Function-feature analysis of emergency sanitation technologies: towards systematic innovation

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There has been increased recognition of the need for innovation in emergency sanitation products and technologies. To support effective design, this paper explores an approach systematically innovate by framing the problem from the perspective of the functions (the desired outcomes of a design) that features (characteristics of a design) achieve. The paper illustrates examples of how such functions can be identified: by analysing existing designs, studying the literature and drawing lessons learned from case studies. Functions may be interrelated and vary in nature and importance in different circumstances. Functions can be achieved by implementing one or more design features. At the same time, features can contribute to achieving one or more functions. By understanding and consolidating all possible functions and features, this approach can support innovation in several ways, most fundamentally by ensuring that important design considerations are not overlooked during the product development process.

Introduction

The need for innovation in emergency sanitation has been increasingly recognised. An emergency sanitation forum held in Stoutenburg, Netherlands, produced a list of 13 needs for sanitation products and technologies (Bastable and Lamb, 2012). More recently, an analysis of emergency water, sanitation and hygiene promotion by Bastable and Russell (2013) identified a number of sanitation gaps as among the most significant. They included: latrines in locations where no pits are possible (urban, high water table / flooding), latrine emptying and desludging, urban alternatives for excreta disposal, final sewage disposal options after desludging and treatment and further development of non-toilet options / early response / mobile solutions.

Some initiatives to address these gaps include the Emergency Sanitation Project by IFRC, WASTE and Oxfam GB and the WASH fund by the Humanitarian Innovation Fund. Examples of activities implemented by these initiatives include a design workshop (McBride, 2013), design contests for public urinals and wastewater disposal, open innovation challenges for latrine lighting and grants for developing new solutions.

While there are many methods for finding solutions to problems, one of the most important steps in design is understanding the problem. However, existing literature do not provide a systematic understanding of the design problems surrounding emergency sanitation. Focusing on excreta disposal, this paper explores one way of approaching the design problem systematically: by framing the problem in terms of the functions that a product or technology’s design features achieve and how these features contribute to safe sanitation.

Motivation behind the approach

The conceptualisation of this approach was instigated by a series of case studies on emergency excreta disposal following natural disasters. This included the Indian Ocean earthquake and tsunami in 2004, Java earthquake in 2006, Cyclone Nargis in Myanmar in 2008, earthquake in Haiti in 2010 and floods in Pakistan in 2010. While the paper does not present the findings of the case studies in detail, it draws examples from these case studies as well as the literature.

Within these case studies, which drew on available reports from numerous sources, failures and limitations of previously implemented solutions were identified. Some of these examples indicated that the implemented designs did not adequately consider the design requirements. In one example, women did not use camp latrines because the plastic sheeting made individual latrines too hot and the noise from the plastic flapping in the wind scared the women. As a result, the plastic sheeting was replaced by dried bushes (Oxfam International, 2011).

This example illustrates two lessons. First, many, even seemingly insignificant, factors may play important roles in achieving safe excreta disposal. This example showed that, in this situation, maintaining an acceptable temperature and preventing noise were important design objectives. Such lessons must be incorporated into future design processes to ensure successful innovation. Second, one design feature can have many roles. In this case, dried bushes not only helped provide an acceptable level of privacy but also reduced heat and noise. A better understanding of how different design features contribute to the outcome of the design will result in more comprehensive designs and, correspondingly, more effective innovation.

Methodology

Functions and features

The authors sought a way to recognise the importance of design details and emphasise the purpose of design features. By familiarising with existing literature and data from reported cases, the authors proposed an approach to design that explicitly links the “features” of a design and the “functions” they achieve. “Functions” refer to the desired outcomes that a design can contribute to (e.g. increase privacy) while “features” refer to the characteristics of the design. Features are typically physical (e.g. superstructure) but may also be a procedure (e.g. covering excreta with soil).

Identifying functions

This paper illustrates two ways of identifying functions and features: one, studying existing products and technologies from literature, practice or industry; two, studying the outcomes of implemented solutions. Identifying functions and features involve analysing the text, categorising relevant sections of data into functions or features and interpreting the data to find links between the two. Where functions and features are not explicitly identified, these were inferred by the authors.

Other methodologies for identifying functions may include gathering data from affected populations and experts but are not demonstrated here.

Example one: analysing the design of bag systems trailed in Port-au-Prince

Patel et al. (2011) describe a trial on bag and Peepoo systems in two internally displaced person camps in Haiti following the earthquakes in 2010. Table 1 lists the design features of bag system implemented and their corresponding functions.

Table 1. Analysis of bag systems trialled by Oxfam GB in Haiti, based on Patel et al. (2011)

Design feature	Function(s)
Bags or Peepoo	Collect human excreta
Bucket or container (T-malice bucket)	Enable in-home usage; hold bag or Peepoo
Cabin with prefabricated commodes	Encourage public usage in designated area
Urinals	Reduce use of bags or Peepoo
Superstructure	Increase privacy
55-gallon drums	Encourage proper disposal of used bags; collect bags of human excreta
Cover (on drums)	Control vectors and odour
Wheelbarrow, flatbed truck or truck	Transport collected bags to intended location
Pit (in Trutier) or composting site	Dispose of collected bags

Note that the analysis may not be complete as the features were not fully described. For example, according to the Peepoo website, Peepoo bags include 6 grams of urea to break down pathogens and bacteria.

Example two: analysing existing literature

A list of functions (Table 2) was compiled by applying a similar methodology in the previous example to first phase excreta disposal technical options as described by Harvey (2007), which included open defecation areas, shallow trench latrines, deep trench latrines, shallow family latrines, bucket latrines, packet latrines and chemical toilets.

Table 2. Functions of emergency excreta disposal options and associated design features

Function achieved	Design feature(s): examples
Encourage defecation in designated area	Demarcation of site with tape, plastic sheeting or fabric; demarcation within site with marking tape and paint, strips with screening or cubicles; access paths to defecation location; supervision by personnel
Collect human excreta	Dug pit (pit of 0.3m by 0.3m by 0.5m, shallow trench of 200-300mm by 150mm, deep trench of 0.8-0.9m by maximum 6m); non-dug containment: tanks, buckets or containers, plastic packets
Store human excreta	Dug pit (pit, shallow trench, deep trench as above)
Facilitate digestion of human excreta	Additives: enzymes and/or chemicals
Prevent infiltration to surrounding environment	Water-tight collection or storage tank
Ensure stability of dug pits	Lining of the top 0.5m
Provide privacy	Screening of site; screening within the site, cubicles; lockable doors
Provide safety	Lockable doors
Provide interface for user to defecate	Slabs or similar: wooden planks, latrine slabs, sit-down toilet or squatting pan
Prevent odour	Cover excreta with soil (with shovels); cover with tight-fitting lid; additives (chemicals); ventilation (screened pipe)
Facilitate cleaning	Floors with non-absorbent material and easily cleanable finish

Example three: lessons learnt from case studies

Identifying issues faced in practice help to identify functions that were important to achieving safe excreta disposal but were not fulfilled by the solutions implemented. For example, a UNIFEM (2010) consultation in Jaffarabad after the floods in Pakistan in 2010 highlight the constant presence of flies and no water or soap for women and girls. They were often embarrassed to be seen accessing lavatories and only went at night or early morning. In Haiti, a survey conducted six months after the earthquake found that 57% of families felt that toilet facilities were unclean, unsafe, or overcrowded and 48% felt that it was unsafe for women and children to use toilets. In addition, latrines were not regularly cleaned. One family stated that their camp latrine was only emptied every two to three weeks despite reaching capacity within one week (Lamp for Haiti Foundation et al., 2010).

Table 3. Example of analysis of sanitation issues from case studies

Issue	Unfulfilled function(s)
Not emptied frequently enough	Store human excreta or remove faecal sludge (applicable to desludging technologies)
Embarrassed to be seen accessing latrines	Provide privacy
Unsafe, especially for women and children	Provide safety
Constant presence of flies	Control vectors
No water for hygiene needs; no soap	Provide hand-washing facilities
Unclean	Facilitate cleaning

Results and discussion

The three examples indicate that no single approach is likely to cover the full range of functions that excreta disposal technologies could fulfil. Each approach has their relative advantages. In general, studying the range of technical options from the literature provides a broad, though not necessarily comprehensive, range of intended functions, making it a useful starting point. Investigating the designs used in specific, real-world cases emphasises functions determined by context. Drawing lessons from the outcomes of excreta disposal interventions highlights functions that tend to be disregarded in existing practice.

Properties of functions and design features

Although many functions have been identified, some functions play a similar role. There are functions that help to prevent environmental contamination (for example, collecting and storing human excreta and preventing infiltration to the surrounding environment), are related to user needs (providing privacy and safety and preventing odour) or ensure the continued functionality of the technology (facilitate cleaning).

Certain functions are only applicable or become especially important in specific circumstances. In Pakistan, for example, the practice of purdah by some women makes the provision of privacy among the most prioritised functions for these communities.

A function may be achieved by one or a combination of design features, as Table 2 shows. However, limitations of the context may prevent certain design features from being feasible in certain situations. For example, UNICEF (2009) reported that the high water table was one of the challenges faced in Indonesia following the Indian Ocean tsunami in 2004. This prevented dug pits from being a suitable design feature. Similarly, the people in Aceh, Indonesia, affected by the tsunami preferred pour-flush type latrines (IFRC, 2005), implying that the user interface would be limited to slabs with a water seal.

Design features may also fulfil more than one function, such as lockable doors which can increase privacy as well as safety.

It is important to understand how individual functions and features are related to each other. At this stage, the distinction between functions and limitations is not well-defined and it is not clear how limitations can be appropriately incorporated into this approach. While this paper focuses on latrines and other technical options to collect human excreta, it is important to consider how these options impact or are impacted by the other parts of the sanitation chain, i.e. desludging, treatment and disposal. For instance the 200-litre tank portable toilets used in Haiti required regular desludging and a dumping site (Eyrard, 2011). On the other hand, deep trenches may place fewer demands on desludging and disposal.

Implications for the innovation process

The "functions" approach go beyond viewing an emergency sanitation product as a combination of components to critically analysing the purpose each design feature achieves. It is envisioned that the functions can be compiled into a database for potential designers to refer to. During the design process, the product developer may not be aware of all the customer and end user needs because it is not fully articulated by the customer. Having a comprehensive database of functions reduces the chances that important design features are overlooked during the innovation process, increasing the likelihood that a potential new product or technology succeeds. The database can be used by customers to identify their design requirements or by the product developer as a checklist.

Furthermore, consolidating such design knowledge into a platform that can be accessed by a large number of people opens up opportunities to individuals and organisations that otherwise might not have the access or resources to gather such information on their own. This allows more people to become involved in innovating for the emergency sanitation sector.

Functions can also support the innovation process by being used as design criteria. A list of design features that contribute to a function will support the product developer in thinking through design possibilities. For example, excreta can be collected using pits, shallow trenches, deep trenches, tanks, buckets, containers or plastic packets. By breaking down conventional designs into its components, it could also stimulate creative solutions by facilitating the combination of design features that are not typically associated with each other. This is similar to the concept of a morphological matrix which is used to generate ideas based on random variations of a problem's characteristics.

Functions can also be used as evaluation criteria. A simple method could involve identifying the design features that contribute to each function and subsequently evaluating whether that function was satisfactorily fulfilled. This approach could be useful during the initial stages of the design process to screen possible concepts. A more sophisticated method would involve being able to evaluate the extent to which a certain design feature contributes to the overall outcome of a function.

Further work

Plans for further work start with developing a comprehensive database of functions and features by analysing existing literature and data that has been gathered through the case studies. The collected functions and features will need to be defined and described in a consistent manner. This is anticipated to be a challenging process because of the complex relationships between different functions and with different emergency contexts. For example, one important and complicated consideration that has not been addressed by the paper is the issue of cost. Cost has many components and hence could be divided into "sub-functions" that reflect capital cost and running costs. "Low-cost" may be considered a function that is affected by features such as the material used, installation procedures, and operational procedures and so on. The material used is dependent on many other features and therefore its properties should be properly understood.

This database can then be used to develop product development tools and techniques to support the design and evaluation of emergency excreta disposal innovations.

Having a list of functions and possible design features is just one part of design and does not in itself effectively support innovation. In a typical design process, design requirements are prioritised by customers to guide the product developer in coming up with an appropriate design. However, this is a subjective procedure that may not always reflect actual design priorities. For instance, the unfulfilled functions listed in Table 3 suggest that these functions should be accorded higher priority in the design process. Therefore, recommendations for future development include prioritising functions and linking functions to specific emergency contexts.

Conclusion

Considering the functions of design features is an alternative, systematic approach to innovating products and technologies for the emergency sanitation sector. In order to develop a comprehensive understanding of the objectives of excreta disposal designs, functions should be identified from a range of sources, including existing solutions, literature and lessons learned. This approach has the potential to support more effective designs as the functions approach think critically of the purpose of a design feature. This can form a basis for creating useful tools to support the product development process.

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