3D printing for Disaster Preparedness

Making Life-saving supplies On-Site, On-Demand, On-Time

Authors: Srinivas Saripalle, Humanitarian Maker, Co-Founder & VP (Technology), Random Designs CA, Inc., Senior Member-IEEE *(Author)*
San Jose, CA USA
sri@randomdesignsca.com

Abi Bush, *(Co-Author)*
Field Ready, UK

Naiomi Lundman, *(Co-Author)*
Humanitarian Maker, San Francisco, CA USA

Abstract— **This paper highlights the use of disruptive and innovative technologies such as 3D printing to "combat" global disasters that result in lost lives and livelihood. During times of any disaster supply chain costs rise, resources are in short supply and time is of essence. 3D printing and similar technologies can be used to make supplies such as utensils, cups, buckets, medical disposables, prosthetic limbs, homes etc. Examples, Case studies and success stories are provided to generate awareness and to involve like-minded people and build a strong community.**

Keywords—3D Printing, Humanitarian, Medical supplies, Disaster, Hazard, Life Saving

I. INTRODUCTION

According to the United Nations, over the past twenty years disasters due to natural hazards have affected 4.4 billion people, claimed 1.3 million lives and caused $2 trillion in economic losses. Disasters change the landscape in numerous ways, and only a portion of the changes are immediately evident. The impact a disaster has on an affected population's health is far from predictable. A variety of factors influence the spread of disease and other health-related issues following an event, and many can be mitigated with thoughtful planning. Here are some key facts:

(1) Disaster-related health needs typically do not show up immediately**.** Some health concerns will not appear until much later. (2) Damage to health care facilities—and diagnostic equipment—can have long-reaching consequences. So, too, can damage to infrastructure such as roads and bridges, keeping people from being able to connect to services they need. In addition, losses that affect the personal lives of healthcare workers also affect the ability of health facilities to provide services. (3) Water, sanitation, and hygiene conditions before and after a disaster can greatly affect the level of impact on a community's health. Drinking water supply and waste management are especially important factors in controlling disease, as is the management of toxic substances released by the disaster. (4) Often, post-disaster outbreaks of disease are associated with population displacement. (5) Disasters can exacerbate reproductive health needs. Along with damage to facilities, equipment, medications, and other infrastructure, access to services could decrease. In addition, periods of high stress and overcrowding and yet, pregnancies and deliveries continue, even with diminished facilities and a decrease in the number of skilled healthcare workers. (6) Breakdown of the supply chain resulting in escalation of costs to procure the most inexpensive item. Establishing such a supply chain is costly: 60 to 80 percent of humanitarian aid is spent on logistics and shipping, adding up to $10–$15 billion annually to aid costs. The use of technology may emerge as a key to develop sustainable and disaster resistant infrastructure and planning. Technology plays a big role in a humanitarian disaster. Simple items can mean the difference between life and death. In remote, difficult to access locations, finding unique parts – replacement parts to a medical device, pieces of a vehicle or generator, custom-made rehabilitation items such as a prosthetic limb – can sometimes be an impossible task.

II. TECHNOLOGY & INNOVATION

3D Printing is an innovative way of building parts and disrupting the supply chain. The potential financial savings on storage and transportation are huge. Organizations such as the American Red Cross, Oxfam, Field Ready have been deploying technologies to developing work arounds to reduce the cost of logistics and transportation. Ninety percent of the cost is logistics and getting a part shipped from China, where it is made, to the Caribbean.

A. A Primer on 3D Printing

3D printing or "Additive manufacturing" is the process of using electronic data to make a three-dimensional object by depositing material successively, similar to 2D printing; a 3D printer is a machine that builds objects. In order to print an object, one needs to design it using a CAD (Computer Aided Design) software. Once the design is complete it needs to be converted into a format such as .stl or .wrl or .ply or a gcode (similar to a .doc or .xls or .pdf which the 2D printer understands)

III. WHY 3D PRINTING

3D printing machines have a small footprint and can be installed at the place of need. These are portable and affordable, and allow individuals to manufacture plastic objects in their homes.

A. On Site

This affordable means of enabling vital parts to be produced as required in remote environments makes it very attractive to be used wherever it is needed.

Plastic pipes supplying vital water to earthquake victims are being joined incorrectly. Most local NGOs do not have the equipment to join the pipes correctly, and the next best thing (compression fittings) are unavailable. Plastic bags, smaller pipe sections, GI fittings (which leak) and other makeshift methods are used to join pipes.

Transporting a 3D printer to the camp to measure the pipes and model a fitting to join the pipes correctly solves several problems. Print the fitting in the camp.

B. On Demand

No wastage, No Inventory, No brokers

It is possible to design parts and critical components with a little training. These solutions can be created whenever a need arises. Instead of maintaining an inventory of parts, the material used to print these parts can be stored. The same material can be used to manufacture different parts. The Case Studies presented will provide examples of the needs that were met.

C. On Time

The solutions are implemented in collaboration with a number local manufacturing technologies such that vital parts can be made where they are needed, when they are needed. 3D printing allows this as it is implemented as and when needed. The setup is easy and relatively inexpensive compared to the cost escalation because of the breakdown of the supply chain and the eco system at the time of a disaster or a hazard resulting in a disaster.

The approach embraces an openness to learning and experimentation and a **readiness to work** with a broad range of stakeholders. The case studies showcased have been successfully implemented by several organizations such as Oxfam, American Red Cross and Field Ready that work in this area. Their vision is to achieve a **radical transformation** in the way that needs are met in disasters, developing countries and other low resource areas.

IV. CASE STUDIES

The Case Studies shared are from the Disaster Readiness and Relief work in Haiti and Nepal by Field Ready. Their approach is to ask**: "if we can't buy it, can we make it?".**

Their vision is to achieve a **radical transformation** in the way that needs are met in disasters, developing countries and other low resource areas.

A. Umbilical Cord Clamp

- Neonatal umbilical sepsis which accounts for as much as 5% of newborn fatalities in Haiti. A typical clinic needs approximately **50** umbilical cord clamps a month.

- Umbilical cord clamps can only be obtained in bulk from China at prohibitive cost. Volunteers from other countries relied upon to bring clamps in their luggage, which means that the supply can be easily disrupted; local string (shoelaces) are also used but this increases the likelihood of sepsis and of the cord not being closed properly.

Figure 1

- Onsite manufacturing of clean umbilical cord clamps. Using a basic design that is tailored to meet local preferences, dozens of clamps can be printed in a day. These clamps are hygienic and inexpensive.

B. Baby Incubator Component

- A hospital in Nepal has 5 baby warmers, but only 2 of them are still running. The others cannot be used due to the failure of the unique plastic clips holding the sides up. The hospital cannot repair the equipment as these machines are no longer in production, and spares are not available.

- Attempts had been made to repair the baby warmers using metal angles. However, these remedies were not effective.

Figure 2.

- Measurement and modelling of the original part enabled an improved design to be 3D printed. The new part fits perfectly and is designed to be more robust.

C. Ventilator Connector

- A hospital in Nepal requires double ended connectors for their ventilators. However, the

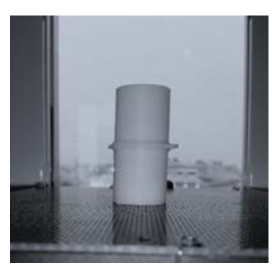

Figure 3.

only connectors they can get are single ended, and must be bought in a kit with other parts of the ventilator.

- Hospital engineering staff cut single ended connectors in half and glue two of the required ends together.

- Measurement and modelling of the original part enabled a double ended design to be developed and 3D printed.

D. Dental Chair Component

- Nuwakot district hospital was severely damaged in the earthquake, and lost a lot of equipment. A dental chair was moved from another hospital, but one of the pedals was damaged in transit leaving in impossible to lower the chair.
- The chair was generally left in the elevated position where possible, and lowered by inserting a screwdriver into the mechanism.
- Due to the damage, the original part could not be replicated. However, a bespoke solution was developed and fitted to the mechanism, and the chair now operates as intended.

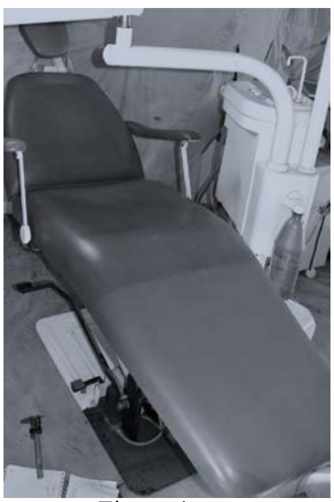

Figure 4.

E. ECG Limb Lead Connector

- ECG clamps are attached to a patient's wrists and ankles in order to read electrical signals from the heart. A hospital was having problems with the clamps coming apart during use due to a poorly designed connector.
- The connector had been glued and taped in attempts to hold the connector in the correct position. However, these fixes only lasted a short while before failing.
- A connector with a much closer fit was designed and printed using a 3D printer.

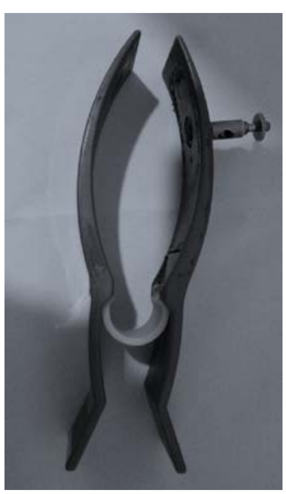

Figure 5.

F. Emergency Sanitation Kit

- Ideas to address hand sanitization, a serious challenge that could help prevent disease and illness among Syrian refugees living in crowded quarters in Lebanon.
- Oxfam partnered with file-sharing platform MyMiniFactory to solicit Additive Manufacturing solutions to "design solutions . . . to solve unique problems that occur during humanitarian emergencies where traditional design and

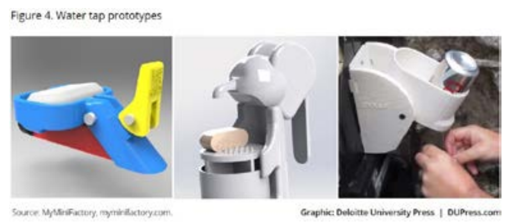

Figure 6.

procurement processes are inefficient.

- Several customized designs were then sent to a printer in the field in Lebanon to be tested and iterated, with the goal of identifying solutions that could be applied on a wider scale.

G. 3D Printed Homes

- Companies in China are now assembling 3D printed houses like LEGO bricks. The modular fireproof home is said to withstand a magnitude-9 earthquake and is made from a special construction material. Material sourced from industrial and agricultural waste, is fireproof and waterproof, and is free from harmful substances such as formaldehyde, ammonia, and radon.
- 'World's Advanced Saving Project' (WASP) uses Big Delta,a 40 foot tall 3D printer to manufacture affordable and sustainable homes using locally-sourced mix of dirt and straw to make them light and strong.
- These houses can be manufactured for $5,000 which is very affordable.

V. SUSTAINAABILITY IS KEY

The adoption and success of disruptive and innovative technologies depends upon sustainability. Key aspects for successful adoption of 3D printing are

A. CAD Design Skills

It is critical to develop the expertise to design the components and parts needed. This expertise may not be easy to come by in times of a disaster. Hence the approach is to develop and involve the community.

A very successful example is that of the eNABLE Foundation that has created a volunteer based community to design and Prosthetic hands for children. The designs are accessible to anyone that has access to a 3D Printer. Designers make several designs, test them and upload to a common repository for anyone to access.

Other community based sites are Instructables, Yeggi, Github etc.

B. Materials

The 3D printers build complex objects using an engineering grade polymer called acrylonitrile butadiene styrene (ABS). ABS is a thermoplastic which means it can be reshaped with heat – hence its suitability for fused deposition modelling. Its mechanical properties vary with the relative proportions of its constituents and the temperature where it is used, but it is generally a strong, reliable material suitable and, hence, appropriate for the sorts of applications that have been described above.

The material used to print these parts could be PLA (Poly Lactic Acid), ABS (Acrylo Butadiene Styrene) or some other metal that can be extruded from the 3D printer.

C. Power

Michigan Technological University Professor, Joshua Pearce, has invented the first mobile, solar-powered 3D printer, offering his design free and open-source in the interest of helping off-grid developing economies.

Battery packs, Portable Battery walls and Fuel cells from companies like Bloom Energy could be viable options.

VI. BENEFITS

The 3D printers are portable, easy to operate, cost less and are easy to maintain.

3D Printing technology involves the deposition of material at high temperatures. Most popularly used materials are PLA (Poly Lactic Acid) and ABS (Acrylo Butadiene Styrene). These are low-cost, light and durable.

Eco-friendly: PLA is an environment friendly durable material which is bio-degradable. Such eco-friendly material makes it easy for adopting solutions and products required.

Durable: ABS, although not bio-degradable, is stronger and more durable and is used for certain products.

Sterile: Since the deposition happens at temperatures as high as 240 degree Celcius, the products are safe for use in basic health care.

VII. NEW DIRECTIONS

When disaster strikes, there is no prior notice. Transportation, Communication and Power are worst hit. Response teams, at times, are not equipped to taken environmental friendly solutions. In order to design solutions and make the best use of 3D printing technology several factors such as power to computer to design the parts and run the 3D printer, 3D printable materials and suitability of the material.

An option being explored is trial installation of a 3D printer in a central healthcare centre or hospital, and train engineering staff in its use. Initially, a Field Ready staff member would be permanently available on site for design support. If this proves successful, support would gradually be removed. The vision is to enable a healthcare system within a district of Nepal to significantly improve its ability to maintain equipment to an appropriate standard, hence improving the standard of healthcare.

Ideally, the trial would be run in an environment where the healthcare centre or hospital is the hub of a well-functioning hub and spoke healthcare system, such that the 3D printer can be used to maintain equipment across a district, not only one hospital. Field Ready would be particularly excited to work with Possible Health due to the emphasis on a strong hub and spoke model, and the work done on developing the systems, organisational structures and capabilities needed for such an arrangement

VIII. A NEW APPROACH

Having an employee travel to identify and solve maintenance problems would be ideal for researching the need for local manufacture in enabling effective maintenance of medical equipment. However, this approach is not suitable beyond the research phase.

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A. Authors and Affiliations

Srinivas Saripalle is a Humanitarian Maker and Co-Founder of Random Designs CA, Inc., a start-up that focuses on commercializing disruptive and innovative technologies and developing applications for the mainstream. 3D Visualization and Printing are key focus areas. Sri is actively involved with non-profit organizations and NGOs in developing countries offering mentorship and expertise.

He is also a Senior Member of the IEEE.

Abi Bush is the Technical Advisor – Nepal at Field Ready.org. Her role is to provide productive support to aid agencies and local partners by addressing supply chain gaps with 3DP, through activities such as 3D printing water pipe fittings in the field, and trialing injection molding of buckets to aid agency specifications by working with local firms. Through deep engagement with aid agencies and local partners, the aim is to make recommendations on how digital manufacturing could be made useful to aid agencies in the Nepal earthquake response specifically and the sector generally.

Naiomi Lundman is the Curator for the Humanitarian Makers. She brings together aid workers & humanitarians with makers, designers, engineers, supply chain experts, technologists and other innovators to shrink the humanitarian supply chain.

ACKNOWLEDGMENT

Thanks are in order to Andrew Lamb (PhD) and Abi Bush of Field Ready for sharing their experiences and success stories in Haiti and Nepal, and

Naomi Lundman of the Humanitarian Makers for her constant support, energy and inspiration based on her project execution and management skills.

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