortex machines is 50% less than that of traditional ATMs.	Pay attention to critical functions that fit local conditions. It was made to function without air conditioning. A user-friendly fingerprint-based biometric authentication system is effective for illiterate people. Utilizing sheet separation technology, even filthy notes can be distributed. Operates with built-in battery backup lasting up to 4 h during power fluctuations and outages.	Performance meets the needs of users in rural areas who want straightforward, reliable, and uncomplicated ATMs. An environmentally friendly, solar-powered ATM uses 10% less energy overall than a typical ATM. Less heat is produced.

Abbreviation: FI, frugal innovation.

Table 3 shows the comparative analysis of case studies to be called a SI based on the criteria [38]. The above selected case studies to be sustainable through novel solution fulfills the three criteria of socially inclusive and rebalances power disparities, overcomes societal challenges, and improves human capabilities and promotes well-being. To be socially inclusive and overcoming power disparities, Narayana Hrudayalaya aims at

TABLE 3 Different aspects of SI as analyzed from the case studies and literature study.

SI characteristics	Sustainable solutions	Novel solution	Socially inclusive and rebalances power disparities	Overcomes societal challenges	Improves human capabilities and promotes well being
Narayana Hrudayalaya	It uses a very cutting-edge healthcare strategy that provides affordable, sustainable cardiac treatment.	Provides a microinsurance program that enables the underprivileged to access high-quality medical care.	Provides affordable and accessible medical care to those who are marginalized.	Provide access to heart surgery at a cost that only 8% of the population can afford.	Offers drastically affordable world-class cardiac care.
General electric's MAC 400 electrocardiogram (ECG) machine	Portable, lightweight, easy to use, and has significantly decreased ECG expenses.	Gives underprivileged patients access to cutting-edge technology.	Created especially for patients who reside in outlying villages.	Tackles the issue of pricey technology being out of reach.	Enables the treatment of patients who reside in distant, rural places.
Siemens CT scanner (SOMATOM Spirit)	Uses less energy, lowers radiation dosage by up to 60% and cuts treatment costs by 30%.	Offers a lot of people a straightforward, cost-efficient answer.	Designed to be used by technicians and other less experienced healthcare professionals.	Tackles the issue of unaffordable technology.	Enables disadvantaged people to receive affordable care.
Vortex Engineering (Solar powered ATM)	Solar-powered uses only about 10% of the energy needed by a typical ATM.	Benefits the millions of ignorant farmers by increasing financial inclusion.	Even persons with no formal education can use ATMs with a fingerprint identification system.	Focuses on the issue of financial exclusion in rural communities.	Gives rural residents access to banking services, which empowers them.

Abbreviation: SI, social innovation.

providing affordable and accessible medical care to marginalized, General Electric make solutions for patients of last mile, Siemens designs their infrastructure which can be used by low skilled people, and Vortex aims at developing fingerprint ATM system which can be used by all without prior formal knowledge. To overcome societal challenges Narayana Hrudayalaya provides access to heart surgery for most of the marginalized, General Electric and Siemens makes the technology cheaper for a wider access, and Vortex Engineering makes the technology to be access and affordable by everyone without any financial constraints. Some of the aspects of FI derived from the cases studies in Table 2 are affordability, quality, performance, cost-effective, weight reduction, lightweight, compact, portable, easy to operate and battery powered (self-sufficient). The characteristics of FI in Table 2 and SI in Table 3 fulfill most sustainable development goals, such as inclusivity, health, equality, and foster innovation, indicating a relationship between the verticals.

3.2 | Design, development, deployment, and test of mPHC

The method employed was that of an open-ended qualitative interview to extract insights. The Singapore University of Technology and Design–Massachusetts Institute of Technology (SUTD-MIT) interview template developed for the product-service system was used (Figure 1). It was done in 7 phases where the author has visited 6 (Phase I), 7 (Phase II), 9 (Phase III), 7 (Phase IV), 11 (Phase V), 5 (Phase VI), 6 (Phase VII) PHCs, respectively. The medical officers, nurses, and patients at the PHCs were interviewed and asked about the facilities and services provided by their PHCs and the improvement areas. Verbal consent was taken from all the respondents before the interview.

The 153 interviews were taken with the medical officers (51), nurses (51) and patients (51) of each PHC. The first question was about the services provided, staff details, and the available facilities. The primary question

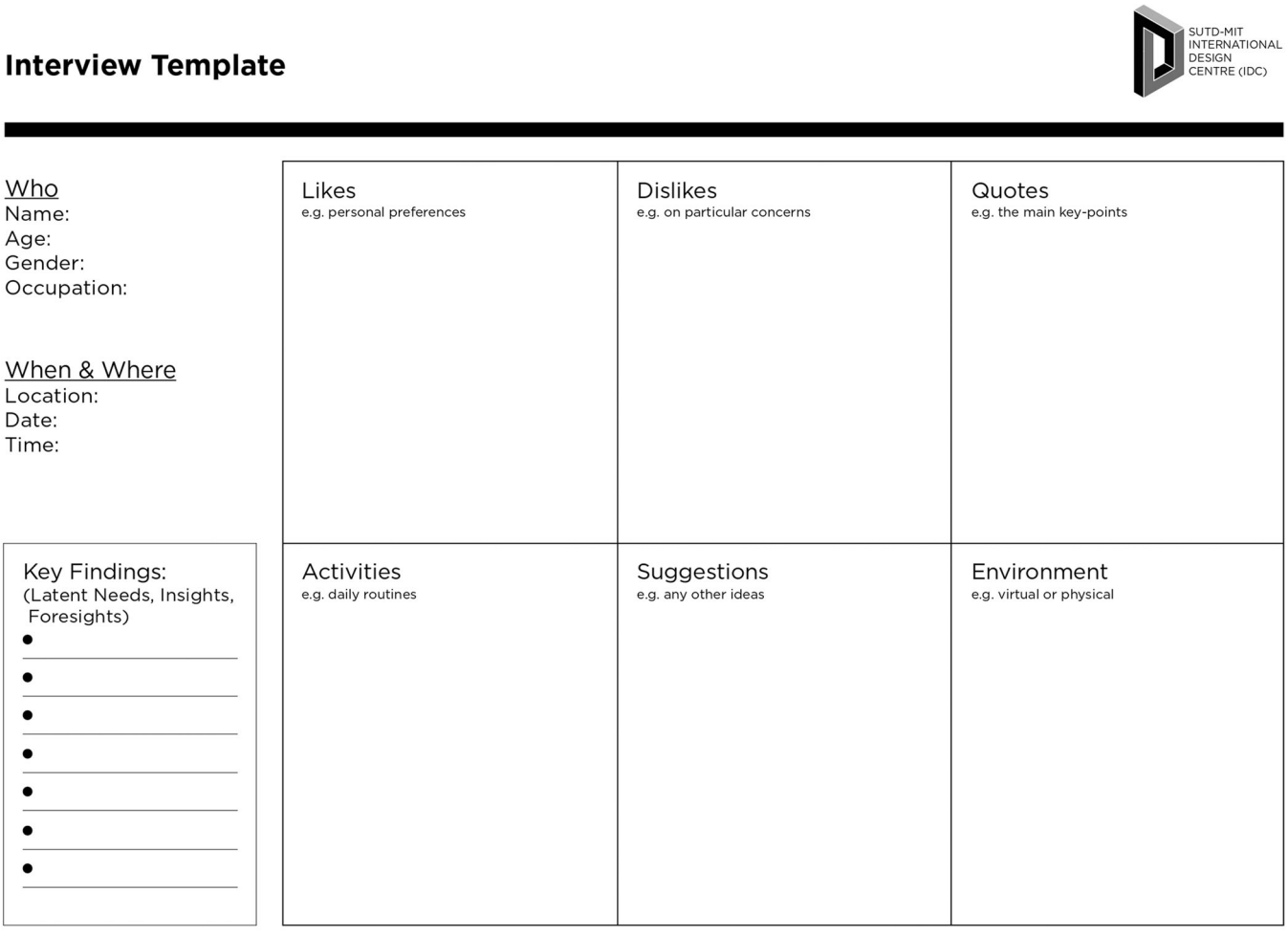

FIGURE 1 The Singapore University of Technology and Design–Massachusetts Institute of Technology interview template for product-service system.

was to narrate a typical day at the PHC with all the different activities performed. The next important question is: What do you like about the overall system of treating patients at your PHC with a follow-up of dislikes for the same? Lastly, the medical officer was asked to give suggestions on improving the present situation (if any). If there are quotes mentioned by the medical officer in between the interview at any point is noted. Author self-observation is also indicated in terms of the overall cleanliness and hygiene of the place. Insights were gathered based on the answers provided by the medical officer to inform design decisions or further steps such as problem identification. During visits, the PHCs were in a radius of 30–35 km. The PHCs were randomly selected based on the availability of medical officers at the time of visit to a particular PHC.

Figure 2 summarizes the direct and latent needs, insights, and foresight. Key issues were synthesized, and solutions were proposed.

The above reported direct and latent needs from the qualitative interviews shows that the PHCs in Kanpur needs improvement in all dimensions, from workforce to infrastructure availability. To have a clearer and more generalized understanding of the factors affecting the underutilization of PHCs, the author(s) employed a quantitative method.

Pareto chart is drawn to quantitatively map the factors responsible for the underutilization of PHCs. A pareto chart works on the principal of 80:20 rule. It indicates those 20% factors which will resolve 80% of the issues. The above graph represents the factors responsible for the underutilization of PHCs in Kanpur (Figure 3). The graph indicates those 20% factors which will resolve 80% of the overall issue in PHCs of Kanpur. Here in this case, those 20% factors which must be addressed are the inaccessibility, shortage of staff, lack of toilet, space, and infrastructure in PHCs which will help in resolving 80% of the overall PHCs issue. Resolving these factors will help in better utilization of PHCs and thus making them more efficient. These issues have already been raised at the higher-level authority but hardly any changes or actions takes place. If at all, changes take place, then due to lack of maintenance, the infrastructure becomes unusable and due to lack of

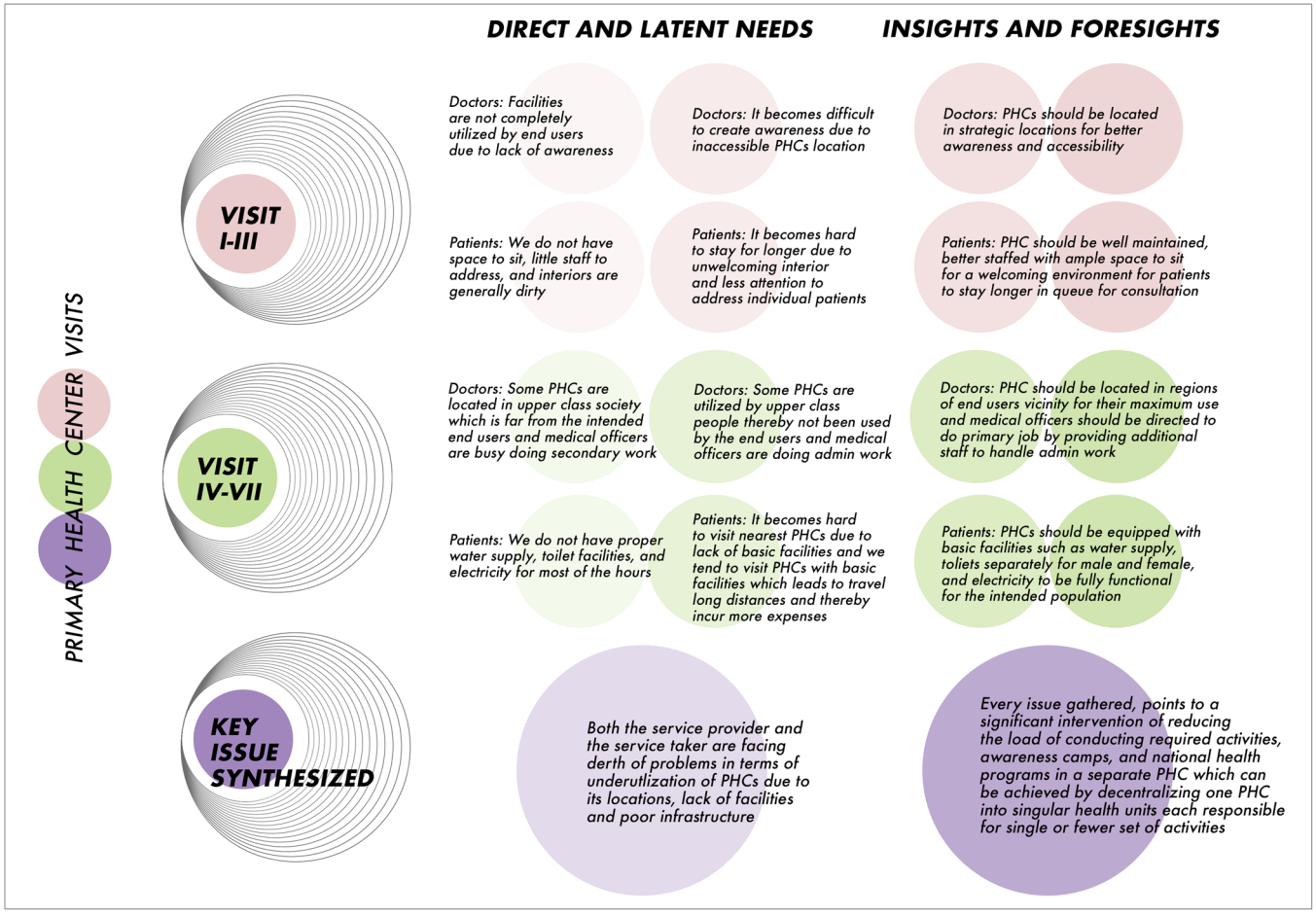

FIGURE 2 Direct and latent needs—Insights and foresights.

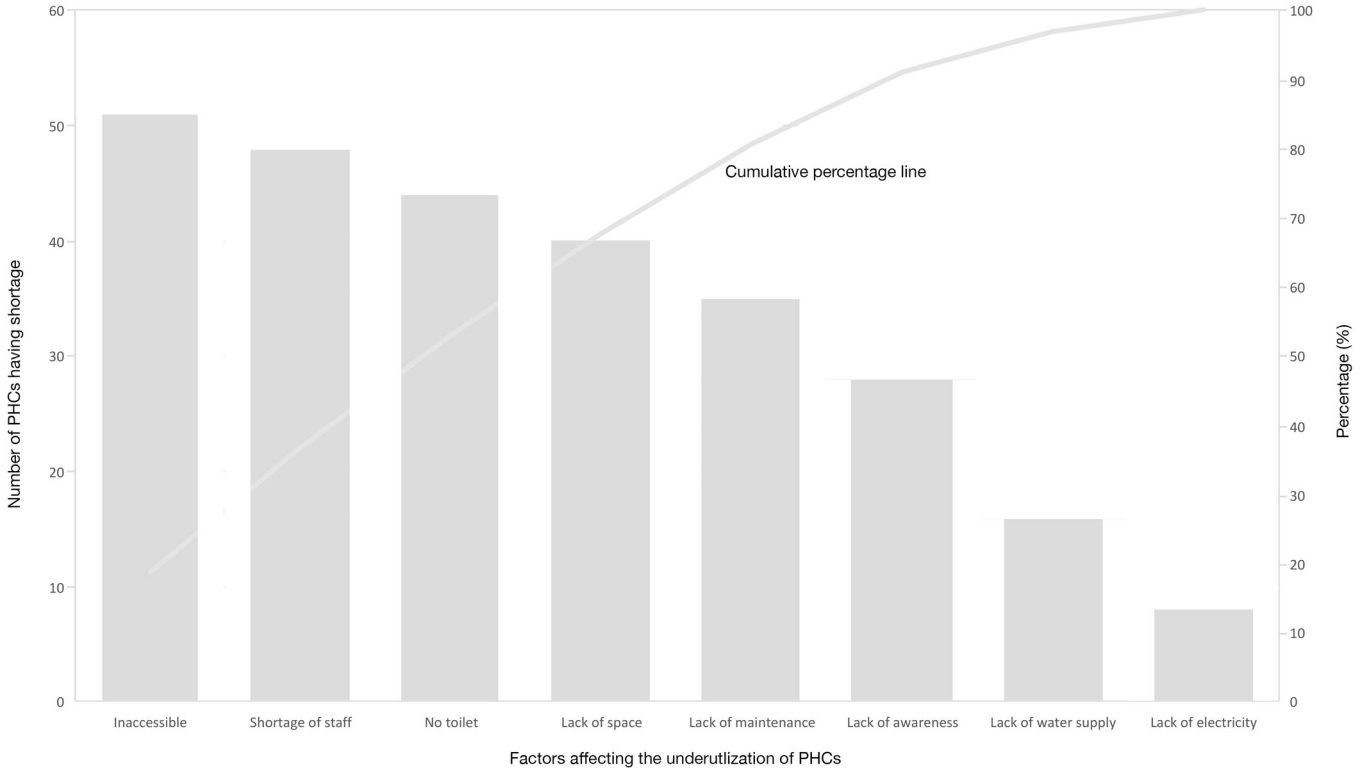

FIGURE 3 Pareto chart showing factors for underutilization of Primary Health Centers (PHCs). The bars represent individual values in descending order, and the line represents the cumulative percentage of the total. The point where the specific percentage on the *y*-axis corresponds to the cumulative percentage of the values up to the point.

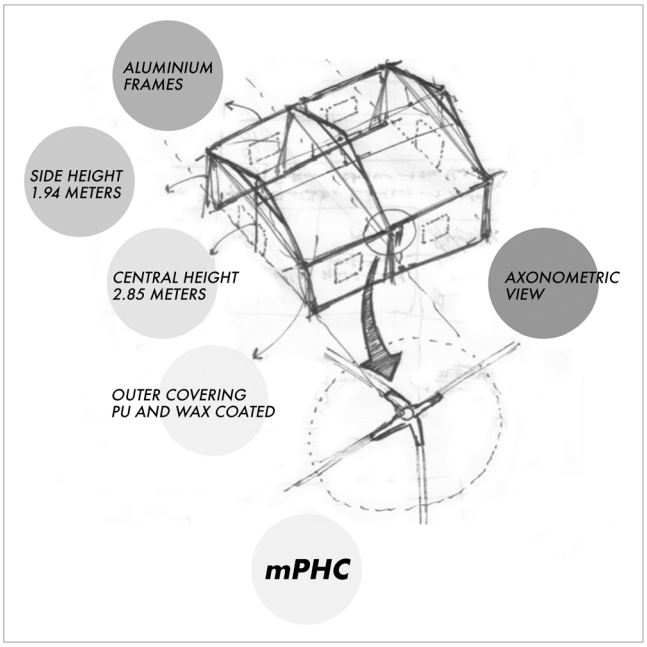

FIGURE 4 Preliminary design sketch of the mobile Primary Health Center (mPHC).

commitment, workforce becomes laid back to the service. Thus, there is a need of disruptive change in the entire infrastructure and thus idea of making the PHC mobile is proposed. Thus, this idea, if implemented can entirely change the overall healthcare system towards a more efficient delivery model.

The main goal of the mPHC is to make a collapsible system which is lightweight, compact, and flexible by design. The author has already deployed a preliminary system to test with the user. A detailed description of the initial design is illustrated below in Figure 4.

The author proposed improvement based on the qualitative analysis of the make-shift layout according to the intended service (in this case, an out patient department [OPD] camp).

Figure 5 shows the interior view of the mPHC, having two patient beds, a doctor and a patient table and a storage space. There are two entry points (one opposite the bed and one near the storage box). We did a live simulation of furniture arrangements in front of a medical officer, paramedical staff, and a technical supervisor to check the best layout possible.

A total of 49 responses were collected on the system designed during the first set of four trial run which includes experts, medical officers, nurses and patients (Figure 6). The feedback received were on running the system on standalone power, making baby feeding cubicle (BFC) collapsible, to incorporate signages and information boards and to design collapsible furniture. The other set of feedback were to focus on exterior

FIGURE 5 Interior view of the mobile Primary Health Center deployed.

FIGURE 6 Responses and insights from qualitative interview of first set of four trial run.

architecture, interior layout and to experiment with new designs. Finally, some suggestion incorporating storage for medicines ad to have provision to defend summer heat for a comfortable consultation for patients.

A total of 246 responses were collected on the system designed during the second set of six trial run which includes experts, medical officers, nurses, and patients (Figure 7). Experts say that the designed system is collapsible. The outer structure and inner furniture are both collapsible. Chair height is little low for a comfortable seat. The whole concept can bring about a change in healthcare delivery. The result will come after some trials in its intended context. Medical Officers say that the deployed system will be best suited for rural areas. The acceptance of such an

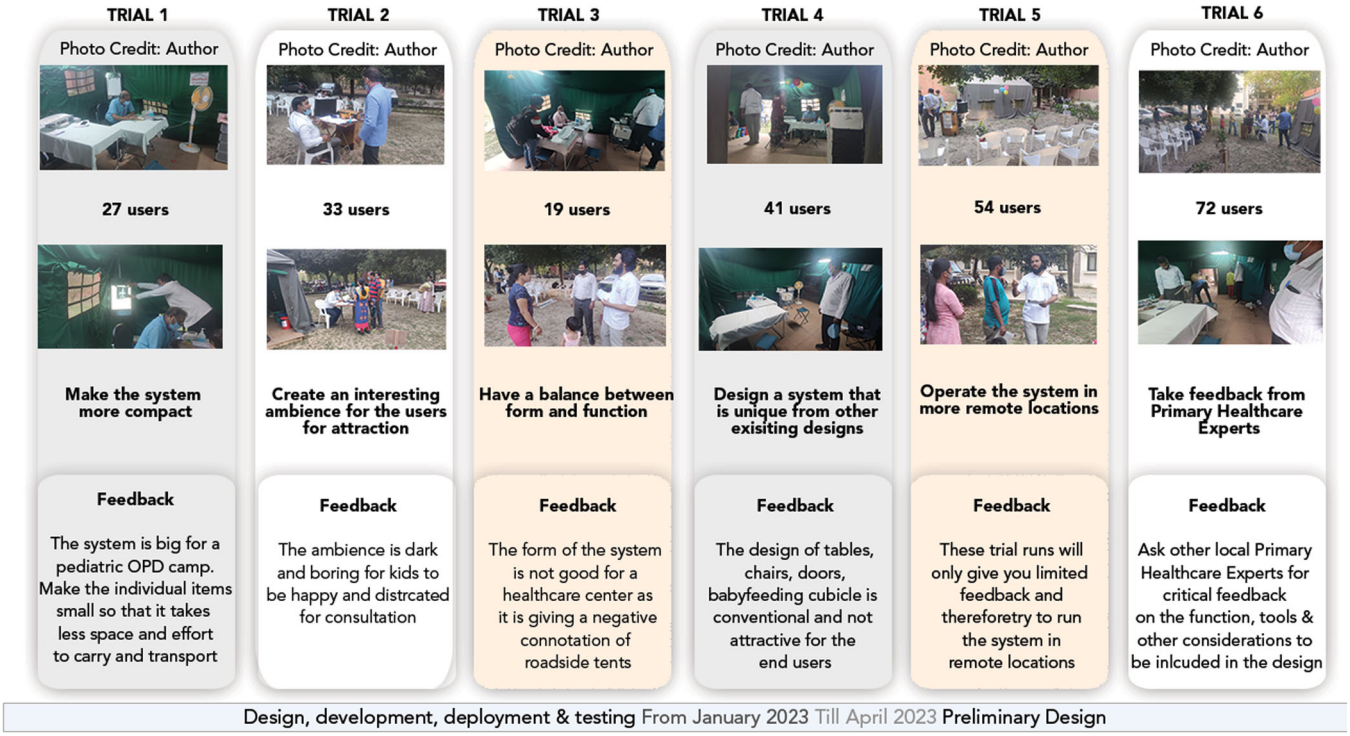

FIGURE 7 Responses and insights from qualitative interview from second set of six trial run.

FIGURE 8 Interior view of the mobile Primary Health Center deployed during a trial run.

approach is not in an urban setting. People living in cities are used to high-class hospitals with high standard maintenance. Nurses say that the proposed system is suitable for camps. It can serve as an awareness program. Patients say that some furniture needs redesign to medical standards. There is a need for a BFC. BFC is often ignored while designing a PHC in any place. It should be a central component of a PHC.

Figure 8 shows the spatial layout of the mPHC during a pediatric OPD camp. The configuration has a patient table, a doctor's table, storage space for medical, chairs to sit with standard height, dustbins, and a breastfeeding cubicle. The workforce includes a doctor, a nurse, a pharmacist, and a receptionist. The main point to be noted here is that all the furniture is collapsible by

TABLE 4 Designed system fulfilling all the criteria for sustainability.

Factors to be FI	Factors to be SI	Factors to be Sustainable
Cost reduction–**Cost of implementation was 350 USD**.	Improves human capabilities–**Providing healthcare services at the doorstep**.	Co-design
Focus on core functionalities–**Providing pediatric services to the end user**.	Socially inclusive & promotes well-being–**Deployed in locations of easy access**.	Human Centered Design
Optimized performance level–**Treating around 50 patients/hour as opposed to 10 patients/hour in conventional PHC**.	Overcomes societal challenges by rebalancing power disparities–**Reaching every doorstep to provide healthcare free of cost**.	Interdisciplinary involvement of stakeholders

Abbreviations: FI, frugal innovation; SI, social innovation.

design. Thus, we gathered insights from the above design, development, deployment, and testing of the mPHC and proposed a framework having FI, SI, and sustainability as driving forces to build sustainable healthcare infrastructure. Assessment of the mPHC design against the factors for an innovation to be frugal and socially driven innovation is analyzed in Table 4.

Table 4 concludes the study discourse into an assessment checklist for sustainability. The designed system thus achieves the FI characteristics through substantial cost reduction with use of cheap materials, focusing on core functionalities and not on esthetics, and on optimized space utility for better performance. The designed system also achieves SI through improving human capabilities by designing such mobile system at the doorstep of the needy, making it socially inclusive and promotes wellbeing, and finally overcomes societal challenges as one of rebalancing the power disparities between the urban and the rural by making the healthcare accessible for all. Finally, the system designed achieves sustainability through codesign with the community, keeping the user at the center of entire design process and the role of different stakeholders making it an interdisciplinary effort.

The key design features which were taken from literature were enlisted in Table 1. The potential of the designed system is its easy deployment and collapsibility which makes it reach the target users. Although the system was successful in bringing healthcare to the end user, it has some limitations in terms of its sterility, more dead weight which is not easy to carry, and need a basic skill to deploy at the site. For LMICs, they can develop the same center by using a similar deployable structure with less weight and more simpler mechanisms which either needs little skill or no skill to develop. In terms of the deployment, there is a need of reducing its weight, designing a manual for anyone to follow and deploy and creating awareness among the last mile people. The designed system differs from existing designs in terms of its ability to collapse in parts which can be packed in bags for easy carry to the site. Other mobile health units are custom vehicles, which can be driven to limited locations and not last mile people due to poor road infrastructure for accessibility. The main benefits of the system were its nature of collapsibility, and the drawbacks include needed skill to deploy, large dead weight not easy to carry, sterility and awareness. The number of people needed to deploy are minimum two and maximum four and the time take to deploy in less than 60 min. The model was approved by the authorities of Kanpur district during a visit to our prototype. The suggestions and feedback for improvement from their side was to make it more lightweight, use other material for outer covering, run the system by a standalone battery and make it look more interesting. We work with a one doctor team, but it is backed by 51 medical officers of Kanpur district.

4 | CONCLUSION

The overarching conclusion of the study is that the end user should always be given the focus of attention while building sustainable infrastructure. Whether it is FI and SI working in conjunction for building without focusing on the end user, the resultant will fail to achieve the intended impact. To foster sustainable development through design, the end users should contribute to making it as consumers, producers, or co-designers. The costs of an innovation can be lowered by concentrating on the most important capabilities and improving performance through the application of technology, techniques, and processes. Concentrate on creating a solution that is socially inclusive by redressing imbalances in power, addressing societal issues, and enhancing human skills to come up with a novel and sustainable solution.

AUTHOR CONTRIBUTIONS

Md Haseen Akhtar: Conceptualization (lead); data curation (lead); formal analysis (lead); investigation (lead); project administration (lead); resources (supporting);

supervision (lead); validation (lead); visualization (lead); writing—original draft (lead); writing—review and editing (lead). **Janakarajan Ramkumar**: Conceptualization (supporting); data curation (supporting); formal analysis (supporting); investigation (supporting); project administration (supporting); resources (lead); supervision (supporting); validation (supporting); visualization (supporting); writing—original draft (supporting); writing—review and editing (supporting).

ACKNOWLEDGMENTS

The authors are thankful to PMRF Scheme, which is under Ministry of Education (MoE), Government of India (GoI). This study did not receive any funding.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study involves human participants only for qualitative interviews after taking verbal consent from all the participants. Participants data/biological material was not involved in the study. This study was performed in line with the principles of the Declaration of Helsinki. The Institutional Ethics Committee has confirmed that no ethical approval is required. Verbal informed consent was obtained before the interview.

INFORMED CONSENT

Verbal informed consent was obtained before the interview. The participant has consented to submitting the information they provided during the qualitative interview to the journal.

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How to cite this article: Akhtar MH, Ramkumar J. Learning from socially driven frugal innovation to design the future of healthcare: a case of mobile Primary Health Center. Health Care Sci. 2024;3:19–31. https://doi.org/10.1002/hcs2.80