HUMANITARIAN INNOVATION FUND

Final Report

Organisation Name	Griffith University

Project Title	A field trial of 3D Printing to assess its potential for improving the effectiveness and efficiency of the humanitarian response
Problem Addressed / Thematic Focus	In both development and disaster response contexts, the timely and cost-effective provision of material to support field operations remains an ever-present challenge. This pilot project was designed to investigate the feasibility and acceptability of 3D Printing as a partial solution to this challenge.
Location	Nairobi, Kenya and Gold Coast, Australia
Start Date	1 October 2014
Duration	6 months
Total Funding Requested	£20,000

Partner(s)	Griffith University; RedR Australia; HK Logistics; Oxfam GB
Total Funding	£30,200 (cash); £8,700 (in kind)

Innovation Stage	Invention
Type of Innovation	Testing the feasibility and acceptability of 3D printing in a humanitarian context
Project Impact Summary	The pilot project confirmed that 3D Printing has the potential to improve the efficiency and effectiveness of the humanitarian logistic (HL) response by reducing lead times, avoiding nugatory 'just in case' transport and warehousing, and using postponement techniques to manufacture locally to meet an identified need.

Reporting Period	1 Oct 2014 – 31 Mar 2015
Total Spent	£30,200

ACTIVITIES CARRIED OUT

1. The overall aim of this pilot project was to confirm that the benefits of the use of 3D Printing (3DP) that have been clearly documented in both the academic and practitioner literature relating to commercial ('for profit') supply chains are equally applicable in the development/disaster response context. To this end, a pilot project that focussed on the area of water, sanitation and hygiene (WASH) was undertaken with the support of Oxfam GB in Kenya. WASH was chosen not only because of its ubiquitous nature but also because it employs a relatively low level of technological sophistication and, hence, was appropriate for the 3DP trial.

2. Based on the above overview of the project, the following activities were conducted prior to the deployment of the field researcher:

- The development of a 'validation matrix' that was applied to the WASH Section of Oxfam's catalogue and a systematic assessment was then made of the items that could and could not be safely manufactured using field-based 3DP.
- In parallel, contextually relevant laboratory experiments were undertaken in order to predict and mitigate potential challenges in relation to printing - for example accuracy and consistency when field printing screw thread fittings.
- The intended design cycle was tested noting that 3DP does not simply replicate an existing component, rather each item must be re-designed as necessary to utilise the advantages and mitigate the limitations of a field based 3D printing process. This resulted in the:

    - Creation of a digital library of catalogue parts that were 'in scope', re-designed for 3DP and which included process information such as print orientation.
    - Testing of the resultant prints covering mechanical function, construction consistency and material properties such as strength and elasticity and time to print.
    - Re-design (as necessary) of failed prints and in order to optimise print times.

3. During the first period of field research, the following activities were carried out:

- Introduction of the technology to Oxfam's Kenya-based staff through demonstrations and presentations.
- Mapping and understanding of the operations of the Kenyan-based WASH projects.
- 3DP of test pieces for feedback from field staff and discussion of the priorities for the staff in terms of the items and the profile of bespoke needs on the ground.
- Mapping and understanding the reality of supply chain as it exists in relation to the specific items identified by the research team for printing in Kenya.
- Initial research into the extent of the technical background (and, hence, relevant skills and expertise) of key operational staff in Oxfam.
- Initial research into the potential of digital technical support outside Oxfam.

4. Following the first period of research in Kenya, parts were re-designed to take into account the specific conditions and potential issues based on information gained from the field-based staff. Parts were re-designed to be more robust in order to mitigate inconsistencies in the technical backgrounds of staff on the ground. There was a particular focus on extending the viable print base of the printers to include larger diameter

pipes (90 mm) and considerable work was carried out to address the problems in consistently producing pipes of these dimensions on the initial size of printer being used.

5. In the second period of field research the focus moved on to people and place, and to researching a viable operational model and printing practice (rather than on the specific print properties). As a result, the following activities were carried out:

- Testing of an exchange of information between two distant locations (Australia/Kenya) achieved by the mapping, sending and receiving information about components found on site, and the building of remote Computer Aided Design (CAD) models that were subsequently printed on site.
- The study of the issues related to the challenge of ensuring a consistency of print accuracy and how to support the human interaction element with the printers on remote locations, as well as strategies for ensuring consistency of print from different printers after they have been physically transported to their operational location.
- Initial trials of the proposed 'Hub and Spoke' organisational construct in which the core design work and engineering testing was undertaken by specialists in the hub (Griffith University – Australia) and the subsequent printing and testing carried out in the spoke (Oxfam HQ – Kenya).
- Scoping out potential caches of technical expertise in Africa who might be available to collaborate with an extended 'Hub and Spoke' model.

6. Following the second period of field investigation, the 'Hub and Spoke' pilot model was formalised based on the results of the research. A dedicated research studio has been set up at Griffith University which is physically laid out to mimic the planned Hub and Spoke model, with a central core and, initially, three spokes for follow up work in different areas as further funding is sourced. Each of the local (Griffith) Spokes will be linked to, and optimised for, a field location in areas of need for development /disaster relief. The aim is that the local Spokes will be linked to an in-theatre Spoke which has been set up to identify specific needs for that location. In this way, we plan to repeat the model of exploration established in Kenya and also have the potential to reach out further and include additional field Spokes as the project gains momentum.

ACHIEVEMENTS

7. The overall aim of the pilot research was successfully achieved and, in particular, it clearly demonstrated that the use of 3DP has significant potential in:

- Reducing logistic lead times from some 4-12 weeks (based on a survey of parts recently supplied to Oxfam Kenya) to 48 hours.
- Reducing warehousing costs as items can be made to order once the demand has crystallised (logistic postponement).
- Allowing improvements in the design of components to enable greater functionality.
- Mitigating the impact of political instability that has the potential to further exacerbate the logistic challenges.

8. The proposed Hub and Spoke methodology was tested and found to be eminently suitable for the taking the project forward into the Development Phase. This was a significant achievement as it has demonstrated the potential to enable the development of more complex, innovative parts to meet bespoke needs that emerge in the field and ensure the quality of the products printed on site. This model is currently being developed

further based on the results of this pilot study for much broader application in different areas of need in development and disaster relief situations.

9. The benefits and limitations of 3DP were demonstrated to a large community of humanitarian practitioners and this, in turn, allowed the community to feed back a number of extremely useful recommendations that have been incorporated into the plans for the Development Phase. Multiple demonstrations of the 3DP technology were carried out to a broad cross section of Oxfam and other NGO staff (ranging from the Chief of Mission to the office cleaners!). Specifically, demonstrations included:

- A formal presentation to 15 specialist staff attending the UN WASH Cluster forum.
- 3 @ Weekly 'stand-up' meetings, each attended by 70+ Oxfam staff.
- 30 @ 1 on 1 detailed briefings and demonstrations with Oxfam staff.

10. A number of specific limitations relating to the printer used on the pilot project were identified such as its current inability to consistently print WASH parts at the full extent of the print plate due to conditions in the field. These will be used to inform the adaptation of the printers to meet the specific conditions of locations selected for the Development Phase through the addition of protective covers, and they will also influence the choice of print bed size going forward. Indeed, the importance of having suitably robust equipment (such as can operate in the extremely dusty environment of South Sudan) was clearly demonstrated and emphasised, and this will impact equipment choice and adaptation.

METHODOLOGY

11. The generic approach adopted was that of 'action research' which is a process of progressive problem solving led by individuals working with others as part of a "community of practice" to improve the way they address issues and achieve results. Thus, in both the preparation and field phases, the researchers worked collaboratively with the practitioner community to develop appropriate solutions to unforeseen problems and obstacles whilst, simultaneously, both teams improved their knowledge and understanding of the benefits and challenges of the use of 3DP in the humanitarian development/disaster response environment.

12. In advance of the deployment to Kenya, the parts deemed achievable through the validation matrix (see above) were then placed into the design cycle to create a library of assets. Importantly, the design cycle was crafted as an iterative tool to methodically develop designs that were fit for purpose and to optimise the capabilities of 3DP. Following the deployment of the researcher to Kenya, the components from the library of parts were printed and their functionality and fitness-for-purpose was discussed with appropriate key informants, together with ideas for alternative requirements that were then trialled and tested using the Hub and Spoke process.

13. In addition, the researcher was able to gain an improved understanding of the latent and potential capability of field staff as a vital basis for the training needs analysis that will form part of the Development phase.

MAJOR OBSTACLES

14. The most significant obstacle to the achievement of the original research plan was that of obtaining approval from the University authorities for travel to South Sudan which was, eventually, <u>not</u> forthcoming. However, in practice, this performed a useful function in

that it reinforced the need to understand the benefits and limitations of alternative locations for the 'spokes' of the proposed organisation model. As a result, the current proposal is that such spokes should, in the first instance, be positioned at a central hub (such as Nairobi) rather than in a relatively remote location (such as Juba). This would allow the development of the overall model to be undertaken in a more operationally stable and less challenging physical and operational environment whilst, simultaneously, achieving a high percentage of the logistic lead time savings. This would also help to reduce the likelihood of the printers being misused in remote locations on unsuitable product applications that have not been fully tested and validated with appropriate equipment and expertise. This reinforces the project's overall approach and its differentiation from projects where field officers are given limited training and then left to their own devices.

15. As indicated above, it was clear from the field trials that a significant percentage of the products needed for Oxfam's WASH projects would require 90mm diameter pipework. Whilst the printer used in this pilot project had a theoretical build size of 120mm, in practice it proved inconsistent at the margins of the print area. However, now that the team are more familiar with the generic constraints in this regard, a slightly larger sized printer will be used in future to overcome this issue and, in addition, it is planned that a housing for the 120mm printer will be developed to support the print quality at its edges.

BENEFICIARIES/HUMANITARIAN INTERVENTIONS IMPACTED

16. The overall aim of the research was that of delivering a 'proof of concept', and to that extent significant direct benefits were not anticipated. That said, and following the success of the pilot, a clear approach to the long term use of 3DP has been developed and subjected to limited testing and feedback from practitioners.

17. In addition, the Oxfam (and other NGO) staff who engaged with the research now have a far greater understanding of the benefits and limitations of the use of 3DP and this can be integrated into their forward planning.

18. As part of the 2nd phase of the field deployment, when the researcher looked for potential collaborators in the area who could have 3DP technical expertise, he met the founder of Tunapanda (a technical institute for underprivileged children that was located near to the Oxfam HQ in Nairobi). Tunapanda staff had been presented with a 3DP as part of a recent competition, but were unsure of the optimal ways of operating and maintaining it. The researcher was able to provide much needed advice and assistance in the short term, but this fortuitous engagement also suggests a potential model for support through collaboration with this and similar organisations for the future.

PARTNERSHIPS AND COLLABORATION

19. The main external partner for the research was Oxfam GB and this proved extremely fruitful throughout the period of the project. Specifically, staff from the WASH division of Oxfam's UK HQ provided most valuable advice as the project was being developed, whilst the staff of the Nairobi office engaged fully with the research team at multiple levels. To a significant extent, therefore, the success of the project reflects this enthusiastic desire to assist the research process and for which the team was most appreciative. That said, it will clearly be important to consider appropriate strategies for ensuring the continued engagement of partner staff – especially when faced with competing priorities.

20. By the same token, the researchers perceive that the HIF should also be counted as a key partner in the project and the team are therefore most grateful for the continuing level of strong support provided prior to and during the research.

DISSEMINATION

21. In addition to the HIF grant, funding was provided from a number of sources both within Griffith University and externally (RedR Australia and HK Logistics). Regular updates were provided to these organisations including inputs to newsletters and websites as appropriate. Input was also provided on a regular basis to the HIF with an average of one blog/month being submitted. It is intended that a summary of the project will be developed for publication of the website of the Humanitarian Logistic Association (HLA).

22. In terms of academic outputs, a paper has been presented to the Australia and New Zealand Academy of Management Operations Management and Supply Chain (ANZAM OM/SC) conference in 2014. This has been further developed into a formal paper for the Journal of Humanitarian Logistics and Supply Chain Management (JHLSCM) which is currently under peer review, and it is anticipated that the paper will be accepted for publication by the end of 2015. A book chapter proposal has been accepted to be published by IGI Global on the project, and a further paper is under development for the Journal of Humanitarian Engineering.

23. A formal presentation and demonstration of 3DP was also given to the members of the UNHCR Horn of Africa Regional WASH Cluster meeting which was attended by representatives of: UNHCR, UNICEF, IFRC, World Vision, Kenya Red Cross, the Norwegian Refugee Council, IRC, Goal, ACF and the Kenyan government.

TRANSFERABILITY

24. Subject to further testing as part of the Development Phase, a key benefit of the proposed Hub and Spoke model is its potential for transferability in terms of both geographic range and scope. In respect of the latter, and as has already been demonstrated by, for example, the parallel work of the Singularity University, 3DP can be used to support the provision of multiple components in the non-food item (NFI) and medical categories. The integration of additional technology such as printers with multiple heads that extrude different materials and the use of 3D scanners, together with the general increase in the capability of printers, significantly enhances the potential here.

25. In relation to the geographic coverage of the model, it is envisaged that future Hubs could well be based around regional Universities (for example one based in Kenya supporting East Africa, or one based in Fiji supporting the Pacific Region) that would both provide an improved cultural understanding of the requirements and potential solutions to emerging requirements as well as minimising the length of the ‘Spokes’ within the organisational model.

26. As part of this process, it is already clear that particular focus will need to be paid to the training and education needs of the field operators at the Spokes as well as ensuring that the equipment is sufficiently robust to overcome challenges such as intermittent power supplies and the impact of environmental conditions (temperature, weather, dust, etc). The use of the dedicated development facility at Griffith University with its local Spokes that are orientated towards a particular region will be an important component of this approach.