The potential for computational IT tools in disaster relief and shelter design

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Abstract
The expanding use of IT has brought an increase in productivity to the world of business, industry and commerce. However, this is not mirrored by an equivalent growth in the use of IT by aid agencies in post-disaster situations. We report a pioneering two-stage study which tested the appetite for the increased use of computational IT tools in this sector, assessed their level of usefulness and whether they can be practically implemented. Thirty aid workers across nineteen countries were surveyed on their use of IT and computational tools in shelter design and provision. The key finding was that none of the participants used any building simulation tools or software packages in any of the design stages of shelter construction. Using this result, two example tools were created—one assessing daylighting and the other environmental impact. A second survey involving 48 aid workers was then carried out to record their experience of using the new tools and 97% of the participants identified a need for such shelter design tools. The majority felt that the new tools were useful and that they would like to use similar tools in their work, most of them preferring tools in the form of web applications. It is concluded that humanitarian workers in the shelter sector are very willing to adopt IT-based computational tools in their work and would appreciate doing so, but only if they have access to suitably simple tools which are quick to use and easy to learn.

Keywords: Information technology, Computational tools, Post-disaster relief, Shelter, Humanitarian aid workers, Design simulation

Background
The number of people fleeing war, persecution and conflict exceeded 70 million in 2018, which is the highest level of displacement for 70 years (UNHCR, 2018; UNOCHA, 2018). It is estimated that future climate change could cause an additional 140 million people to be displaced by 2050 in just three regions of the developing world: Sub-Saharan Africa, South Asia and Latin America (Rigaud et al., 2018). Given the widespread adoption of IT (information technology) and computer modelling by commerce and industry over recent decades, it seems reasonable to investigate whether the level of adoption has been similar in the humanitarian aid response sector and whether further adoption by the aid sector might be useful and practical. Laguerre (2013) examined at least four aspects of the aid sector to which IT has contributed and where its impact is most visible: cash management (mobile banking), remittance flows, tax disbursed to government funds, and employment growth in both formal and informal sectors. Indeed, aid organisations represent an important source of funding for projects involving IT in low- and middle-income countries. However, limited numbers of such organisations acknowledge IT as a new and important asset in the development sector (Schware and Choudhury, 1988; Belliveau, 2016; Benrós et al., 2011; Carrasco and O’Brien, 2018; Cheng, 2018). The potential contribution of IT was also identified by Grimes and Lyons (1994), including centralisation and decentralisation as possible outcomes of adopting IT. Major restricting factors include political agendas and the availability of funds and the necessary skills (Downs, 1987; Bhattacharya, 2001; Andersen et al., 2002; Benrós., et al. 2011; Biswajit, M. and B. Bhattacherjee, 2015 ). Although low- and middle-
income countries have enthusiastically embraced IT, they are equally aware of the negative impact that
dependence on imported technology and services might have (Bortnick, 2010). Figure 1 shows that there are
some cases in which technologies that would be seen as advanced outside the aid sector have also been adopted
by the humanitarian aid agencies, even in challenging conditions such as insecure and inaccessible remote
locations. Jacobsen (2017) traced the development of the United Nations High Commissioner for Refugees
(UNHCR) biometric adaptation of pilot projects and the way that the emergence of digitalized biometric refugee
data had affected the relationship between the UNHCR, donor states, host states and refugees.

One of the areas in which technological advances might play a significant role in humanitarian agencies is
in the provision of shelter. Aid agencies are provided with hundreds of different designs and prototypes for
shelter-based innovations and most of these products are based on the idea that a single product can function
effectively in all settings (Ramalingam et al., 2009; Dabaieh and Alwall, 2018; Daubman et al., 2019). Such
product-based innovations can actually be detrimental in the aid sector because they can lead to inappropriate
and impractical interventions. Therefore, a different attitude to innovation might be needed to address failures
in shelter provision. There is a need for shelter design tools, as opposed to shelter prototypes which tend to be
designed by inexperienced architects or engineers who are not involved in managing disaster responses. A
simple-to-use design tool would enable aid workers themselves to assess, compare and decide on a particular
shelter design type for a specific location. Some modeling and simulation tools concerning disaster response
have been developed for emergencies (Yeung and Harkins, 2011; Davis et al., 2011; Benrós et al., 2011; Wuthikornthanawat et al., 2007), but the majority of those
tools focus on urban types of emergency, such as fires in office or school buildings, or earthquake incidents, and
are often only suitable for small-scale emergency responses. In the event of a disaster which results in mass
displacements, rapid housing and camp management solutions are needed. At present, however, existing meth-
odologies for camp management and shelter design face many challenges. These include a lack of inclusive and
longer term government policies, gap between aid agencies and host governments, treating shelter projects as of
a temporary nature project (while camps last for decades), rigidity towards permanent look of shelters, lack
of funds, gap between aid sector and private sectors (academia and specialist consultancies), etc. (Samuelhall.
org, 2012; Manfield, 2000; Sabie et al., 2017). The inclusion of stakeholders in the early stage of design, particu-
larly the affected family, is equally important, and a shift of focus from product to process is needed (Global
Shelter Cluster, 2018). Computational tools can play a vital role in this transition.

It has been suggested that the solutions developed and prescribed by the aid agencies need a profound revision.
There is a need for these solutions to be supported by computer-aided architectural and engineering tech-
iques, tools and design strategies (Benrós et al., 2011; Davis et al., 2011; Yeung and Harkins, 2011; Jinuntuya
and Theppipit, 2007; Ajam, 1998; Dabaieh and Alwall, 2018). For example, shelters can be too cold in winter
and too hot in summer (Albadra et al., 2017; Fosas et al., 2018). This indicates the need to improve the designs,
and IT has a role to play in this, for example, by allowing
for thermal modelling prior to the rollout of a design. One key element in developing any technologically supported design solutions and/or tools will be the accurate assessment of the time, information, resources and skills available in the humanitarian sector.

In this paper, we study the use of IT in a post-disaster context, with a focus on shelter design. We also investigate whether there is an appetite for the increased use of IT and how useful IT might be in this sector. The following questions then arise:

1. Do agency staff members use computer tools for design?
2. If yes, on what topics?
3. What other technical approaches do they use?
4. Might they find design tools useful?
5. What level of complexity might they be willing to accept?
6. How much time might they be willing to invest in using a design tool?

These questions were addressed by means of two separate but sequential surveys. The first survey addressed questions 1 to 3 and the second, questions 4 to 6. The first was a detailed survey of aid workers in several countries (with the majority of the participants being in the developing world) on their use of IT in shelter provision. Their responses were then used to develop two shelter design tools which were then used as the subject of the second survey of aid workers who had used them.

The adoption of IT by the construction industry and the commercial sector
It is clear that many aspects of the modern world are connected with the growth of IT (Downs, 1987; Belliveau, 2016). Computation as a design support tool combined with appropriate software has significant potential to make the construction industry more effective and efficient (Bhattacherjee, 2015). Information technology has been adopted widely in the construction industry and it is difficult to imagine planning, organising, communicating and managing stakeholders on a global scale without using IT within multi-national corporations (Love et al., 2005). IT is helping the construction industry not only to automate its design processes but also during the construction processes itself—robotic construction machinery and 3D printing are key examples. Additionally, the emergence of e-commerce has significantly helped the tendering and bidding processes (Kong et al., 2001). The potential use of IT in completed developments (residential, commercial or communal infrastructures) is also important (Andersen et al., 2002; Elliman and Orange, 2000). There is an intensive demand for IT in the development of smart buildings because of the need for automated and adaptive energy systems, remote monitoring and control systems and several other assistive technologies (Ozumba and Shakantu, 2018). IT has transformed the construction industry from a traditional to an industrial process. Even so, some areas are ripe for further enhancement, such as product definition processes and the use of systems products and recycling, in which IT can play a significant role in improving productivity and quality (Molnár et al., 2019). Construction companies in many developed countries create their own industrialised building concepts that have an underlying reliance on IT (Lessing et al., 2005). Both 2D and 3D CAD (computer-aided design) software is used in almost all construction companies (Molnár et al., 2019) and very few of them are unable to handle 3D CAD and BIM (Building Information Modelling) software packages.

Uses of IT in the post-disaster context
In post-disaster reconstruction, one critical aspect is the communication of information as well as of the required actions to mitigate the risk of any further casualties. This establishes an integral role for IT in the sector (Biswajit and Bhattacherya, 2015; Farley and Hecht, 1999). Social media, radio, television, mobile phone networks and ICT (information and communication technology) infrastructure can all play crucial roles in all three stages of effective disaster management, the awareness and preparedness, response and risk mitigation, and recovery stages (Kleinau, 2015; Alexander, 2014a; Alexander, 2014b; Barr, 2011). However, a singular technology in a complex process such as disaster management and response would never be sufficient (Ismail et al., 2014; Daubman et al., 2019).

Various types of IT have to be adopted to identify, detect and assess disasters, as well as aid in the accurate identification of the extent of vulnerability of the survivors. Disasters occur suddenly and can have a huge impact, often resulting in the mass displacement of people. Managing the delivery of aid assistance at such a scale poses a great challenge to aid agencies and local governments. To ensure a swift response and sustainable recovery, human error needs to be minimised and rapid collaboration and rapid response is required. Hence, the need and potential for IT in simulation and design optimization arise (Chang et al., 2010).

Currently, the majority of reconstruction and rehabilitation procedures are undertaken manually and limited technology-backed strategies for project implementation are adopted. Automation of the procedures, prediction and simulation of the entire design process for post-disaster activities is needed to help to select rapid, optimal and real-time solutions (El-Anwar et al., 2009).
Additionally, the communication of critical information between the survivors and rehabilitation stakeholders/planners is a requirement which needs careful attention to avoid duplication, shortage in the delivery of vital assistance, and corruption, and to enhance quality control and make monitoring more effective (Wang and E. Taylor, 2014). Some of the more traditional information system measures include radios, telephone systems, mobile phones and SMS (short message service), but given the current advanced levels of IT, these measures seem outdated and inadequate. However, at least 100,000 lives were saved by a single phone call in the coastal areas of South East Asia during the 2004 Tsunami (Biswajit and Bhattacherjee, 2015), which highlights the potential significance of even the simplest technology in the aid sector.

Geographical information systems (GIS), which can be defined as a system of both software and hardware, are regularly employed for the storage and retrieval, analysis and mapping of the geographic data of a disaster site. The information provided by GIS is further employed for scientific investigations, as well as for planning and resource management (Erskine and Gregg, 2012). Another application of IT is the extension of GIS to remote sensing technologies and tools for the acquisition and measurement of information about a disaster using a recording device, which gathers the necessary information about a location without physically being there. This is very useful because different agencies tend to work in different areas during a disaster and this technology can keep the agencies virtually connected with the progress of humanitarian aid measures at all sites. It also provides a visual image of critical information during an emergency (De Longueville et al., 2010) and a means of mapping who is doing what and where. The use of spatial data from the web is one of the older, yet effective, uses of IT in many industries, and this includes the aid sector. For several years, spatial data activities were limited to a particular organisation (Goodchild and Glennon, 2010), but the Web 2.0 and mobile application era has made spatial information more accessible. This has played a significant role in reaching wider geographical areas for aid delivery (Langston and Langston, 2008).

The use of IT may be sporadic in post-disaster rehabilitation but it is slowly gaining momentum. One example is the use of social media in disaster risk reduction and crisis management. In the field of post-disaster humanitarian aid, social media (such as blogs) and messaging sites (such as Facebook, Twitter, WhatsApp and Instagram) can be used in several different ways. These include listening to actions and reactions during post-disaster rehabilitation, monitoring the situations from different perspectives, extending and outsourcing the response, as well as collaborative development and furthering the humanitarian causes (Hosein and Nyst, 2013; Alexander, 2014b). Social media are beginning to change the way in which humanitarian interventions are carried out. For example, within the social media context, calls for action and aid come across as requests and heart-warming appeals, rather than direct orders. This approach results in a bigger response and deeper involvement. Furthermore, most organisations now share information over social media, which makes them work as a team rather than as competitors during a crisis (Yates and Paquette, 2011).

Opportunities and obstacles to adopting IT in the aid sector

The majority of the advanced technologies which are being used in humanitarian aid have fused the physical, digital and biological worlds and the use of technology can question the concepts of war and peace, ethics and human rights (Kleinau, 2015).

A critical review of the literature on humanitarian aid suggests that technology gives humanitarian agencies unparalleled access to war-hit communities (Felter, 2018; Ben Ramalingam, 2016; Jason Susim, 2019; Chaudhri et al., 2019; Arnold et al., 2018; Wilson and Jumbert, 2018; Harvard Humanitarian Initiative, 2011; Gilman, 2014; Lüge, 2014; Comes, 2016; Sandvik et al., 2014). A similar finding was made by the Scientific Foresight Unit and the European Parliamentary Research Service (EPRS) (European Parliamentary Research Service, 2017, 2019). This has ensured the timely and efficient delivery of aid to war-torn areas (Benróis et al., 2011; Daher et al., 2015; Downs, 1987).

Despite the obvious advantages, there are some drawbacks to using technology for humanitarian aid (Bortnick, 2010; Daher et al., 2015; Sandvik et al., 2014) and there are a number of criticisms of their use (O’Driscoll, 2017). For example, using surveillance tools like UAVs (unmanned aerial vehicles) can give rise to ethical and political challenges if the information collected by humanitarian agencies finds its way to one or other faction in a conflict, and might then be used to threaten communities, governments or individuals. This possibility has led to discussions about how the process of gathering humanitarian data could be improved and strengthened (Oldham and Astbury, 2018; Anema et al., 2014). Suggested solutions include a code of conduct for the collection and use of information, training aid workers to use data ethically, and involving the affected communities in how they would like their data to be used and stored (Chang et al., 2011). However, UAVs can help aid workers get a quick overview from above, thanks to their high-resolution, cost-effective insights. Humanitarian drones are today being employed across a
range of sectors, by organisations as diverse as The World Bank and Geneva International Centre for Humanitarian Demining. (Soesilo et al., 2019 & 2016), and the use of UAV drones in humanitarian action is a rapidly emerging field (Dowson, 2018; Tasevski, 2018). Kalkman (2018) carried out exploratory research into humanitarian aid agencies’ use of technologies during post-crisis rehabilitation and found that the use of IT had significantly increased in these areas. It was concluded that technology must not be treated as a neutral fix since it can leave political aftermath if used incorrectly (Raghad and Dave, 2016). It has also been shown that using excessive technology during humanitarian aid activities could result in the domestic and international aid personnel growing distant from the communities they are helping (Carrasco and O’Brien, 2018). The conclusion drawn was that if internet tools are to be used in the development of emergency response systems, then factors such as the accessibility, accuracy, validity, feasibility and scalability of the proposed methods should be carefully assessed, especially when applying them in resource-poor settings (Bartell et al., 2006).

Similarly, despite the positive impact of using social media for humanitarian aid, there is further potential for negative aspects, such as the dissemination of rumours promoting hate and terrorism, facilitating terrorists and undermining the authority of the aid organisations (Kabra et al., 2015). This has prompted an argument about the ethics of using social media during aid activities, but even though there are some clear risks, such as the possible violation of privacy and security, most people view the social media as a good way to uncover corruption and malpractice during aid activities (Alexander, 2014b; Cheng, 2018). Even so, ethical warnings must be heeded to make sure that social media practices are not misused (Hammon and Hippner, 2012).

Others have concerns such as improper or inadequate implementation, as well as potentially high costs of maintenance for complex IT systems. Moreover, it is possible that the proposed technology might not fit (Bond, 2011) with the technology preferred by aid workers, consequently causing more harm than good since the aid actors may be untrained or unprepared to handle such solutions. Moreover, this lack of expertise in the aid sector could lead to a compromise in data and deliverables. It has also been observed that aid workers can have issues with the rapid evolution and development of information technology (Belliveau, 2016). The opportunities are clearly far greater than the obstacles, and the main obstacle in most situations is the lack of information, skills and appropriate tools, which can be mitigated by developing easy-to-use non-specialist tools and providing proper training.

The use of IT-based simulation techniques for shelter design
Predicting future performance and providing feedback when designing real-world systems or products is the key purpose and primary advantage of simulation activities (Ouyang, 2014). Prior to actual construction or production, simulation allows stakeholders to determine the efficiency of a product or system (Antonelli et al., 2018) and enables designers to investigate problems in a wide range of scenarios (Zhu et al., 2017). This is equally true in building design (Kotireddy et al., 2018; Kneifel and O’Rear, 2017; Nguyen et al., 2014). In some cases, however, generating high-quality simulation models can be very expensive, might take too long or might require a lot of information.

The performance of various types of shelter was analysed by Cornaro et al. (2015) by simulating the thermal properties of different materials and they concluded not only that shelters can be made more comfortable in terms of indoor temperature, but that they can be also made more sustainable in terms of embodied energy, embodied carbon and energy use in general if customised optimization and simulation techniques are used. The building-oriented thermal performance simulation tool ‘Energy-Plus’ was used by Attia (2014) to analyse the thermal performance of an emergency shelter and various solutions were suggested for improving internal environmental conditions.

Obyn et al. (2014) suggested that using IT-based simulation packages during various stages of shelter design would help the resulting designs to perform better and ensure the thermal comfort and privacy of the occupants. They studied the difficulties in achieving a realistic thermal model of lightweight structures, taking into account the air permeability of fabrics, their light transmission and the overlapping of several elements. A model of the UNHCR standard family tent was created for that study, again using Energy-Plus, enabling an objective assessment of the performance of that shelter in a wide range of contexts. Similarly, the thermal performance of Bedouin tents was assessed and improved using computational simulation by Attia (2014) and that of emergency shelters in extremely cold artificial environments by Ashmore et al. (2003).

There are, however, some barriers to adopting computer-based architectural solutions (Chu et al., 2014). These include the lack of availability of resources and information, cost fluctuations, corruption, socio-economic complexities and the cultural standards of the affected communities in post-disaster construction contexts. Even though simulation software packages cannot
address the majority of these barriers themselves, such tools can nevertheless help designers and stakeholders to plan risk-mitigating measures and test those measures at the design stage. The cases briefly described above show that thermal performance is an issue which needs closer examination to determine whether computer simulation can contribute to its improvement.

### IT-based simulation for optimising and predicting thermal performance

Al-Ghamdi (1993) studied thermal comfort in the temporary shelters of pilgrims in Mecca and suggested that the cause of most thermal discomfort was poor ventilation and high relative humidity, which reduced occupants’ ability to cool down. Which highlights the need for thermal modelling and simulation before the shelters are manufactured.

Susanti (2015) found that PMV (predicted mean vote) and PPD (predicted percentage dissatisfied) overestimated the comfort level of the tents that were studied. A similar issue was highlighted by Albadra et al. (2017) in a multidisciplinary study undertaken in refugee camps in Jordan, in which it was found that the surface temperature of a white cotton tent can reach 55 °C and that even the use of a ventilated courtyard had no significant impact during the mid-day period (Al-Hemiddi and Al-Saud, 2001). Knight (1988) investigated the thermal loads associated with a bush fire and predicted that bushfire reflective tent shelters can maintain an internal temperature 40 °C lower than the outdoor temperature for several minutes, which can play a significant role in saving lives in the case of a fire. In real life, however, ‘several minutes’ is not long enough. An interesting finding was that the survival of a single occupant in a reflective tent is limited by rises in mean body temperature, whilst multiple occupants can survive slightly higher intensities, with the limiting factor being an excessive rise in air temperature (Taylor et al., 2015). The reflective quality of the fabric could, therefore, be useful for producing safe refugee shelters in hot climates.

Given that most displaced families in refugee shelters and informal settlements cook inside their shelters, they face serious risks of fire, and this makes research efforts to address the issue highly relevant. A study of Palestinian refugee shelters showed that the significant thermal discomforts experienced by occupants in summer and in winter were mirrored in the PMV calculations (Saleh, 2011); it has been found that PMV overestimates in warm conditions and underestimates in relatively cool conditions (Fosas et al., 2018; Saleh, 2011; Humphreys and A, 1976; De Dear and Brager, 1998). A series of architectural strategies have been applied to shelter design using computer simulation techniques, resulting in significant reductions in overheating (Fosas et al., 2018). The comfort band found using logistic regression ranged from 28.4 °C to 17.2 °C, suggesting significant adaptability of refugees, but still well outside the temperature range found on site. In such settings, natural cross-ventilation alone will not be sufficient for achieving summer comfort. A shelter solution that successfully includes insulation, and possibly thermal mass, seems more important (Albadra et al., 2017). The thermal conditions inside a temporary shelter were assessed by Crawford et al. (2005) using ESP-r simulation software. They investigated casual gains from both occupants and solar radiation and concluded that the use of such sophisticated techniques and the required materials would only be possible in limited numbers of locations. The validity of these results was, however, limited by the lack of measures to assess accurately the air infiltration values.

As this review of the literature has shown, the use of IT-based engineering/architectural simulation packages by researchers has been evidenced to some extent. However, there is no documented case of aid workers using IT simulation tools. Additionally, the literature review suggests that in at least one field, namely the thermal performance of shelters, simulation has an important role to play.

### Methodology

Because of the geographical spread of aid workers, two sequential online surveys were conducted with those involved in the provision of shelters for displaced people. The aim of the first survey was to evaluate the current shelter design practices by investigating the level of knowledge of the participants in relation to the science of building physics and the perception of aid workers towards having a tailored shelter design tool. The second survey was conducted to assess the usability of shelter design tools in the aid sector. Survey questionnaires were sent to four hundred aid workers (shelter officers) who were either directly or indirectly involved in the provision of shelters, using social media platforms, email addresses and humanitarian websites. Thirty participants responded to the first survey and forty-eight responses were received for the second survey. Google Forms were used as the data collection instrument. Online surveying was adopted because the participants were in various countries. The first survey contained 50 questions, the second eight.

### Investigating current design practices and knowledge (survey 1)

The initial survey was designed using a thematic approach (Tuckett, 2005; Guest et al., 2012; Guest et al., 2011; Braun and Clarke, 2014; Clarke and Braun, 2013) to capture different aspects of shelter design practices and also to understand the level of knowledge of aid workers in relation to different aspects of the science of
building physics and other design-related issues. The survey addressed the following topics:

- Lighting technologies in general (daylight and artificial lighting)
- Ventilation strategies
- Thermal comfort in shelters
- Shading technologies
- Energy use and environmental impacts
- The green agenda in shelter projects
- The knowledge and familiarity of aid workers in relation to technical terms of the science of building physics

### Table 1 Questions asked in the post-user evaluation survey (survey 2)

| Chart | Question                                                                 | Response options                                                                 |
|-------|---------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| A     | How easy was the tool to use?                                             | (Rate your answer 1 to 5; 1=very easy, 5=very difficult)                          |
| B     | Was the number of inputs about right?                                     | (1 to 5; 1=I would have been happy to input more data; 5 = the tool asked for too much data) |
| C     | How clear and understandable was the input section of the tool?           | (1 to 5; 1=very clear, S=not clear at all)                                        |
| D     | How clear and understandable was the output section of the tool?          | (1 to 5; 1=very clear, S=not clear at all)                                        |
| E     | Can you imagine using such a design tool on any topic to evaluate existing shelter designs? | (1=such simple tools might be very useful, 5=such simple tools are unlike to ever be useful) |
| F     | Can you imagine using such a tool on any topic to evaluate potential new shelter designs (remember, this is a general question about computer-based tools, not a question about a tool for daylight calculations or environmental impact assessment)? | (1=such simple tools might be very useful, 5=such simple tools are unlike to ever be useful) |
| G     | Might you ever recommend such a shelter design tool (on any topic) to your colleagues who work in the field? | (1=yes, frequently; 5=never on any topic)                                         |
| H     | In what form would you preferred the shelter design tool to be?            | a. Excel-based
|       |                                                                           | b. Web application
|       |                                                                           | c. Standalone interface (internet not needed)                                     |

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![A) Location and B) experience of the survey participants](image)

**Fig. 2 a** Location and **b** experience of the survey participants
The cultural aspects of shelter design and
- The perception of aid workers towards the need for a shelter design tool.

The thirty respondents who returned completed questionnaires included staff from UNHCR, IOM (International Office for Migration), NRC (Norwegian Refugee Council), IRC (International Rescue Committee), OXFAM, Shelter Centre, CARE international and independent aid workers.

Appendix A presents the 50 survey questions and sub-questions.

Using the findings from this first survey, two design tools were created, one in the form of a web application to assess the environmental impact of a shelter design and the other in the form of a spreadsheet. With the first tool, participants in the second survey were able to assess the environmental impact of their existing (or any type of proposed new) shelter designs, and with the second tool, they were able to propose a new window layout design for a shelter.

**Post-use evaluation (survey 2)**

The two tools described above were sent to aid workers for them to use, test and review in the second survey (see Appendix B). A snapshot of the tools and a list of the required inputs for both tools are given in Appendix C. Links to the second survey were embedded in both tools so that the aid workers could record their feedback easily.

The eight questions in the second survey addressed topics such as usability, ease of understanding, the number of inputs and outputs and the perception of aid workers towards such non-specialist shelter design tools. The survey took a quantitative approach by providing the participants with a Likert-style numeric scale. The

![Fig. 3 Daylighting technologies in shelter (current practice and knowledge)](image-url)
questions are set out in Appendix B and are summarised in Table 1.

Again, the recruitment of respondents was by the Google Forms online surveying tool. Forty-eight participants completed the survey, including staff from UNHCR, IOM, NRC, IRC, OXFAM, Shelter Centre, CARE international and independent aid workers.

**Results**

**Evaluating current design practices and knowledge (survey 1)**

It is clear from Fig. 2a that wide geographical coverage was achieved across the 30 respondents and a broad level of experience was accessed (see Fig. 2b).

From the results of this survey, it was clear that the vast majority of the participants (27; 90%) encouraged the use of openings to let light inside the shelters (see Fig. 3a). However, eighteen (60%) of them had performed no science-based calculations on this; they used the 'just encourage' policy (see Fig. 3b) and twelve (40%) of them reported performing some sort of calculation whilst only five of the twelve had used a computer, but the use of no particular daylight simulation software was mentioned (see Fig. 3c). The remaining seven (23%) participants had used a manual calculation method. This was probably due to limited knowledge and lack of information and knowledge amongst the aid workers regarding the subject (see Fig. 3d, e and f) or the unavailability of appropriate and practical resources/tools in the aid sector. Figure 3d shows that thirteen participants (43%) were not familiar with the technical terminology (such as the unit for the amount of light striking a surface being a lux). They were asked how good or bad a 100-lux level would be for lighting in a bedroom. Five of the seventeen participants who claimed familiarity with the term lux thought that 100 lux is poor whereas eight believed that 100 lux is good (which is not true in most cases). More interestingly, seventeen participants did not know whether 100 lux would be too much light or insufficient. This indicates that the majority of the participants in the survey had limited knowledge of

![Graph A](image1.png)

**Fig. 4** The effects on cultural and safety issues due to the size and location of openings
technical terms in relation to lighting technologies. Daylight factor (DF) measures the overall daylight within a space, and Fig 3f shows the responses related to DF, showing it to be a slightly more familiar concept than lux. Some of the participants did use computation to perform DF calculations, but none of them mentioned any specific simulation software or computation tool.

Details of the responses on the effects of size and location of openings (such as windows) on safety and cultural aspects are presented in Fig. 4. It can be seen that only ten (33%) of the participants considered that the size and location of openings could compromise the safety of the occupants of shelters (see Fig. 4a). Similarly, Fig. 4b shows that half of them (fifteen participants) considered that the size and location of openings could compromise the cultural issues of the occupants of shelters (such as privacy). The majority of the respondents had never thought about the fact that the location and size of openings might compromise the privacy or safety of the occupants. Lack of consideration about issues such as this will lead to shelters not being used by displaced families or to families having to adapt poorly designed shelters according to their type of clothing. Some of the participants did consider aspects of safety when designing openings but did not consider that this design factor has the potential to compromise the cultural values of refugee shelters.

In terms of artificial lighting, the majority (90%) of the participants encouraged shelter occupants to use electric lighting equipment; this could include encouraging the use of solar panels or lights (see Fig. 5a). However, nineteen (63%) of the participants used the ‘just encourage’ policy (see Fig. 5b). Twenty-six (87%) of the participants did not perform any sort of calculation regarding artificial lighting technologies, and the remaining 13% of the participants (see Fig. 5b) used manual calculations (where applicable). Only two participants reported using computers to perform calculations related to artificial lighting in shelters, but they did not report the use of any particular simulation tool.

Figure 6 shows the responses on ventilation and it can be seen that participants are divided into three categories (see Fig. 6a). The majority (80%) did consider the amount of ventilation required in shelters, and the remaining six (20%) were divided into three who thought that it is not important to consider the amount of ventilation required in shelters and three who had not considered the issue at all. Eighteen of the thirty (60%) respondents adopted ‘just sensible/feasible’ approaches when asked about the method used to establish the amount of ventilation required in shelters. Only six (20%) did perform some sort of calculation to establish the ventilation strategy of shelters (see Fig. 6c) and of these, only one used a computer (see Fig. 6b). However, twenty-four (80%) of the respondents did not perform any calculation to establish any ventilation strategies. This is quite concerning because ventilation is an important aspect of refugee shelters, given that most refugee camps and settlements are in hot locations, so it is the key cooling mechanism; it is also relevant to air quality especially when cooking with wood. It was also observed that even though some of the respondents were familiar with technical terms related to ventilation strategies, they did not consider using such techniques in the design process of shelters (see Fig. 6d).

The majority of the survey participants did consider winter and summer temperatures inside shelters (see Fig. 7a) and the majority used a ‘just sensible/feasible
policy’ approach to decide indoor temperatures (see Fig. 7b). Six (20%) of the participants performed calculations to design indoor temperatures in shelters (see Fig. 7c) and more than half (60%) did not perform any calculations related to thermal comfort.

Only one used software to calculate and predict the thermal performance of shelters, but no particular simulation software was mentioned by any of them, which indicates that very few or almost none of the participants performed energy simulations in their
everyday practice. In relation to familiarity with the science of building physics (which plays a main role in predicting thermal comfort in any building), twelve (40%) of the participants did not know any technical terminology in the subject and eleven (37%) were familiar with the technical terms but did not apply such techniques in their everyday practices (see Fig. 7d).

Details of practices in relation to designing the size of cooling/heating systems and energy use in shelters are presented in Fig. 8. Very few (eight; 27%) of the respondents considered the need to design the size of the heating or cooling systems for shelters and the remaining twenty-two (73%) either did not consider the subject or regarded it as unnecessary (see Fig. 8a). Four of the eight who did consider sizing heating and cooling systems in shelters performed calculations (see Fig. 8b) but all of them used a manual calculation method and reported no use of any computational tools (see Fig. 8c). Half of the participants considered the energy need in shelters but one believed that calculating energy use in shelter projects is not important (see Fig. 8d). Thirteen of the fifteen participants who considered the amount of energy needed in shelters used the ‘sensible/feasible’ approach. Only three participants reported performing some sort of calculation (see Fig. 8e); two of them used a manual method and only one used a computer, but no particular energy simulation software or computation tools were mentioned (see Fig. 8f).

Figure 9 details the responses on shading technologies and strategies practised by the aid workers, showing that the majority used a ‘sensible/feasible’ approach to establish the size or design of shading in shelters. Twenty-three (77%) did consider incorporating shading in the design of shelters (see Fig. 9a) but twenty (67%) participants used the ‘just sensible/feasible policy’ approach (see Fig. 9b). Only three (10%) participants carried out calculations and the rest did not consider calculating how to provide effective shading to reduce the amount of heat from the sun entering a shelter, and of those three, only one used a computation tool to perform the necessary calculations (see Fig. 9c).

There have been various studies of the environmental impact of shelters (Escamilla and Habert, 2015a; Escamilla...
and Habert, 2015b; Song et al., 2016; Atmaca and Atmaca, 2016; Dong et al., 2018; Félix et al., 2013) and the UNHCR shelter guidelines state the need for shelters to be environmentally friendly (Ashbridge et al., 2012). Although some of the respondents said that they did consider reducing the environmental impact when designing a shelter, the majority used ‘just sensible/feasible’ policies and no IT-based tools were utilised (see Fig. 10).

Finally, the participants were asked about the potential usefulness of electronic shelter design tools. All but one of the participants (97%) felt that this was a good idea. However, the participants rated the usefulness of such a design tool differently (see Fig. 11).

In summary, building physics concepts such as daylighting were familiar to the participants but the technical terminologies used in these fields were not well known to them and the use of simulation tools was extremely rare. All but one of the participants confirmed the need for a shelter design tool, but their lack of knowledge about the terminology will clearly make this a challenge.

Post-use evaluation (survey 2)

As previously explained, the findings of the first survey were used to construct a shelter daylight calculation tool in the form of a Microsoft Excel spreadsheet and an environmental impact assessment tool for shelters in the form of a web application, and these tools were sent to aid workers for them to use, test and review. This enabled these participants to complete the second survey. The results of this survey are shown in Fig. 12.

Of the 48 respondents, the majority (71%) found the tools generally ‘easy’ to use, whilst eight (17%) of them found them ‘very difficult’ to use (rating 4 out of 5) (see Fig. 12a). Similar numbers of participants (73%) reported the actual number of inputs about to be ‘about right’ (see Fig. 12b). In terms of the inputs of the tools, 79% found them ‘very clear and understandable’ (see Fig. 12c), but a smaller number (61%) found the output sections of the tools only ‘clear and understandable’ (see Fig. 12d).

Importantly, the majority (around 80%) of the respondents wanted to use such design tools to evaluate existing or potential new shelter designs (see Fig. 12e f). This highlights...
the clear desire and openness to adopting IT-based shelter design tools in the aid sector. Similarly, 77% of the respondents felt positive about recommending such shelter design tools to colleagues who work in remote areas (see Fig. 12g). Finally, the participants were asked about the desired form of such a design tool and their responses are shown in Fig. 12h. The most popular format (22 participants) was a web application, but five were not interested in the form or shape of the tool. There was, however, consensus that the tool should be freely available in whatever format.

Summary of the results
It was found that the concept of daylighting was familiar to the majority of the participants, but no particular daylight calculation tool was used during the design stages of shelter projects. Very little consideration was given to the compromises caused by placing and sizing openings to let daylight in and provide ventilation. Most importantly, no use of any suitable software or design tool was evidenced and limited knowledge of technical terms was found amongst the respondents to the survey. The majority of the participants used a ‘feasible/sensible’ approach to choosing the size and location of openings and no accurate calculations were reported by the participants for establishing the amount of energy needed or consumed by shelters. Almost half of the participants were unfamiliar with technical terms related to the environmental impact of the buildings, which has probably contributed to shelter designs not being eco-friendly. No software was used by any of the survey participants to design shades and avoid overheating during the summer or to increase solar gain in winter. However, the majority of the participants confirmed the need for a shelter design tool that covers various aspects. As previously explained, the findings of the first survey were used to construct a shelter daylight calculation tool in the form of a Microsoft Excel spreadsheet and an environmental impact assessment tool for shelters in the form of a web application. These tools were sent to aid workers for them to use, test and review. This enabled these participants to complete the second survey. The results of this survey are shown in Fig. 12.

The majority found the tools generally ‘easy’ to use, whilst very few of them found the tools ‘very difficult’ to use and the number of inputs in the shared tools were found to be “about right” by a similar number of respondents. The inputs of the tools (shared with the participants) were found to be very clear and understandable for the majority of the survey participants.

The majority of respondents expressed the desire to use such design tools both in the evaluation of the existing or new shelter designs, which indicates the openness to adopting IT-based shelter design tools in the aid sector. It is interesting to see that after using two different forms of design tools (a spreadsheet and a web application), the majority of the participants prefer the design tool in the form of a web application. However, it is desired by the participants that the tool should be freely available has to be easy to use and freely available (minimum simulation skills required).

Conclusions
It is clear that many aspects of the modern world are connected with the growth of IT. It is also clear that the humanitarian sector has been using IT for various activities but not for shelter design. Lack of information, time, resources and the necessary skills are believed to be the key barriers (Kabra et al., 2015; Goodchild and Glennon, 2010; Bartell et al., 2006; Yeung and Harkins,
A similar issue was highlighted by Kim et al. (2015), who noted that “we need steps to not only implement but also train professionals in the proper use of these solutions”. Albadra et al. (2017) showed that many shelters do not provide suitable conditions for promoting health and wellbeing, and Fosas et al. (2018) showed that the use of engineering and computation tools can help to improve this situation.

The results of the first survey clearly show that aid workers had some understanding of building physics concepts but little knowledge of the related terminology...
or units. They did not generally use calculation in design but would like to be supported by tools which are appropriate for their ability and knowledge base.

Two targeted tools (one on environmental impact and one on daylighting) were created. A second set of aid staff from the same agencies used these tools and assessed them. The majority found these new tools to be easy to use and 80% of them wanted to use such design tools in their work, ideally in the form of a web application.

Fig. 12 Post-use evaluation survey

- **A** How easy was the tool to use? (rate your answer 1 to 5; 1=very easy, 5=very difficult)

- **B** Was the number of inputs about right? (1 to 5; 1=I would have been happy to input more data; 5=the tool asked for too much data)

- **C** How clear and understandable was the input section of the tool? (1 to 5; 1=very clear, 5=not clear at all)

- **D** How clear and understandable was the output section of the tool? (1 to 5; 1=very clear, 5=not clear at all)

- **E** Can you imagine using such a design tool on any topic to evaluate existing shelter designs? (1=such simple tools might be very useful, 5=such simple tools are unlikely to ever be useful)

- **F** Can you imagine using such a tool on any topic to evaluate potential new shelter designs? (1=such simple tools might be very useful, 5=such simple tools are unlikely to ever be useful)

- **G** Might you ever recommend such a shelter design tool (on any topic) to your colleagues who work in the field? (1=Yes, frequently; 5=never on any topic)

- **H** In what form would you preferred the shelter design tool to be?

- **I** Number of responses per option

- **J** Web application, Standalone interface, MS Excel based, Not sure, Freely accessible in whatever practical form, Such tools are not aid sector

- **K** 22

- **L** 12, 4, 4, 5, 1
It is important, however, to note that whilst IT can provide many benefits for shelter projects, from design and planning to construction and implementation, it is not a complete solution in itself. Unless there is a robust framework of funding, policy and political will, amongst others, even the most advanced IT tool will fail. Nevertheless, this study has clearly identified the need and desire for computational tools to support shelter design and has shown that it is possible to create tools which are seen as useful by those working in the field.

**Supplementary information**

Supplementary information accompanies this paper at https://doi.org/10.1186/s41018-020-00869-1.

**Additional file 1.** Appendices.

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**Authors’ contributions**

Each author has made a substantial contribution in preparing this journal article and they have approved the final version. The authors were involved in different aspects of the paper as follows: N. K and D.C developed the conception or design of the work; data collection tools were constructed by N.K and D.C; data analysis and interpretation was done by N.K; D.C and P.S.; the article was drafted and compiled by N.K; critical revision of the article was carried out by P., S., J.JH, A.C. The final approval of the version to be published D.C and N.K.

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Development of an interactive environmental assessment tool can be found at https://www.hhftd.net/calculator.

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**Availability of data and materials**

The data can be found at https://doi.org/10.15152/BATH-00550. The environmental assessment tool can be found at https://www.hhftd.net/calculator.

**Competing interests**

There are no conflicts of interest to declare and the stated authors who are all aware of its content and approve its submission have written the article.

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