Cost-effectiveness analysis of human-centred design for global health interventions: a quantitative framework

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ABSTRACT

Introduction Human-centred design (HCD) is a problem-solving approach that is increasingly used to develop new global health interventions. However, there is often a large initial cost associated with HCD, and global health decision-makers would benefit from an improved understanding of the cost-effectiveness of HCD, particularly the trade-offs between the up-front costs of design and the long-term costs of delivering health interventions.

Methods We developed a quantitative framework from a health systems perspective to illustrate the conditions under which HCD-informed interventions are likely to be cost-effective, taking into consideration five elements: cost of HCD, per-client intervention cost, anticipated number of clients reached, anticipated incremental per-client health benefit (ie, disability-adjusted life years (DALYs) averted) and willingness-to-pay. We evaluated several combinations of fixed and implementation cost scenarios based on the estimated costs of an HCD-informed approach to tuberculosis (TB) contact investigation in Uganda over a 2-year period to illustrate the use of this framework.

Results The cost-effectiveness of HCD-informed TB contact investigation in Uganda was estimated to vary from US$8400 (2400 clients reached, lower HCD cost estimate) to US$306000 per DALY averted (120 clients reached, baseline HCD cost estimate). In our model, cost-effectiveness was improved further when the interventions were expected to have wider reach or higher per-client health benefits.

Conclusion HCD can be cost-effective when used to inform interventions that are anticipated to reach a large number of clients, or in which the cost of HCD is smaller relative to the cost of delivering the intervention itself.

INTRODUCTION

The past two decades have seen unprecedented investment in research and development of new health innovations for low and middle-income countries (LMICs). However, very little of this investment has been directed towards design and delivery innovations.1 One example of this discrepancy is in the field of tuberculosis (TB) research, where less than 13% of TB research funding is allocated to operational research (or epidemiology).2 The predominant biomedical research model often implicitly assumes that interventions proven to work in certain settings will be transportable to others. Unfortunately, this assumption often does not hold—and for a given intervention to be effective in a new setting, it must be tailored to the specific context.3 One potential approach to this problem is human-centred design (HCD), a creative process aimed at improving efficiency and facilitating innovation of a product or intervention by putting people at
the centre of the design focus. HCD allows one to gain insight into the needs of the beneficiaries, create innovative approaches to meet these needs and deliver solutions tailored to specific socioeconomic contexts. Early definitions of HCD “presumed an intended and predetermined use for each item/service as well as a static ‘user’ envisioned by the designer/engineer”. This definition has evolved to emphasize the ‘understanding of needs, desires and experiences’ of users and the techniques needed to reach this understanding through communication, interaction, empathy, and stimulation.

While HCD was first implemented in industrial design and engineering, it has been increasingly used in the global health context, especially given the strong focus of HCD on people and their communities and its emphasis on human interactions from design to implementation. Examples of HCD-informed contributions to global health range from smaller ‘incremental’ innovations to bolster existing interventions, such as the development of a marketing strategy for Nigerian health insurance, to larger ‘disruptive’ innovations that result in completely new interventions such as the design of new services in Zambia to decrease unplanned pregnancy among girls aged 15 to 19.

As the role of HCD in global health expands, a major consideration is whether HCD can be cost-effective in resource-limited contexts. Alternatives to HCD exist, including implementing without a specific strategy (which entails no additional costs) and tailoring interventions to address determinants of practice based on behavioural theory (which may be less expensive but more time-consuming than HCD). Until local capacity can be more broadly built, HCD often involves sourcing technical guidance and expertise through partnerships with design firms based in high-income countries, resulting in large up-front costs. The return on this investment (in terms of health benefit) varies, so decision-makers must generally assess whether an HCD-informed intervention would be cost-effective before initiating the HCD process. We, therefore, sought to develop a quantitative framework to help answer the question, ‘What level of anticipated incremental health benefit is needed to justify investment in an HCD-based global health intervention?’

**METHODS**

**Patient involvement**

As part of the HCD process, the parent study engaged patients with TB, community members, healthcare workers, and implementing partners in the development and refinement of the proposed TB contact investigation implementation strategy.

**Overview**

Our primary objective was to identify the conditions under which HCD can be cost-effective, when applied to health interventions in LMICs. To accomplish this objective, we first defined a range of reasonable HCD costs in consultation with the non-profit design studio IDEO.org. The costs included fixed costs from the design phase and variable implementation costs that comprised of personnel, travel, and equipment costs. Using these costs, we then estimated the incremental cost-effectiveness of a hypothetical HCD-informed intervention using an analytical framework with five elements: (1) cost of HCD, (2) incremental per-client intervention cost (HCD-informed minus non-HCD-informed), (3) anticipated number of clients reached, (4) anticipated incremental per-client health benefit (ie, DALYs averted) and (5) willingness-to-pay.

**Motivating example**

To provide a benchmark example, we projected the potential cost-effectiveness of an HCD-informed intervention for TB contact investigation in Kampala, Uganda. This intervention targeted urban and peri-urban communities surrounding the health facilities previously identified based on their geographic proximity to the Uganda-based implementing partner, Uganda Tuberculosis Implementation Research Consortium (U-TIRC). The target population included household and non-household contacts of people newly diagnosed with pulmonary TB in these clinics.

As envisioned by the design partner IDEO.org, the HCD process consists of three phases: inspiration, ideation and implementation (figure 1). For this intervention, the inspiration phase involved understanding community beliefs and priorities through interviews and focus group discussions. The ideation phase involved generating new ideas through brainstorming sessions, rough prototyping and the testing and refining of these prototypes through participant feedback. The inspiration and ideation phases of the HCD process resulted in rough prototyping and the testing and refining of these prototypes through participant feedback. The inspiration and ideation phases of the HCD process resulted in development of the ‘Tuli Wamu Nawe’ (Luganda for ‘We are with you’) strategy. This strategy emphasises a team-based approach, in which community health workers are supported by ‘health riders’, who transport health workers to patient homes and sputum specimens to...
Clinics. This strategy also includes printed informational materials to help community health workers to educate patients diagnosed with TB and to help patients educate their household and close contacts. The Tidi Wami Nawe strategy is now in the implementation phase and undergoing evaluation in a stepped wedge cluster randomised trial. Both implementation and effectiveness outcomes are under evaluation, including the incremental proportion of contacts completing screening and testing, and the incremental number of contacts diagnosed with microbiologically confirmed TB.

**Cost-effectiveness of HCD-informed TB contact investigation**

In deciding whether to pursue HCD, expenditure data on the (future) intervention are rarely available. Thus, to better replicate the decision-making process, we assume availability of budget estimates (rather than expenditure data) and take a health systems perspective. To estimate costs in our motivating example, we sourced itemised budgets from both IDEO.org and U-TIRC. In doing so, we assumed that the incremental cost of the HCD-informed intervention (relative to the standard of care) includes both an up-front cost associated with the inspiration and ideation phases (ie, costs that must be incurred before any clients benefit from the potential intervention) and an ongoing cost associated with the implementation phase (ie, personnel, travel, and equipment costs). For purposes of providing a transparent decision-making framework, we assumed that the inspiration/ideation phase cost (ie, cost of design) is fixed, whereas the implementation phase cost scales linearly with the number of clients reached.

We compared the budgets from this project to actual expenditures for other HCD-informed interventions and for prior contact investigation activities in Uganda to confirm that cost estimates were reasonable. All costs were converted and inflated to 2020 US dollars using the World Bank gross domestic product (GDP) deflator for the USA at 3600 Ugandan shillings to 1 US dollar. Future costs were discounted at 3% per year, as recommended by the US Panel on Cost-Effectiveness in Health and Medicine.

To estimate corresponding effectiveness (ie, health benefit), we first estimated the number of TB cases that might be identified through contact investigation, using data from a meta-analysis of household contact investigation. Given that contact investigation may still occur without the HCD process, we considered two scenarios: one in which the HCD-informed intervention was ‘incremental’ (ie, without HCD, contact investigation would still be performed, but less efficiently—defined here as diagnosing 40% of all household cases), and one in which this intervention was ‘disruptive’ (ie, without HCD, no contact investigation would be performed). Based on projections from the ongoing trial, we assumed that this ‘disruptive’ intervention could reach 720 household contacts—regardless of underlying TB status—if implemented across six clinics for 2 years. We then used a published transmission model calibrated to South Africa to estimate the corresponding cost per disability-adjusted life year (DALY) averted based on the cost per case detected, over a 2-year time horizon. We also explored potential economies of scale from reaching larger client volumes.

**Generalisable framework for estimating cost-effectiveness of HCD**

Using our estimates above as a benchmark, we used sensitivity analyses to create a more general framework to estimate the incremental cost-effectiveness of a generic HCD-informed intervention. We considered three scenarios for the up-front cost of the HCD process: equal to the projected cost of HCD in the TB contact investigation intervention above, 50% lower and 50% higher. We also considered three scenarios for the incremental per-client cost of implementing the HCD-informed component of the intervention (US$0.10, US$1 and US$100), to illustrate the wide range of potential costs that might be anticipated across different types of global health interventions. Using these estimates of incremental HCD cost, we then plotted the projected incremental cost-effectiveness of HCD (cost per DALY averted) according to the number of clients projected to be reached and the incremental number of DALYs averted per client (ie, DALYs averted with HCD minus DALYs averted without HCD). These estimates are then compared with different willingness-to-pay thresholds to provide decision-makers with an initial estimate of whether undertaking an HCD process would likely be considered cost-effective under prevailing cost-effectiveness thresholds. In making this comparison, we assumed that cost-effectiveness could be evaluated based on society’s willingness-to-pay for health utility (ie, DALYs averted), and that incremental cost-effectiveness thresholds could be used as a proxy for willingness-to-pay thresholds.

**RESULTS**

Based on detailed budgetary review, we estimated the up-front cost of the HCD process for TB contact investigation as US$356 000, including design, creation, and testing of contact investigation over a 20-week period from inspiration to implementation. We estimated the corresponding incremental cost of implementing the HCD-informed component of the intervention (eg, printing materials, supporting ‘health riders’) as US$0.41 per client (household contact) reached. Assuming a baseline prevalence of 3.1% of active TB in household contacts, we estimated that HCD-informed household contact investigation could detect 22.3 cases of active TB across six clinics over 2 years (table 1).

Assuming a low (2.2%) and high (4.4%) prevalence of active TB in household contacts resulted in detecting 15.8 and 32.7 cases, respectively. Assuming that, without HCD, contact investigation would not occur (ie, HCD as ‘disruptive’), we estimated the incremental cost-effectiveness
of the HCD-informed intervention as US$17700 per case detected, or US$51200 per DALY averted with the baseline prevalence of active TB. The incremental cost-effectiveness in low and high prevalence settings was estimated as US$24900 and US$12400 per case detected or US$72100 and US$36100 per DALY averted, respectively. Cost-effectiveness estimates were less favourable if we assume that contact investigation would still occur in the absence of HCD, with similar costs but lower efficiency (ie, HCD as ‘incremental’).

The incremental cost-effectiveness of an HCD-informed intervention improves as the number of people reached by the intervention increases and the cost of the HCD process decreases (figure 2). For example, in the case of HCD-informed TB contact investigation in Uganda, the incremental cost-effectiveness of the intervention was estimated at US$306900 per DALY averted if only 120 contacts could be reached, but it improved to US$8400 per DALY averted if 2400 contacts were reached and the up-front costs of the HCD process were cut in half. Similarly, if more DALYs could be averted per client reached, the estimated cost-effectiveness of the HCD process was projected to improve (figure 3). For example, in the primary scenario for HCD-informed TB contact investigation, we estimated that 0.011 DALYs would be averted per contact reached. For an intervention with similar

| Design          | Active TB prevalence (cases/100 people) | Incremental contacts reached | Incremental cases detected | Incremental cost of HCD | Cost per case detected | DALYs averted per case detected | Cost per DALY averted |
|-----------------|-----------------------------------------|------------------------------|----------------------------|-------------------------|------------------------|---------------------------------|-----------------------|
| HCD as ‘disruptive’: no activity without HCD | Low: 2.2 | 720 | 15.8 | US$356 000 + US$0.41/contact | US$24900 | 0.345 | US$72 100 |
|                 | Mid: 3.1 |                              | 22.3 | US$17 700 | US$12 400 | US$51 200 |
|                 | High: 4.4 |                              | 31.7 | US$36 100 | US$36 100 |
| HCD as ‘incremental’: 40% efficiency without HCD | Low: 2.2 | 432 | 9.5 | US$356 000 + US$0.41/contact | US$41 500 | 0.345 | US$120 200 |
|                 | Mid: 3.1 |                              | 13.4 | US$29 400 | US$85 300 |
|                 | High: 4.4 |                              | 19.0 | US$20 700 | US$60 100 |

DALY, disability-adjusted life year; HCD, human-centred design; TB, tuberculosis.
cost that was instead able to avert 0.1 DALYs per client reached, incremental cost-effectiveness would fall from US$51,200 to US$5630 per DALY averted (Figure 3, red dot to white dot).

Figure 4 presents estimates of incremental cost-effectiveness of HCD at three different estimates of up-front HCD costs (US$178,000; US$356,000 and US$534,000) and incremental HCD costs per client reached (US$0.10, US$1, US$20, and US$100), under different assumptions regarding the number of clients reached and the incremental number of DALYs averted per client reached. For example, assuming an HCD-informed intervention for which an incremental 2000 clients were estimated to be reached and an incremental 0.05 DALYs were estimated to be averted per client reached, estimated cost-effectiveness of the HCD process was US$1800 per DALY averted assuming US$178,000 up-front and US$1 per client reached, versus US$3562 per individual reached.
In this study, we developed a framework to assess the cost-effectiveness of HCD-informed health interventions in high-burden countries. This framework illustrates the importance of considering the up-front cost of the HCD process in the context of the overall intended scope of health benefits (DALYs averted per client). To date, most cost-effectiveness analyses of global health interventions have tended to ignore the substantial upfront costs that are often required to design interventions in a manner that is responsive to local priorities. When such design is not required (e.g., a standardized intervention already exists), cost-effectiveness estimates by a factor of more than 10. This framework can be useful to decision-makers in LMICs who must consider whether the anticipated benefits of increasing the volume of clients reached and willingness-to-pay can justify the often large up-front costs of the HCD process. To date, most cost-effectiveness analyses have failed to incorporate the important role of the design process in informing the up-front costs that are often required to design interventions in a manner that is responsive to local priorities.

Table 2: Estimated incremental cost-effectiveness of a representative HCD-informed intervention

| Per client cost | Low HCD up-front cost (US$178,000) | Mid HCD up-front cost (US$356,000) | High HCD up-front cost (US$534,000) |
|-----------------|------------------------------------|------------------------------------|------------------------------------|
|                 | US$0.10 | US$1 | US$20 | US$100 | US$0.10 | US$1 | US$20 | US$100 | US$0.10 | US$1 | US$20 | US$100 |
| Incremental cost-effectiveness (2000 clients reached, 0.05 DALYs averted per client) | | | | | | | | | | | | | |
| Incremental cost per DALY averted | US$1782 | US$1800 | US$2180 | US$3780 | US$3562 | US$3580 | US$3960 | US$5650 | US$5342 | US$5360 | US$5740 | US$7340 |
| Number of clients that must be reached to achieve cost-effectiveness (0.05 DALYs averted per client) | | | | | | | | | | | | | |
| US$1000/DALY threshold | 3570 | 3630 | 5930 | * | 7130 | 7270 | 11900 | * | 10700 | 10900 | 17800 | * |
| US$500/DALY threshold | 7150 | 7420 | 35600 | * | 14300 | 14800 | 71200 | * | 21400 | 22300 | 106800 | * |
| Number of DALYs that must be averted per client reached to achieve cost-effectiveness (2000 clients reached) | | | | | | | | | | | | | |
| US$1000/DALY threshold | 0.089 | 0.09 | 0.109 | 0.19 | 0.178 | 0.179 | 0.198 | 0.28 | 0.267 | 0.268 | 0.287 | 0.37 |
| US$500/DALY threshold | 0.178 | 0.18 | 0.218 | 0.38 | 0.356 | 0.358 | 0.396 | 0.56 | 0.534 | 0.536 | 0.574 | 0.74 |

*Cannot achieve cost-effectiveness because US$100 per client (at 0.05 DALYs averted per client) would exceed the threshold. DALY, disability-adjusted life year; HCD, human-centred design.
of HCD per client was estimated to be US$0.10 versus US$1.00, but substantial differences existed when varying the up-front cost by ±50%. In general, as seen in figure 4, an HCD process costing US$178,000 up-front could be justified at a cost-effectiveness threshold of US$1000 per DALY averted if a sufficient number of clients could be reached—whereas a process costing US$534,000 could rarely, if ever, be justified at this threshold. These findings argue for the importance of innovations to reduce the up-front cost of HCD for global health interventions, while retaining their quality.

Another important consideration when evaluating the cost-effectiveness of HCD-informed global health interventions is the local willingness-to-pay for health. This threshold may vary widely across contexts and perspectives, whereas GDP per capita was traditionally used as a standard threshold for willingness-to-pay for one DALY averted, it has been more recently argued that decision-makers should consider either higher thresholds, based on individuals’ valuation of a year of statistical life, or lower thresholds based on revealed willingness-to-pay. The sensitivity of the willingness-to-pay threshold to the assessment of HCD cost-effectiveness speaks to the importance of defining this threshold in each local decision-making context.

Fuge et al highlighted the diversity in HCD methods in a pattern analysis that spanned 809 HCD case studies. These authors found that 87% of interventions used ‘hear methods’ (inspiration phase) compared with ‘create and deliver methods’ (ideation and implementation phases). These authors also compared projects involving industrial designers or engineers within IDEO.org and projects using non-IDEO.org designers. They found that IDEO.org designers tend to have much higher usage in the initial ‘hear stage’ (inspiration phase), with greater preference for methods that involve end users at an early stage of the design process. Future cost-effectiveness analysis could consider comparing HCD-informed interventions applied by laypeople versus professional design teams.

Our streamlined analytical framework makes a number of simplifying assumptions. First, we assume that the up-front and per-client costs of HCD (as well as the number of clients reached and DALYs averted per client) can be estimated separately and also in incremental fashion relative to a non-HCD standard of care. This challenge was also noted in another HCD intervention carried out in Nigeria, Ethiopia and Tanzania, where researchers and designers faced challenges in measuring the total design cost and isolating the cost of HCD. In such cases, this framework may still be useful to decision-makers in highlighting the costs for which assumptions must be made in order to estimate the incremental cost-effectiveness of HCD. Our primary analysis is also anchored on a single emblematic intervention and thus cannot account for the full spectrum of on-the-ground realities of HCD implementation. We intend to validate this framework using data from an ongoing trial of the intervention in our motivating example; future refinement could also explore alternative HCD methodologies as well as applications of HCD to other interventions, comparing those interventions to the framework presented here. Finally, this framework simplifies a wide array of ongoing costs. Quality control, refresher training, monitoring and evaluation are considered as ‘per-client’ implementation costs when, in reality, many of these costs scale non-linearly with the number of clients served. As such, this simplified framework should only be used for initial planning and should not be interpreted as a full cost-effectiveness analysis of any specific HCD-informed intervention.

In summary, even though global health is a common focus area in HCD research, a framework for estimating the cost-effectiveness of HCD-informed interventions in global health has been lacking. This research provides a transparent, quantitative framework, whereby global health decision-makers can obtain ‘first-pass’ estimates as to whether an HCD process is likely to be cost-effective, based on a small number of inputs. This framework illustrates the importance of considering the up-front cost of HCD in any economic evaluation of an HCD-informed intervention, and also of future work to make HCD available at lower cost (yet high fidelity) in the global health context.

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