



Routes to Resilience through Distributed Manufacturing and Circular Economy approaches

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Cover image: Global Auto Systems team members assembling 3D printed face shield (Photo Credit: GAS)



Executive Summary

The COVID-19 pandemic and its aftermath has demonstrated the weaknesses of supply chain systems that withhold production control from communities impacted by disasters. Moreover, the pandemic has highlighted that a long-term strategy for resilience is desperately needed so communities are able to handle a wide range of future shocks and challenges that will continue to appear and may not be well anticipated.

This brief shares the key lessons learned from COVIDaction Local Production Local Solutions (LPLS). Through its work, LPLS identified that localisation of production, distributed manufacturing and circular economy approaches can help increase resilience to emergencies and improve the responsiveness of production systems to community needs. These approaches can also help to reduce waste, limit carbon emissions, and mitigate the impacts of production systems on the environment.

This Policy Brief outlines six key pillars of resilient production systems: Flexibility; Collaboration; Local materials; Human potential; Retention of value and Transparency / Visibility. It shares key lessons for any ecosystem actors seeking to support each of these pillars of resilient local production systems, including innovators, policymakers, and investors.

Delivering resilience is a collective effort. Consequently, we hope that the findings here are of interest to a broad readership – including innovators, but also anyone whose work is reliant on sometimes fragile production and supply systems. In practice this could mean those working in a wide variety of fields, including public health, international development, and humanitarian relief.

Introduction

The COVID-19 pandemic and its aftermath exposed the limitations of a reliance on global production systems and long-distance supply chains. Severe shortages in PPE and other medical supplies and devices demonstrated the weaknesses of supply chain systems that shift production control away from communities impacted by disasters. Analysis [from the Lancet](#) showed that in March 2020, only 104 (57%) of 182 countries had the functional capacity to perform crucial activities at national and subnational levels. 32 (18%) countries had low readiness and would require external resources to control an emerging infectious disease event.

All people, but particularly healthcare workers who put themselves at disproportionate risk to protect our communities, have a right to be protected; 14% of cases [reported to WHO](#)



were among healthcare workers – rising to 35% in some countries. Ensuring they have access to the Personal Protective Equipment (PPE) they need to stay safe is an essential component of this protection, as PPE significantly reduces the risk of COVID-19 infection. However, global logistics have been compromised by lockdowns and border controls across the Global South, leaving many businesses without key parts of their supply chain. At the same time, there has been immense global demand for PPE, which is typically single use. Data from global surveys undertaken in 2020 found [that 70% of healthcare organisations](#) in Low and Middle Income Countries lacked PPE. Lower income communities were disproportionately affected by supply chain shortages, with the politically powerful monopolising inadequate global medical supplies.

The aftermath of COVID-19 serves as an important lesson that a long-term strategy for delivering resilient production systems is desperately needed for communities to be able to handle a wide range of future shocks and challenges, beyond global health, that will continue to appear and may not be well anticipated. These include shocks driven by [climate change](#), but also a range of other potential interrelated drivers, including [material insecurity](#), [water scarcity](#), [population growth](#), [conflict](#), and [growing economic inequality](#). Without resilient production systems, there is a risk that communities will not be able to effectively respond to these shocks, meet their human needs, and that wider goals and opportunities may be compromised - including the Sustainable Development Goals.

What is LPLS?

COVIDaction Local Production & Local Solutions (LPLS) is a UK Foreign Commonwealth & Development Office (FCDO) funded program that was designed to address issues around the demand for PPE and other unavailable goods. Utilising the expertise and knowledge base of a consortium of partners, the project began by crowdsourcing and mapping innovative responses in adapting local supply chains of essential goods from global, just-in-time supply chains towards more resilient, shorter, regional chains.

From over 500 entries across three rounds, the project surfaced remarkable pivots and innovations dealing with the demand for unavailable goods. Synergistic approaches of localisation of production, distributed manufacturing and circular economy came to the forefront in the shortlisted entries, and these became key focus areas for the LPLS work. Definitions of these approaches have been provided below. [Nine implementing partners were selected from five countries to participate in LPLS](#), and were provided with small grants to continue to test and iterate innovative solutions and generate real-world evidence.

Key Terms for LPLS

Localisation of production refers to bringing globalised manufacturing systems back into the hands of the producers that work close to where the product is being used. This includes everything from making sure that the products being used are sourced from local materials to harnessing skills and the local ecosystem and ensuring that the factories, and people employed in them, are rooted in the communities that will be using the product, and understand their needs. It also includes ensuring products can be repaired and maintained by individuals in the local community.

Circular economy is a related term and refers to employing more sustainable production principles like reusing materials, reducing or eliminating waste and pollution, and encouraging the creation of products that can be repaired and continually used. In this way, materials are constantly used and then reused to generate different products for local communities.

Distributed manufacturing relates to a decentralized approach for producing materials that has been unlocked by the power of technologies like cloud computing and 3D printing. Using this model, and shared technologies, geographically distributed manufacturers can produce the same products by utilising the same intellectual property. For example, printers located anywhere in the world could theoretically produce the same product if they used the same computer aided design. This model also enables interconnected suppliers and producers to work together to produce a mixture of new goods or services to end customers. These processes unlock economies of scope and provide flexibility that can't be delivered via traditional manufacturing approaches and machines, which require substantially longer lead-in-times to develop new product lines. This flexibility also enables local engineering teams to eliminate unnecessary inventory by creating items on-demand.

Findings: Six Pillars of Resilience through Local Production Systems

Through our work with the innovators and partners on LPLS we have identified six key pillars to enabling resilient production systems. Here resilient production systems refer to systems that can meet the needs of local communities and enable them to thrive, as well as respond quickly to counter the impact of systemic shocks – like a global pandemic or climate change.

Each of these pillars are key qualities of resilient local productions systems that ecosystem actors (producers, policymakers, funders, and others) might support via their work. These encompass different aspects of localisation, circular economy, and distributed manufacturing. In the section below we have provided more details on each of these interrelated pillars, including lessons on how best to support and enable each pillar.

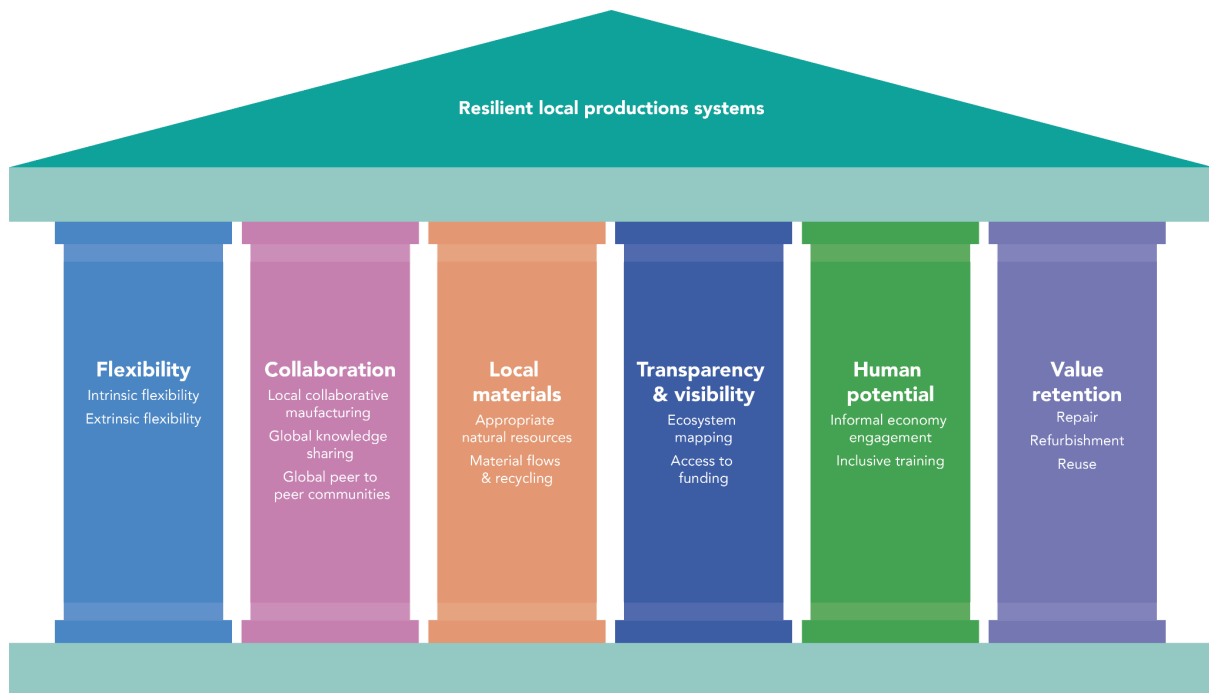


Diagram: Six pillars for resilience in manufacturing and supply chains

1. Flexibility

Technologies, practices, and processes that allow flexible production capacity and allow companies to adapt their range of products in response to market demands, without making extensive changes to their infrastructure or operations. Lack of flexibility means companies cannot respond to sudden changes in the market or take advantage of new opportunities rapidly enough. This was seen clearly during the pandemic as the hyper efficient but rigid modern supply chains were unable to respond to the rapidly changing needs of communities globally.

How can we enable flexibility?

Across the LPLS work, we have witnessed a few key types of innovative flexibility where businesses in LMICs were able to pivot and better respond to the COVID-19 pandemic. We



have broadly split these into two categories which we have denoted as intrinsic and extrinsic flexibility.

Intrinsic Flexibility

This refers to increasing the internal flexibility of production without input from outside the company. One major focus area employed by the LPLS innovators was the use of digital fabrication equipment (including additive manufacturing, Computer Numerically Controlled (CNC) and laser cutting) which are becoming much more widely available. Products which used to require a larger set of machines and therefore greater initial capital expenditure to even prototype are much more accessibly and affordably produced using this technology. By reducing the cost, digital fabrication has a great potential to democratise and localise innovation and subsequent production globally. Additionally, digital designs and expertise can be shared from anywhere in the world meaning that expert led designs can be made locally using computer-controlled machinery.

Extrinsic Flexibility

This refers to activity occurring outside the business itself that increases flexibility. Rather than having heavily flexible internal capacities, mutually beneficial collaboration between businesses enable new products to be produced with only minor changes to each business's practice. This is explored more in the next section.

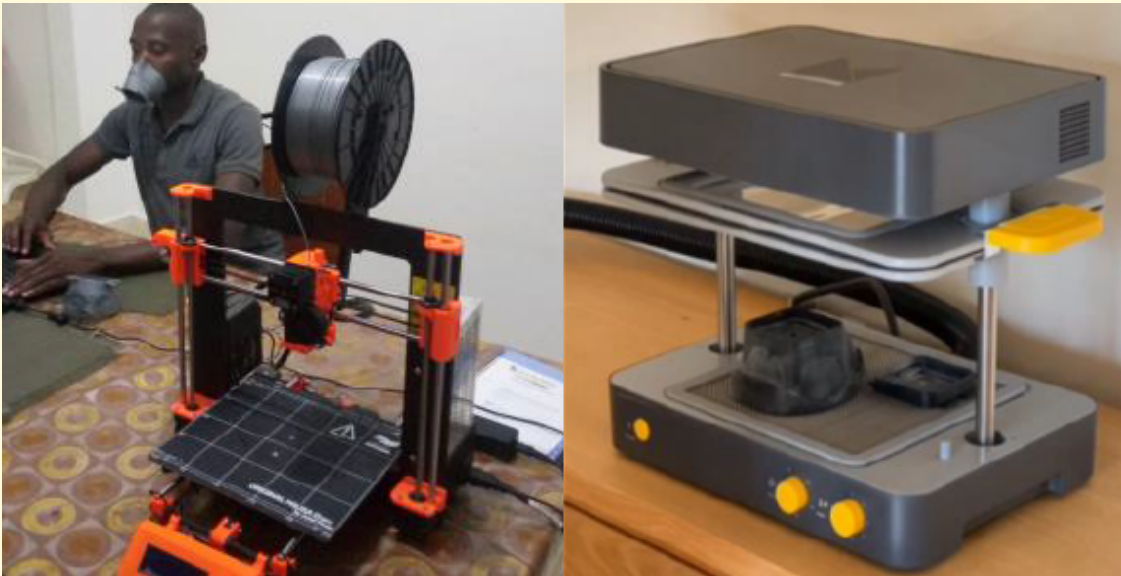
One way to enable greater flexibility within supply chains, is to support organisations which adopt technologies, practices and processes that unlock flexibility. LPLS supported multiple innovators to use digital fabrication technologies to produce items in response to the pandemic, including Global Auto Systems in Uganda, Zener Technologies in Nepal, Safe Motherhood Alliance in Zambia and Clintonel Innovation Centre in Nigeria.

Case Study: Global Auto Systems

LPLS supported Global Auto Systems (GAS) in Uganda to produce face shields and face masks for their community. Using an expanded stock of 3D printers and vacuum moulding machines, they have increased their production capacity from 50 face shields a month to a monthly production capacity of 2,000 face shields and between 100 – 300 3D printed/vacuum moulded face masks during the pandemic.

Importantly, through using digital fabrication equipment, GAS were able to develop products around the specific needs of the local community they served. As innovator Dr William Wasswa put it, "local production promotes inclusive design based on user-centred principles. We have been able to develop the 3D print model of the face masks based on a local population face size, so it removes the possibility of importing masks that don't fit the intended users."

While the GAS production facility is still currently focused on COVID-19 related products, it can be applied to other products with great ease depending on what its community needs. They are currently looking at ways to use this capacity for other medical devices and education supplies for schools, such as digitally designed anatomical models for teaching biology and allowing users to design their own items through their web portal.



3D printed & vacuum-moulded face mask production in Uganda (Photo Credit: GAS)

2. Collaboration

A key factor for creating more resilient ecosystems is creating better connections throughout. Collaboration between producers within an ecosystem can create flexibility within a system, as well as increase the overall potential outputs of the system. This includes the flexibility of producers to make rapid and informed responses to systemic shocks and changing markets. While local collaborations are often effective, knowledge and expertise and peer to peer communities need not be local. Connections between similar operators across differing localities can unlock rapid identification and potential replication of beneficial practices. Stronger connections between producers and local consumers are also important. These connections can enable more targeted contextualised products that fulfil specific needs.

How can we enable collaboration?

There are a range of ways in which collaboration within supply chains, and production ecosystems more generally, can be better supported. This includes supporting open design practices, where designs for in-demand products (such as PPE) are shared openly, so that others with flexible fabrication capacities can begin production. Two key approaches are discussed here.

Local collaborative manufacturing

One way to enable collaboration is to directly facilitate and support collaboration between different local producers. The connection between very different producers is full of potential, including formal-informal collaboration. By working together, the advantages of both can be retained, while offsetting their individual weaknesses, as the case study below on SilAfrica and the Jua Kali demonstrates.

Case Study: SilAfrica and the Jua Kali

LPLS supported a partnership between [SilAfrica and the Jua Kali in Nairobi](#) where the flexibility of human skills found in the informal sector paired with a formal traditional factory production line allowed the rapid pivot to PPE gowns, without major alterations to either infrastructure. In this partnership, SilAfrica, a large scale plastics packaging company, pivoted their operations and re-calibrated some of their machinery to produce plastic sheeting. This sheeting is then transformed into gowns by the Jua Kali - a co-op of 100s of informal tailors. This approach aims to produce over 100,000 medical gowns, at a considerable cost saving which SilAfrica intend to pass on to the buyer as a social good.



[A SilAfrica team member wearing their medical gown PPE items \(Photo Credit: SilAfrica\)](#)

Local collaboration can also be supported via online and offline collective manufacturing platforms. These platforms can help provide different producers and consumers with visibility of one another's needs, and capacities, and serve as a basis for connections and

partnerships. One example of an effective platform was the Makerko platform, developed by Zener Technologies. See below for more details.

Case Study: Zener Technologies

[Zener Technologies in Nepal](#) have a range of digital making technologies and traditional machinery that can be applied together to many different outputs. LPLS has supported them to create an online platform called Makerko that connects makers across the region, and allows consumers in Nepal to access the collective manufacturing capacity of a range of producers. The platform supports consumers to find producers that are as local to them as possible, and supports manufacturers to produce products that require a range of different production methods, and inputs.

During the pandemic, to make a face shield, the production involved assembly across different neighbourhoods in Kathmandu, Nepal's capital and largest city. The frame was created in a factory in Baniyatar; the elastic came from two workshops in Thamel. The visor sheet was laser cut in two locations, then assembled and packaged at Balaju.

As Zener co-founder Ram Chandra Thapa explains, collaboration can enable new, more inclusive, ways of working, that go against the grain of globalised supply systems:

"I have witnessed this pandemic as an innovation and market opportunity for the small local enterprises breaking the mould of established supply chain systems. Companies have started making sanitiser dispensers, foot-powered hand wash stations, robots for delivering supplies in isolation wards, PPE, disinfectant robots, health care systems, thermal scanners, and much more. These are the collective efforts small local businesses are making as a response to the pandemic."

Peer-to-peer learning communities

As part of the LPLS work an online peer-learning community was developed, so that innovators could share their learning with one another. The network enabled rapid identification and replication of beneficial practices.

In one example, our innovator Safe Motherhood Alliance (Zambia) required umbilical cord clamps for their baby delivery kits. Zener Tech (Nepal), along with Field Ready and the Frontier Technologies Hub [had already done work specifically on this problem](#). LPLS was able to connect them through the peer-to-peer community work and facilitate knowledge sharing so that SMA could begin 3D printing the clamps. These parts are now included within baby delivery kits that SMA produce and distribute to expectant mothers in Zambia.

3. Local Materials

The identification and utilisation of local materials provides a key route to resilience. If value creation is concentrated overseas, then the local economy will always come last, and the carbon footprint of shipping will always be higher than necessary. During the pandemic global logistics broke down, and within import-dependent, lower-income countries, it is people that pay the greatest price for that. If materials can be sourced and processed locally then supply chains are less reliant on distant economics, and more revenue can circulate and benefit the local community.

How can we enable identification and utilisation of local materials?

Biomaterials

Some LPLS innovators demonstrated the benefits of manufacturers identifying and utilising local biomaterials. These are sustainable, renewable materials, which biodegrade safely within the natural environment, and provide an alternative to conventional and petroleum-based materials, which dominate global production.

Case Study: Safe Motherhood Alliance

LPLS worked with [Safe Motherhood Alliance](#) in Zambia who have moved to producing sanitary pads from banana fibre as a biodegradable locally sourced alternative to pads that are imported at multiple times the price and just go to landfill. These pads are sterilised following production and don't contribute to landfills. Importantly, SMA were able to sell the pads at a considerably lower price point than existing alternatives, delivering significant benefits, as SMA founder Muzalema Mwanza told us;



"We are excited about this product because we also inadvertently solved a problem for adolescent girls who miss school because of their period and can't afford the regular sanitary pads because of cost."

Sanitary pads made from absorbent banana skin fibres.
Image credit: Safe Motherhood Alliance

Case Study: CIST Africa



LPLS also supported the Centre for Innovation, Science and Technology East Africa Industries Limited (CIST Africa), based in Kenya, to make better use of biomaterials to help respond to the pandemic. [CIST Africa explored the possibility of recycling Water Hyacinth \(aquatic weed found in Lake Victoria\) into ethanol for use in hand sanitiser production.](#) Water Hyacinth is an invasive species and can clog waterways at the expense of local fishers, threatening the food security of the local community. CIST's work has helped to reduce this problem by providing a profitable solution to an economic problem. In the longer term, CIST is considering repurposing the ethanol for a multitude of other products, from biofuels to surgical spirits to industrial applications.

CIST East Africa alcohol-based hand sanitiser (Photo Credit: CIST)

Material recovery and reutilisation

Local economies can also benefit from better identifying and reusing the materials already found within supply chains. Indeed, once materials have entered the local arena, their use should be maximised as much as possible.

LPLS has been working with two companies in Africa who look to improve the utilisation of waste materials from consumer and production sources. [Garbage In Value Out](#) in Nigeria collects and recycles plastic waste from households, individuals and businesses. Their process includes washing, drying and shredding these materials into very small granules, which are then used to produce injection moulded face shields.

LPLS also supported [Taka Taka Waste Solutions](#) in Nairobi to pilot an integrated waste management and recycling solution for Covid-19 PPE. The company is piloting a collection-return system of traditional PPE gowns from local health centres. Here, used PPE medical gowns are gathered in various locations in containers and stored using appropriate health and safety measures. The materials are then sorted with the non-plastic parts, disassembled and processed into high quality recycled plastic pellets for further use by identified off-takers.



Converting recycled bottle caps to PPE face shields (Photo Credit: GIVO, Nigeria)

4. Human Potential

Human skills, potential and agency underpins each of the key routes to resilience outlined in this paper. Indeed, without doubt, the greatest resource that a community has is the people that comprise it. They are also the greatest source of the requirements of a healthy community. If human potential is not fully nurtured then their value will simply be outweighed by their requirements, and the community will not be self-sustainable or resilient, without continued external input.

The informal sector and the 'gig economy' is a highly under-potentialised sector, that could be better incorporated into wider industry if the right mechanisms could be developed. It accounts for [up to 90% of the jobs in the lowest income Sub-Saharan countries](#) such as Central African Republic and the Democratic Republic of the Congo. However, care must be taken in initiatives that disrupt the status quo of this sector.

How can we enable the realisation of human potential?

Direct offline engagement for funding calls

When LPLS began planning its outreach to find the innovations that were responding to the covid pandemic, we set a goal to engage with offline communities in seven focus countries — Nigeria, Ghana, Cameroon, Uganda, Zambia, Kenya and South Sudan. COVIDaction and [Afrilabs](#) partnered to ensure that technical support and financial assistance got to the last mile and other hard to reach communities. Afrilabs organised local scouts to go into communities and seek out grassroots innovators who were doing great things for their community, but who we wouldn't reach with an online media push. We collected 79 applications across 7 countries, surfacing some remarkable responses to dealing with local demand for unavailable goods — including hand washing stations, sanitisers, and PPE products. Working with the scouts helped us to shape a strategy for inclusiveness that breaks common grant cycles, uncovers new methodologies, and brings out very different innovations for support. More information can be found [here](#), with various insights that the team found through this process. One overarching point was that local grassroots producers lacked confidence in stakeholders who provide funding and other opportunities, as they had had little contact with them in the past. This points to gaps in the reach of funders in areas that could hold great potential to impact local communities.

Training and capacity building



Capacity building training with locally scouted producers (Photo Credit: Afrilabs)



From the scouting work outlined above, the LPLS team moved to find ways to support these local producers. Capacity building workshops in an offline / face to face format were provided by Afrilabs via three support hubs dubbed 'Offline Support Hubs'. In particular, producers were provided with technical support to address the challenges they had previously experienced, when accessing traditional funding opportunities.

To evaluate the success of the initiative five key performance indicators (KPIs) were developed — resilience, confidence, knowledge, self-reliance, and understanding. Along those axes, key areas of insights were garnered through conducting the sessions and feedback shared from the offline capacity building support. Findings across these KPIs and an overview of the offline communities initiative can be found [here](#).

5. Retention of Value

Critical to ensuring products meet the continued needs of local communities, is maximising the length of time that those products give value to the community. Many products have built-in obsolescence and product life-cycle is often not considered, especially when produced overseas. Increasing product life-cycles can reduce the burden on the production ecosystem, and capacity can be built in resultant services such as repair and maintenance.

Fortunately, one of the advantages of low income markets compared to high income markets is that low income communities do indeed maximise product value as much as possible. This is precisely because access to what is needed is poor, and the replacement of products is a considerable financial burden or might just not be possible. This is why in LMICs, the informal repair economy has a very strong presence across sectors, even if the products they repair are still not designed with optimised repair in mind. Ways to optimise these repair economies must be found.

In building local production, a stronger focus should be placed on repairable design. In local systems, there is an opportunity for the manufacturer to obtain revenue from supplying continued service to consumers in the form of maintenance and spare parts. It should also be noted that design for repair usually supports ease of disassembly, which would enable better material recovery and upgradability as additional routes to value retention.

How can we enable greater retention of value?

Provide training and raise awareness

For existing products, LPLS has been looking at ways to increase the potential of repair, particularly regarding medical equipment. Health administrators and donors in low-income



settings often fail to recognise the maintenance and repair problem, or label it as a partner problem. Improving this situation could be done with training in these areas, preferably via manufacturers or topic experts. LPLS worked with Amalthea Trust to remotely connect top UK expertise with [Biogenics](#) staff in Uganda to train them on specific medical imaging equipment repair, at a day-long workshop. LPLS also supported [Clintonel](#) in Nigeria to develop their hardware community, which aims to facilitate knowledge sharing around repair to increase this potential.

Advocate for repairable design

In building local production, a stronger focus can be placed on repairable design. As it is local, there is an opportunity for the manufacturer to obtain revenue from supplying continued service to consumers in the form of maintenance and spare parts - this then becomes attractive for innovation. It should be noted also that design for repair usually also supports ease of disassembly, which would enable better material recovery and upgradability as additional routes to value retention. One way in which different actors could look to support repairable design is through advocating for 'right to repair' initiatives and policies - similar to those the UK government is planning to adopt.

Facilitating collaboration between producers and the informal sector

In the context of countries like Kenya, fostering collaboration between producers and the informal sector also offers potential for enabling retention of value. Whereby, as the SilAfrica case study outlined above indicates, partnerships between the informal sector (represented co-operative organisations like the Jua Kali) and producers, might offer great potential - including, in this case, the potential for a collaborative repair economy.

6. Transparency and Visibility

In production ecosystems, good decisions can only be made with adequate information – which enable opportunities to be identified, and risks need to be weighed up. This is true for producers and investors. Consequently, system wide data and intelligence is required. Indeed, system-wide access to data can support collaboration, connect the inputs and outputs of production and support the efficient re-allocation of 'waste'. To provide ecosystem actors with system wide data and intelligence, transparency and visibility are essential.

Transparency

The ecosystem around ventures needs to be transparent - both to the ventures within it and to outside investment. When this transparency is lacking, ventures will miss opportunities to collaborate or access resources; and investors will not be able to fully comprehend the



ventures they might support, particularly if the ventures themselves have complex relationships in the ecosystem around them.

Visibility

Ventures need to be visible. This goes beyond marketing and branding, which is of course vital if ventures want to reach their consumers. They must be visible to potential collaborators in the ecosystem as well, and this means more than just what they sell. By making visible the capacity and skills they possess, their potential for further business can be shown, without being transparent enough to jeopardise their competitive edge.

How can we enable greater transparency and visibility within ecosystems?

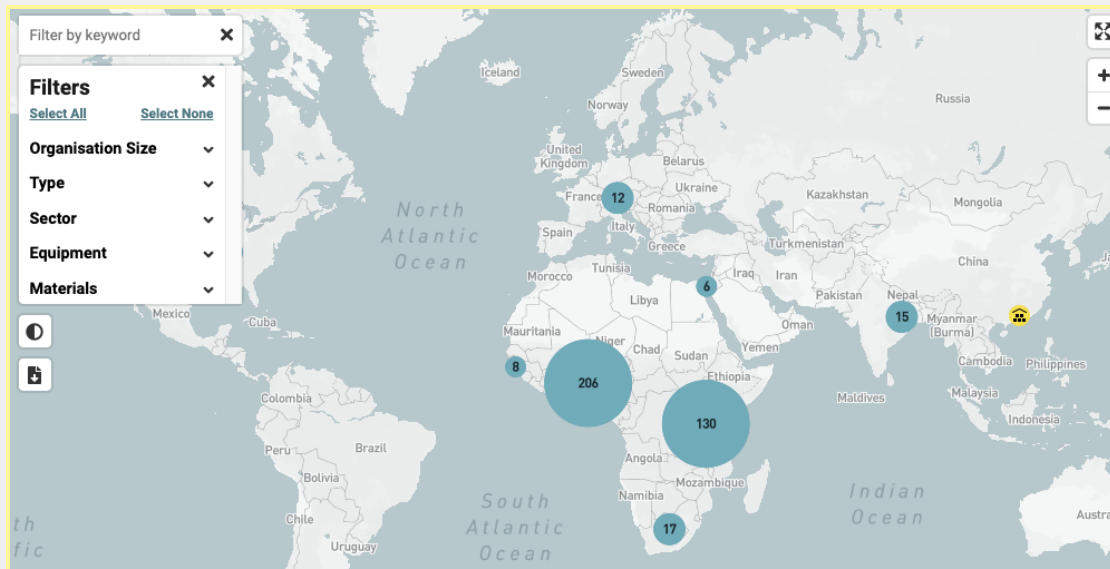
One approach to improving visibility and transparency is through mapping producers and innovation activity. Maps, such as those created by the Innovation Action initiative (see details below), can allow ecosystem actors to identify what facilities and equipment are in use within maker communities, and enable someone who wants to access manufacturing facilities to find out who they should be contacting. In doing so, they provide local ecosystems with visibility which enables both collaboration, and the delivery of products produced via flexible manufacturing techniques and from local materials.

Another approach for enabling transparency and visibility is for organisations to map 'material flows' within their ecosystem. These are maps which record the mass and flow of different materials both in, and out of production sites, and provide a visualization, which extends beyond mapping actors, facilities and equipment. [While data poor environments in many developing economies pose a challenge to effective analysis of these flows](#) - such analysis can unlock wider benefits - including the identification of opportunities for better utilisation of local materials in production, or for embedding circular economy approaches within value chains.

Case Study: Innovation Action

LPLS is part of the Innovation Action initiative that aims to create mappings of various sectors, so that local ecosystems can be better understood, and potential beneficial relationships can be identified. As part of this over [600 producers have been mapped](#), mainly within Africa, with materials equipment and product types as well as other data being available. Other sectors are being mapped concurrently, and by housing these maps together, we create a cross-referenceable resource, and potential partnerships can more easily be recognised. The initiative is also partnered with [the Open Know Where Project](#), which aims to allow different mapping initiatives to cooperate more easily with a common data standard. This is guided by the

principle that the best way for all these resources to bring social good is by working together and compiling unified data on all of the various sectors and specific aims that different organisations have.



Innovation Action map of producers

Call to action

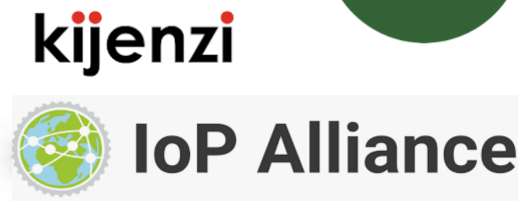
If you are interested in learning more about the work of COVIDaction Local Production Local Solutions, or want to collaborate and share learning on Distributed Manufacturing and Circular Economy approaches, please get in touch!

Please contact us at hello@frontiertechhub.org.



Our Friends

As well as our original consortium of partners, here is a list of some of the amazing organisations that have helped us make COVIDaction LPLS what it is today:



In addition to the organisations represented above, we would also like to thank African Emergency Tech Response Forum, and Manufacturing Africa.

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Women in Kathmandu, Nepal working on the assembly of safety goggles made via an injection moulding process (Photo Credit: Zenner technologies)