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Shrinking the Supply Chain:

Hyperlocal Manufacturing and 3D printing in Humanitarian Response

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KEY MESSAGES:

- The cost of humanitarian aid has increased dramatically in recent years, with an estimated 60 to 80 per cent spent on logistics.[1]
- As demand for humanitarian assistance rises, the sector's dependence on complex international supply chains presents many challenges. They include sudden and unpredictable spikes in demand; hard-to-reach locations; disruptions due to conflict or disasters; and normal supply-chain problems of leakage, spoilage and other losses.
- Current solutions target the efficiency and effectiveness of the supply chain, and/or focus on reducing the need for foreign goods through local sourcing or cash transfers.
- However, these efforts fail to resolve some key problems:
  - Even when supply chains are improved, they remain vulnerable to disruption and delay, particularly during a cross-border crisis.
  - The large-scale influx of relief goods can disrupt local markets and economies.
  - Commercial supply chains are driven by customer demand, but in a humanitarian emergency the lack of market forces and clear information makes it hard to provide the correct quantities and types of goods.
  - The pressures of logistics tend to favour large-scale, standardized resources that fail to address local cultural preferences or the need for one-off products or replacement parts.
- There is an opportunity for new technology or strategies to simultaneously reduce reliance on complex international supply chains, empower local markets, and provide tailored goods and products by producing them at the "hyperlocal" level.
- These technologies include high-tech applications, such as three-dimensional (3D) printing, and low-tech solutions, such as producing goods from recycled and local materials.

Many of these technologies are only just beginning to be used in humanitarian response. But existing pilot projects indicate great potential, particularly in the areas of specialized items and prototyping, combined with the ever-increasing availability and affordability of the technology. To catalyse and accelerate this progress, the humanitarian community should:

- Encourage a broader research agenda around hyperlocal manufacturing, such as 3D printing.
- Expand support for innovation through increased funding and technical assistance to help scale projects.
- Engage with the private sector to develop customized technologies for humanitarian response.
- Foster links and collaboration within and beyond the humanitarian community through specialized networks, social media and open-source design libraries.

[1] Peter Tatham, and S.J. Pettit, "Transforming humanitarian logistics: the journey to supply network management", *International Journal of Physical Distribution and Logistics Management*, Vol. 40 No. 8/9 (2010), pp. 609-622.

PART I: Introduction

The demand for humanitarian aid has grown dramatically in recent years. In 2013, major natural disasters in 109 countries affected 97 million people, many of them in remote locations.[2] Conflicts such as the Syrian civil war are also driving mass displacement and humanitarian crises, contributing to over 51 million currently displaced people worldwide—the highest level since the Second World War.

At the centre of any response to these problems are the logistical challenges of getting the right goods to the right people and in the right place at the right time. Logistics is not only central to any assistance project; it is also the most expensive part. An estimated 60 to 80 per cent of the cost of humanitarian aid is spent on logistics, amounting to US$10 billion to $15 billion per year.[3] Many of these goods are procured in wealthier countries and supplied to disaster zones, often without considering the impact on the local economy or the unique needs of people or communities.

Humanitarian operations must contend not only with the challenges of moving vast amounts of goods over long distances, but also with difficult and disrupted environments, unexpected and huge unmet needs and a slow adoption of technology. Much of the effort to solve these problems has focused on improving efficiency and effectiveness, as well as on strategies to engage with and develop local markets.

> ***Already today, with the exponential increase in needs we have seen just in the last three years, the humanitarian financing system is nearly bankrupt.***
>
> **UN High Commissioner for Refugees**
> **António Guterres,** 30 September 2014

However, new technologies and approaches are opening up the possibility of hyperlocal manufacturing: producing required items where they are needed, such as in a health clinic, a workshop or a displaced persons settlement. New technologies such as 3D printing are only beginning to be used in development and humanitarian contexts, but they are spreading rapidly and have considerable potential. Traditional forms of logistics will remain central to humanitarian response, but 3D printing and other hyperlocal production techniques have the potential to improve efficiency, while better engaging affected people and building local capacity.

This paper starts by looking at the challenges faced by humanitarian supply chains, efforts to address them and remaining gaps. The paper then looks at the potential for hyperlocal approaches and new technologies, including additive manufacturing (more commonly known as 3D printing), particularly to transform the landscape. It concludes by proposing broad recommendations for building on these promising opportunities.

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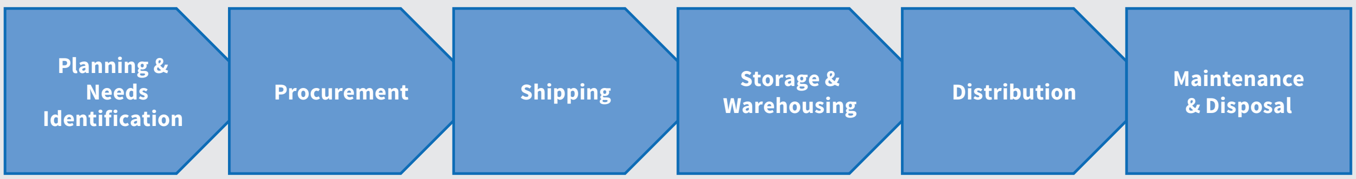
[2] Centre for Research on the Epidemiology of Disasters, *CRED Crunch: Disaster Data*, Issue No. 35, (April 2014).

[3] Peter Tatham, and S.J. Pettit, pp. 609-622.

The challenge of humanitarian logistics

In a standard humanitarian supply chain, products and goods “flow through the relief chain via a series of long haul and short-haul shipments,”[4] all under pressure to be fully accountable and efficient. The standard supply chain can be broken into six phases as shown in Figure 1.[5]

Figure 1: Standard Supply Chain



The recognition that humanitarian logistics lags behind the commercial sector is spurring efforts to develop new methodologies, strengthen performance measurements, foster increased collaboration and embrace new technologies.[7] Examples include HELIOS, software that improves transparency along the humanitarian supply chain,[8] and AidMatrix, a group that offers supply chain management software for hunger relief organizations on par with commercial counterparts.[9]

Logistics attempts to minimizing costs and travel time while maximizing the satisfaction of demand points, through factors such as facility location, stock pre-positioning, and distribution systems. In addition to dealing with huge and unpredictable spikes in demand, often in remote locations, humanitarian supply chains also face the usual challenges of minimum orders, stock shortages, spoilage, breakages and wrong orders.[6] A further frequent challenge, particular in the context of complex emergencies, is the restriction on the movement of goods imposed by the various factions.

Regional stockpiles in places like Dubai and Bangkok have begun to allow for rapid deployment in response to sudden onset disasters. However, stockpiling relies on standardized products that may not meet the needs that arise in a particular emergency.

Much of the focus has been on the first three phases, from planning to shipping. However, in the later phases of the supply chain, there have been fewer innovations, and efficiency and accountability problems remain significant at warehouses and during distributions. In addition, the current humanitarian logistics system has some intrinsic and unresolved challenges, as follows:

- Even when supply chains are improved, they remain vulnerable to disruption and delay, particularly during a regional crisis.
- The influx of relief goods can disrupt local markets and economies. For example, large international interventions in countries such as Haiti and Timor Leste have created “bubble economies” with significant inflation.
- Commercial supply chains are informed by customer demand, but “the aid recipient operates in an unregulated monopoly, where the stakes associated with supplies are often life or death. Moreover, there is no formal contract between NGOs and recipients with agreed-upon stan-

4 Burcu Balcik and Benita M. Beamon, “Facility location in humanitarian relief”, *International Journal of Logistics: Research and Applications*, vol. 11, No. 2, pp. 101-21 (February 2008), p. 8.

5 Eric James, *Managing Humanitarian Relief: An Operational Guide for NGOs* (Rugby, Practical Action, 2008); also see Anisya Thomas, *Humanitarian Logistics: Enabling Disaster Response*, White Paper (Fritz Institute, 2005), and Balcik and Beamon, “Facility location in humanitarian relief”.

6 See, e.g., Eric James, *Managing Humanitarian Relief*; (Practical Action, 2008) and Vasileios Zeimpekis, Soumia Ichoua, and Ioannis Minis (eds.) “Humanitarian and Relief Logistics: Research Issues, Case Studies and Future Trends”, Operations Research/Computer Science Interfaces Series, (New York, Springer, 2013).

7 “Developing flexible technology solutions will improve responsiveness by creating visibility of the materials pipeline and increasing the effectiveness of people and processes. Furthermore, advanced information systems will create the infrastructure for knowledge management, performance measurement and learning.” Anisya Thomas and Laura Rock Kopczak, 2005. *From Logistics to Supply Chain Management: The Path Forward,* White Paper (Fritz Institute, 2005).

8 Oxfam and other NGOs have used HELIOS, created by the Fritz Institute. See: http://www.fritzinstitute.org/prgTech-HELIOS_Overview.htm

9 See http://www.aidmatrix.org

dards."[10] As a result, it becomes difficult to provide the correct quantities and types of goods.

- The harsh and changing conditions of a humanitarian disaster create a large demand for replacement parts or other objects, which is difficult to plan.
- The pressures of logistics tend to favour large-scale, standardized resources. In a disaster, needs extend beyond food, water and shelter to include items related to protection, gender, education, livelihoods and well-being. Cultural considerations also determine the effectiveness of aid in reducing suffering, as in the case of a standardized pot that does not suit local dishes or cooking practices. People also often need specialty or individual "one offs", such as replacement parts for crutches or eyeglasses, a fitted medical part, or parts for vehicles and generators. The current approach to humanitarian logistics makes such customized and targeted aid difficult.

Using local markets: local procurement and cash transfer

Focusing on an efficient international supply chain does not fully recognize or take advantage of local capacities in a response. Scholars have noted this failure: "The developing canon of humanitarian logistic literature has, to date, been relatively silent on the subject of the contribution of the local population to the overall logistic management challenge."[11]

Fortunately, there is growing interest in ways to decrease reliance on international supply chains. One strategy has been to procure goods locally or regionally. For example, the production of tarps, a basic material for emergency shelter, is concentrated in Asia, but most humanitarian relief is in Africa. The NGO Advance Aid is facilitating the production of relief goods in Africa to shorten the supply chain while supporting local markets. In 2011, in partnership with World Vision and Catholic Relief Services, Advance Aid assisted Kenyan producers in supplying emergency kits for the Dadaab camp, including tarps, mosquito nets and jerry cans.[12]

The growing practice of cash distribution[13] is an additional strategy to address the problem of moving goods into disaster zones, including the effects on the local economy There are many good examples, including direct payments, vouchers and account transfers, supported by tools such as Emergency Market Mapping Analysis.

These strategies are important, but they do not solve the problem: local procurement still does not allow for fully customizable, targeted aid, while cash-based approaches only work when local markets already have the necessary goods or can adapt quickly to the arrival of displaced people.

Clearly, additional strategies are necessary to address the limitations inherent to complex humanitarian supply chains. Fortunately, recent advances in technology and new ways of thinking about old techniques are creating opportunities to produce goods directly at the scene of a disaster.

10 Beamon, Benita M. and Burcu Balcik. "Performance Measurement in Humanitarian Relief Chains." *International Journal of Public Sector Management*. 2008.

11 Allan Sheppard, Peter Tatham, Ron Fisher, and Rodney Gapp, "Humanitarian logistics: Enhancing local engagement", *Journal of Humanitarian Logistics and Supply Chain Management*. vol. 3, No. 1 (2013), p. 22.

12 Mark Tran, "Helping Africa manufacture its own emergency and disaster relief supplies", *The Guardian*, 6 August 2012. Available from www.theguardian.com/global-development/2012/aug/06/africa-manufacture-emergency-disaster-relief

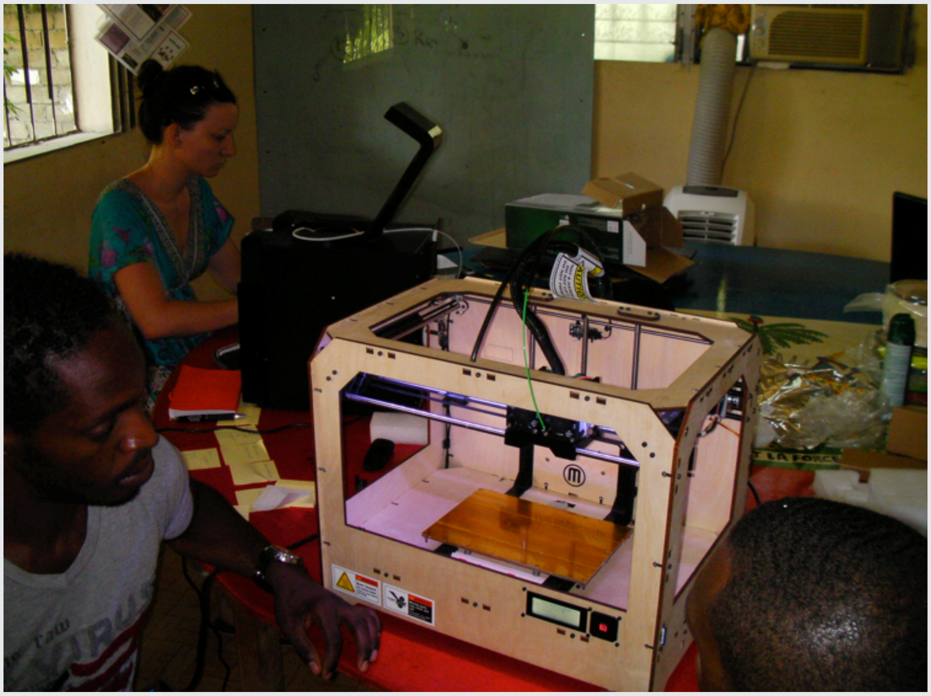
13 Between 2007 and 2010, humanitarian cash-transfer programmes grew from $1.8m to $52m. See "Tracking spending on transfer programming in a humanitarian context," Global Humanitarian Assistance (2012). Available at www.globalhumanitarianassistance.org/wp-content/uploads/2012/03/cash-transfer-financing-final.pdf

PART II: New approaches to providing humanitarian relief goods

Much of the recent focus on technology for humanitarian response has been on information and communications. However, the benefits of digital technology are increasingly coming to the physical world. Many of these technologies are at an early stage, but they are developing exponentially, helped by rising computing power and falling prices, leading to comments that a "Third Industrial Revolution" is underway.[14]

Additive manufacturing (3D Printing) in humanitarian response

A centrepiece of these developments is additive manufacturing, more commonly known as 3D printing. This term refers to a range of technologies and processes that have the potential to build an object without a predetermined mould.



The most basic form of 3D printing is "fused deposition modelling", in which a plastic filament (or other material) is heated and extruded to build an object. There are many different types of 3D-printing technologies. Systems are available that build objects out of metal, ceramic or carbon fibre (and other materials such as wood, silicon and concrete), as well as human and animal cells for biomedical printing.[15] But these can require complex systems and are not the immediate focus of this paper. Because of their relative simplicity and portability, smaller commercial systems seem to offer the best uses in humanitarian settings. But in the future, larger industrial-scale printers may be increasingly available in a crisis through private companies, Governments or militaries.

3D printing offers a number of benefits including flexibility and adaptability due to the manufacturer's proximity to the user and an ability to fine tune objects following the production of a prototype solution. The 3D printer was invented in the mid-1980s, but it took until 2005 for the process to spread from industrial to personal and other uses, and then another six years to become widely available.[16] First gaining popularity in the "maker" and "open source" movements, many devices are now available, such as Makerbot, Printrbot and Ultimaker. The number, sophistication and utility of models are set to expand as commercial entities increasingly rely on 3D printing for tasks such as prototyping. Projects are under way to print everything from food to human organs.

LEFT: Field Ready staff set up a 3-D printer in Haiti. CREDIT: FIELD READY

[14] Jeremy, Rifkin, *The Zero Marginal Cost Society*, (New York, Palgrave MacMillan, 2014).

[15] For the last example, see "Using Ink-Jet Technology to Print Organs and Tissue", www.wakehealth.edu/Research/WFIRM/Our-Story/Inside-the-Lab/Bioprinting.htm

[16] Dale Dougherty, "A brief history of personal 3D printing", Make: Special Edition. (Winter 2014).

Local manufacture of humanitarian relief goods

3D printing has the potential to reduce the cost and increase the flexibility of humanitarian logistics. This is because it allows for rapid and customized manufacturing, with the most basic forms requiring relatively little set-up or training depending on the complexity of the output required. By manufacturing at the point of use, humanitarians can avoid ordering products that may take months to transport and clear customs. Transporting raw filament or other materials is efficient, requiring limited packaging and less space than finished goods (i.e., a high mass-to-volume ratio). And 3D printing allows for on-the-spot customization, which can meet the unique needs of affected people while promoting interoperability between equipment with minor differences in pipe-bore sizes, screw threads, etc.[17]

Field Ready is a US-based NGO dedicated to bringing manufacturing to the point of use in humanitarian response. It has identified practical items that can be made at or near where they are most needed (see figure 2).

Figure 2

3D Printing Items by Sector (FieldReady.org)

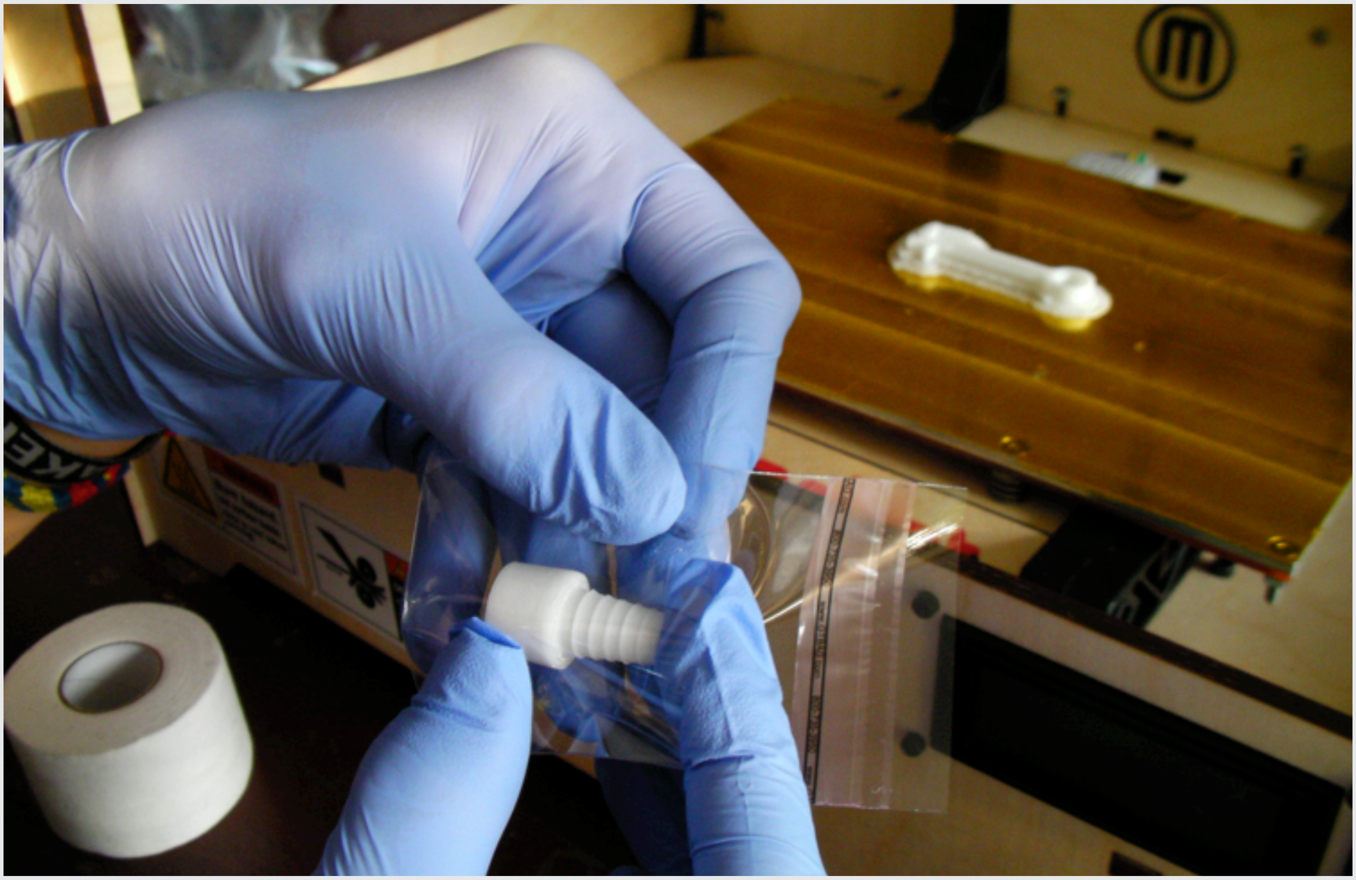
Sector/ Cluster	Printed Items
WASH	Pipe/hose connectors, spigots, washing points, soap holders and dispensers, latrine hinge-covers
Health	Medical disposables (e.g. IV bag hooks, oxygen splitters, umbilical cord clamps), combs, medical waste containers, prosthetic limbs, 3D models for planning and patient education
Camp Management	Durable signs, clipboards and items to secure rope for crowd control
Shelter	Tent stakes, enclosures, tools and rope clamps
Food/Nutrition	Measuring cups, specialty utensils and eating ware
Protection	Pill dispensers, eye-glass repair, family images/figurines, toys, rudimentary locks, whistles, door jams
Education	Learning tools and models, musical instruments
Logistics	Spare parts (plastic and rubber), office organizers, tablet stands, keyboard key replacements
Telecommunications	Connectors, wire wraps, zip ties, equipment holders and organizers
Early Recovery	Plastic voucher cards, items for home-based employment, agriculture, and sustainable livelihoods

[17] Peter Tatham, Jennifer Loy, and Umberto Peretti, "3D Printing (3DP): A Humanitarian Logistic Game Changer?", 12th ANZAM Operations, Supply Chain and Services Management Symposium, (2014), available from http://docs.business.auckland.ac.nz/Doc/Tatham-anzamsymposium2014_submission_104-final.pdf

To date most commercial 3-D printers have used a simple plastic filament (usually ABS[18] or PLA[19]). However, the range and quality of materials that can be used are expanding rapidly to include nylon, carbon-reinforced PLA, memory foam and others, allowing for printing more robust objects or those with unique properties (such as elasticity).[20] Printers for metal and other materials also exist, but they are generally industrial size and significantly more expensive and complex to operate.

Current humanitarian projects have focused on producing relatively simple objects, such as clips that close plastic sheeting for shower stalls, replacement pump parts or latrine-cover hinges. Many of these items are small, but they can account for a sizable portion of goods brought into an emergency, and they can be critical for effective use of other products, such as tarps. In addition, much more sophisticated items are increasingly possible, notably prosthetic limbs and other medical devices (see Box 1).[21] In addition, 3D printers can produce component parts for more sophisticated tools. For example, 3D-printed cases can be combined with electronic components that are increasingly available in most countries (or at least much easier to import than finished electronics) to produce small computers, controllers or sensors, such as water-quality testers.[22]

BELOW: Newly printed IV bag connector in Haiti produced by Field Ready.
CREDIT: FIELD READY



[18] Acrylonitrile butadiene styrene (ABS) is a common thermoplastic polymer.
[19] Polylactide (PLA) is a biodegradable thermoplastic aliphatic polyester
[20] Examples include Proto Pasta – carbon fiber-reinforced PLA; ProtoParadigm – magnetic PLA; ColorFabb – XT copolyester; ColorFabb- special fills, bamboo, wood, bronze, copper glow; Recreus – Filaflex elastomer; Taulman – nylon, etc. and 3D printed memory foam.

[21] See www.fieldready.org
[22] http://www.3ders.org/articles/20141124-open-source-3d-printed-water-quality-tester.html

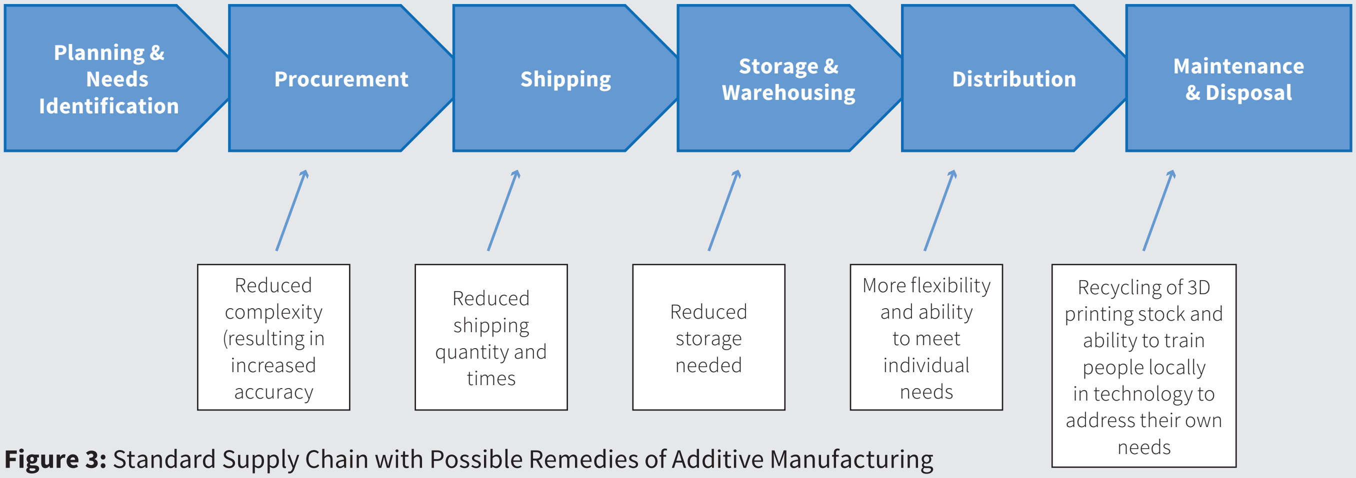


Figure 3: Standard Supply Chain with Possible Remedies of Additive Manufacturing

Figure 1 showed a common framework for supply chains, with six closely linked phases. 3D printing allows improvements, efficiencies and shortcuts at virtually every phase (see Figure 3), reducing time and space requirements and complexity while providing greater flexibility. The technology also has the capacity to address environmental, labor and safety concerns (such as through recycling) while building local capacities.

Many pilot projects are exploring the use of 3D printers to produce the types of goods outlined in figure 2, but no attempts have been made to develop major production hubs. For example, in Haiti, Field Ready, supported by the Humanitarian Innovation Fund (HIF), is producing medical disposables and training local people in the technology, with the goal of significantly reducing procurement costs and transport time.[23] A separate HIF-funded project in Kenya is working with Oxfam Great Britain to field test the production of parts for water, sanitation and hygiene (WASH) projects.[24]

Facilitating research and development

3D-printing technology also allows the rapid prototyping of ideas, enabling innovation on the fly. Because of the ease of sharing and manipulating the digital files used for 3D printing, ideas in one location can be easily duplicated or repur-

[23] "Rapid manufacturing for quick onset disasters", available from http://www.humanitarianinnovation.org/projects/small/Field-Ready

[24] "A field trial of 3D Printing to assess its potential for improving the effectiveness and efficiency of the humanitarian response", available from http://www.humanitarianinnovation.org/projects/small/Griffith-Uni

Box 1: Prosthetic limbs in Sudan and Syria

To demonstrate that 3D printing technology is applicable to a humanitarian setting, the US-based Not Impossible Labs decided to help a Sudanese boy who lost both of his arms in a bomb attack. It created a 3D-printed prosthetic limb for the boy with financial help from Intel and Precipart, and with the collaboration of Richard van As, co-inventor of a mechanical solution called the Robohand, and Tom Catena, an American surgeon working in the area. Their inspiring project also left behind a pair of printers and trained locals to produce more prosthetics, extending the life and impact of the project.

Refugee Open Ware (ROW) is running a 3D-printed prosthetics pilot programme in Jordan, assisting Syrian refugees, Jordanians, Yemenis and other amputees from the Middle East. ROW co-created an open-source Flexy Hand with a 6-year-old Yemeni boy treated by Doctor's Without Borders. When asked who his superhero was, he said, "Ben 10." A Jordanian mechanical designer based in Fab Lab Barcelona then customized this hand for him, including an embedded Arduino computer with animation of Ben 10 aliens. The human-centered design process was essential for acceptance of the prosthetic, as the robotic 3D-printed designs popular in North America are generally not culturally suitable in the Middle East.

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The hand was 3D-printed in carbon fiber-reinforced co-polyester material for under $75 on a $1700 Ultimaker 3D printer by Asem Hasna, a Syrian refugee on the ROW team who learned 3D printing in three weeks. Asem and the ROW team are training Jordanian prosthetists of the Royal Medical Services on 3D printing and 3D design software, so the project can be sustained in the long term.

ABOVE: A six-year-old Yemeni boy who was severely burned and lost a hand in a household fire tests out his new 3D-printed prosthetic limb.

posed. 3D printing requires training (despite ongoing efforts to make software and printers more user-friendly), but it is simple enough that affected communities can develop their own ideas to address humanitarian or livelihood needs.

For example, Oxfam and MyMiniFactory.com, a free library of 3D-printable objects, have launched a project to help rapidly design, manufacture and test items to address the water hygiene issues of Syrian refugees in Lebanon. In May 2014, designers from around the world were invited to submit designs for hand washing devices. The selected designs were e-mailed to humanitarian workers for testing and feedback.[25] The final design will be mass produced using conventional manufacturing techniques.

Limitations to current 3D printing

Cost is a particular issue, as basic fused deposition modelling printers cost between $1,000 and $3,000. This price is fast reducing in line with Moore's Law.[26] The filament (the medium in which objects are made) can cost $25 to $80 per kg, also raising environmental concerns. Efforts are under way to produce filament more cheaply and sustainably from recycled materials (see box 2). Machines that can produce filament from plastic bottles already cost less than $300,[27] so on-site production of filament from waste and debris after a disaster has the potential to provide economic and environmental benefits.

A second issue is durability, as the low-cost desktop machines are fairly fragile and often unreliable. This is aggravated by the lack of consistent power supply and difficult conditions in many field sites. Developing units that are robust and resistant to dust, moisture and temperature extremes, and which can use batteries, solar power or other alternative energy sources, will be critical.

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25 "Oxfam teams with MyMiniFactory to provide humanitarian aid in Syria, using 3D printing", 8 May 2014, http://3Dprint.com/3400/syrian-crisis-oxfam/

26 Moore's Law holds that "The number of transistors incorporated in a chip will approximately double every 24 months." It is used to refer to "exponential capability increases." www.intel.ly/1BiqaDS

27 See "Turning old plastic into 3D printer filament is greener than conventional recycling", (2014). Available from http://www.3ders.org/articles/20140304-turning-old-plastic-into-3d-printer-filament-is-greener-than-conventional-recycling.html

There are also potential security concerns, particularly in unstable contexts. Bomb or gun components, or even crude operational firearms, could be a concern,[28] as these untraceable non-metallic weapons can get around security mechanisms (e.g., checkpoints) and policies (e.g., sanctions).[29] This concern remains largely hypothetical however, and as with any dual-use technology, proper monitoring and safeguards would limit practical risks in most situations.

In addition, 3D printing is presently too slow to print a large number of parts, which are typically needed in humanitarian settings. 3D printing is useful for producing replacement parts, but currently it does not have the capability to supersede the quantity of production that is achievable in a traditional supply chain.

Finally, it is important to appreciate the importance of correct and appropriate design for 3D-printed parts. For example, in the case of WASH equipment, the item must be able to withstand the operating pressure so that it does not rupture and cause death or injury. Such issues are routinely considered as part of the traditional design-and-production process, but there is a clear danger that the ability to print on demand will lead to unsafe practices in this regard.

Box 2: The Ethical Filament Foundation

Environmental, labour and safety concerns have led to the creation of the Ethical Filament Foundation. One of its goals is to create an independent filament production standard and a certification process that guarantees quality and ethical value. Research from the foundation will promote the dissemination of these ideas. Using a Fair Trade approach, it promotes filament sourced directly from waste-picker groups in developing countries, creating income-generation opportunities. Adopting an approach similar to the Sphere Project, the Ethical Filament Foundation has a set of minimum standards on child labour and working hours. A critical piece of its work is furthering research and development to improve the process for waste recycling at the grassroots level, which may also have applications for humanitarian contexts.

Fabrication labs and alternatives to 3D printing

In all the enthusiasm around 3D printing, it is easy to forget that it is simply a tool and that there are other, often better, ways to make the same objects. Alternatives include laser cutters and milling machines, both of which benefit from the advances in digital design and control that drive 3D printing. These are subtractive in nature, as tools remove bits, slices and fragments from pieces of wood, metal or plastic, rather than add material as a 3D printer does. These more traditional tools are heavier, generate more waste and generally require more training than 3D printing, but they will likely remain a critical part of future hyperlocal manufacturing systems.

For example, mobile fabrication labs ("fab labs") bring together tools that include 3D printers, computer-assisted milling machines, laser cutters and welding gear. A fab lab created at MIT in 2007[30] combines computer-aided design and manufacturing with traditional machines in a containerized trailer. The US military deployed its Expeditionary Lab Mobile to Afghanistan, which is a mix of equipment in a 20-foot container manned by two engineers, with equipment including generators and satellite communications.[31] These labs allow production and repairs far beyond what 3D printers can do alone, offering a promising model for humanitarian operations.

[28] Andy Greenburg, "How 3D Printed Guns Evolved Into Serious Weapons in Just One Year," Wired (May 15, 2014). Available from http://www.wired.com/2014/05/3d-printed-guns/

[29] Gustav Lindstrom, "Why should we care about 3D-printing and what are potential security implications?" GCSP Policy Paper (2014). Available from http://issuu.com/thegcsp/docs/gcsp_policy_paper-3d_printing-linds/4?e=8641782/9654566

[30] See "Mobile fab lab hits the road", http://web.mit.edu/spotlight/mobile-fablab/

[31] "U.S. Army Deploying Mobile FabLabs," 6 March 2013, http://3dprintingindustry.com/2013/03/06/u-s-army-deploying-mobile-fablabs/

TOP: Aerial image of the Oso mudslide. The white outline indicates the area scanned and 3D printed. CREDIT: USGS.
ABOVE: The 3D print of the area affected by the Oso mudslide by the Field Innovation Team. CREDIT: FIELD INNOVATION TEAM.

3D scanning

Another complementary technology is 3D scanning, which allows the rapid creation of digital models of physical objects. The digital models can then be used to 3D print or otherwise manufacture replicas or physical models of the original object. 3D models can be produced from conventional cameras or LIDAR,[32] or from a range of new dedicated scanners, which are increasingly portable and inexpensive.[33] One recent example was the work of the Field Innovation Team (FIT), a US-based NGO,[34] after a major mudslide in Oso, Washington, USA. FIT initially brought in a small unmanned aerial system (drone) jointly with Roboticists Without Borders to capture a 3D image of the mudslide-affected area. But as the resolution was not high enough using UAVs, they turned to LIDAR data from the US Geological Survey to complete the 3D model.[35] The 3D model was then printed and used to facilitate planning of long-term recovery efforts.[36]

Alternatively, the digital models can be used for analysis, letting people work remotely and limiting the number of people who have to visit the physical site of a disaster.

32 LIDAR, which stands for Light Detection and Ranging, is a remote sensing method used to examine the surface of the earth. www.1.usa.gov/1cWKAXs

33 For example, the Sense by 3D Systems is a hand-held 3D scanner selling for about $400, although more expensive models can still cost thousands of dollars.

34 The Field Innovation Team, or FIT, a registered 501C3 non-profit organization, rapidly responds to crises and deploys teams of experts who work with the populace and response network in place to develop innovative solutions in real-time.

35 Palmer, Tamara; "FIT Deployment In Support of SR 530 Washington State Mudslide & Flooding Disaster (WA-4168-DR)"; September 2014, http://fieldinnovationteam.org/wp-content/uploads/2014/09/Field-Report_SR530-Mudslide_Oso_WA_2of2.pdf.

36 Based in part on this experience, FIT and volunteers have co-written a 3D computer modelling and printing Standard Operating Procedure using Autodesk's software for use in disasters. http://fieldinnovationteam.org/wp-content/uploads/2014/09/FIT_3D_SOP.pdf

Low-tech approaches to local manufacturing

Local design and manufacture predates the proliferation of 3D printing. Designers and humanitarian workers have drawn on concepts of appropriate technology,[37] participation, and human-centred design and decision-making to create a rich variety of solutions to common problems. Here are some examples:

- In 1994, in collaboration with UNHCR in Rwanda, architect Shigeru Ban began developing shelters made from cardboard tubing, which could be assembled easily by untrained workers.
- In response to the Kosovo crisis in 1999, I-Beam Architecture and Design developed a design for a house that could be produced rapidly, and with minimal tools, using the shipping pallets used to transport other materials.
- Potters for Peace, a US-based NGO, works with low-income artisans in Central America to make ceramic water filters,38 a basic form of additive manufacturing.

Novel designs, sometimes facilitated with digital modelling, may be mixed with traditional construction techniques and locally available or recycled materials. However, there are few examples of these approaches being used on a large scale in disasters. One notable exception is the work of My Shelter Foundation in the Philippines.[39] This group adopted the "Liter of Light" system that uses plastic bottles filled with water and bleach to refract light into homes, providing 55 watts of brightness. This was then expanded so that the original solar bulb was supplemented with a solar-powered LED to keep the light on at night.

The organization also developed a simple street-lighting system, critical for creating a safe environment in camps or disaster-affected areas. However, rather than rely on expensive and time-consuming imports of completed lighting systems, My Shelter Foundation developed training kits to teach communities how to build the simple night-lighting systems by hand. Trainings in the Philippines were conducted with partners such as the Technical Education Skills and

37 See, e.g., Eric Schumacher, *Small is Beautiful: A Study of Economics As if People Mattered*. (London, Blond and Briggs, 1973)

38 See http://pottersforpeace.com/

39 See http://aliteroflight.org/

Palo Leyte solar street lighting system, assembled in the Philippines by volunteers working with the My Shelter Foundation.

CREDIT: LITER OF LIGHT PROJECT, MYSHELTER FOUNDATION

Development Authority, a nationwide Government entity that trains young people. Micro-solar panels, or solarettes, and other parts widely available in the Philippines are assembled by hand using components easily accessible in most cities. The kits could therefore be rapidly produced and lighting restored to disaster-affected communities, shelters or IDP camps soon after a disaster. Following Typhoon Yolanda in December 2013, the project distributed thousands of lights to poor communities in Leyte, Samitar and other affected areas.

These approaches are promising, but it will be necessary to fully assess the effectiveness of different methods against conventional techniques and integrate these methods into planning processes. For example, using low-tech water-purification technology[40] might reduce the need for imports of bottled water; if bottled water is being brought into an emergency, there should also be plans in place to re-use the plastic bottles for lights, conversion to filament or other uses. Exploring and finding ways to scale these techniques appropriately will be a critical part of realizing the promise of hyperlocal manufacturing.

Future of hyper-local manufacturing technology

The use of 3D printers in hyperlocal manufacturing is still in its early days. In the near future, the source materials that can be used will increase dramatically, allowing for the production of items as different as vehicle parts and skin grafts. The US military is even looking at 3D-printed food, which could provide nutrition tailored to specific people.[41] Intriguing examples of the possibilities include:

- Using readily available raw materials and solar power, such as in the Solar Sinter Project created by art student Marcus Kayser. He created a bowl out of sand using natural sunlight and photovoltaic cells.
- Printing objects as large and complicated as a house. This has been achieved by architect Enrico Dini and by Chinese company WinSun.
- 4D printing, which allows materials to self-assemble into 3D structures. Applications might include auto-erecting structures (such as health clinics and bridges), self-fixing infrastructure and water systems that unfold automatically.

With the exponential development of the technology, humanitarian professionals must be able to articulate their needs and build partnerships with academics and private companies to realise the potential in these concepts. An example might be the proposed “intelligent hub” with industrial designers and 3D-printing specialists that is being developed at Australia’s Griffith University to support 3D operators and operations in field locations.

40 See “15 Concepts and Solutions for Providing Clean Drinking Water”, 16 May 2012, available from http://www.treehugger.com/gadgets/concepts-providing-clean-drinking-water.html and “The ‘Origami’ Inclined Plate Settler”. Available from http://www.humanitarianinnovation.org/projects/large-grants/origami

41 Jane Benson, “Chow from a 3-D printer? Natick researchers are working on it”, 18 July 2014 Available from http://www.army.mil/article/130154/Chow_from_a_3_D_printer__Natick_researchers_are_working_on_it/

Conclusions

The challenges of humanitarian response are mounting, but available logistical approaches are inefficient and rigid and can hurt local economies. Hyperlocal manufacturing, and 3D printing in particular, has the potential to revolutionize the humanitarian endeavour. It is likely that we are only at the inflection point of exponential growth that will make these tools easier to use, inexpensive and widely available.

To help ensure that hyperlocal manufacturing technology benefits people affected by disasters, the humanitarian community can help catalyse and accelerate progress by:

1) **Encouraging further study and research around hyperlocal manufacturing:** It is important to formalize and promote a broader research agenda that includes all the areas discussed in this paper, including the potential applications at each stage of the supply chain, the production of specialized items, prototypes for design and testing, larger-scale production of simple items, mobile fabrication labs, and the lessons and potential of low-tech efforts. Research should capture the knowledge and experience of humanitarian workers in the field, including local efforts such as maker communities in Kenya.
2) **Engaging with the private sector:** Humanitarians should engage with manufacturers to produce more robust equipment for field use, speed dissemination of the advances from the commercial sector and tailor user interfaces for use by humanitarians.
3) **Fostering links and collaboration:** Several joint efforts are under way, as well as field-level collaboration. But more can be done face to face and through volunteer and technical communities that focus on 3D printing and local manufacturing, or through communities of practice to help share experiences and ensure that innovations reach greater efficiency and scale. Designs and concepts should be systematically shared through open-source libraries or other mechanisms.
4) **Expanding support for scaling innovation:** Effectively taking advantage of the opportunities for hyperlocal manufacturing will require substantial support for research and development, and for moving promising ideas to a scale where they can have an impact. At present, there are few donors in this area. Notable standouts are DFID's Humanitarian Innovation Fund, USAID's Development Innovation Ventures and the new multi-donor Global Innovation Fund. More coordinated donor and private sector support is needed to advance the ability to experiment, learn from and extend innovations where they can make an impact.

Additional Sources

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