African European Maker Innovation Ecosystem

Deliverable 4.4

Contracts – Model & Prototype

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DELIVERABLE

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Abstract (for public dissemination only)	This document examines contracting models for distributed manufacturing, highlighting the need for flexible, role-based frameworks and digital tools to address quality, payment, legal, and coordination challenges while unlocking its potential for localised, efficient, and sustainable production.
Keywords	Contracting, distributed manufacturing, roles, local production, automated system, orders, final report

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List of Abbreviations

A-MEG	African Makerspace Ecosystem Gathering
AQL	Acceptable Quality Level
CNC	Computer Numerical Control
DCM	Decentralised Manufacturing
DFID	**UK Department for International Development,** dissolved in 2020 and replaced by replaced by **Foreign, Commonwealth & Development Office (FCDO)**
DIH	Digital Innovation Hub
DM	Distributed Manufacturing
DMP	Data Management Plan
DoA	Description of Action
IMA	Innovative Manufacturing in Africa
IOP	Internet of Production Alliance
IoT	Internet of Things
IP	Intellectual Property
OCBM	Open Catalogue of Business Models
ORDP	Open Research Data Pilot
QA	Quality Assurance
QMS	Quality Management System
RFID	Radio Frequency Identification
RISA	Research and Innovation Systems for Africa
STEM	Science, Technology, Engineering, and Mathematics

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TRL	**Technical Readiness Level**
VF	**Valueflows**
ZSI	**Centre for Social Innovation**

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Executive Summary

This report presents the outcomes of research into contracting and order processing models tailored for distributed manufacturing (DM). Distributed manufacturing represents a shift from centralised production to localised, smaller-scale manufacturing networks, enabling products to be designed, produced, and distributed closer to end-users. While this approach offers flexibility, cost reduction, and local empowerment, it also introduces significant complexities in contracting due to decentralised roles and varying stakeholder responsibilities.

Key Findings

Contracting Models for Distributed Manufacturing

Distributed manufacturing contracts must address a broader spectrum of scenarios compared to centralised manufacturing to effectively manage the multiparty contractual relationships required in these various situations. Distributed manufacturing often involves multiple entities, each with roles unique to this context, differing from those in a centralized production workflow.

Ensuring appropriate specifications in product documentation and contract terms is critical to addressing key contracting challenges, particularly in maintaining consistent quality levels across multiple manufacturers, defining responsibilities across jurisdictions, and accommodating unique production capabilities.

Role-Based Frameworks

A detailed definition of roles in each different DM scenario must form the basis for an adaptable and flexible contracting solution. This report highlights and emphasises the role of makerspaces as hubs for local production, quality control, skill development, and machine rentals.

Prototyping and Trials

Virtual and physical trials were conducted to test prototype systems, showcasing scenarios where multiple makers collaborate under a unified contract. These trials included the successful production and quality assurance of healthcare products. The trials highlighted the importance of clear workflows, automated quality assurance, and effective coordination to streamline DM processes.

Digital Contracting System

A prototype of a digital contracting framework was developed based on a selected DM scenario and simulations of order placement and completion were carried out to test how such a system could ensure transparency, accountability, and efficiency. This system highlights the importance of clear role assignments, clear contractual relationships, and automation of distributed workflows.

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Applicability in Distributed Manufacturing

The findings reveal significant potential for DM to democratise production, particularly in underserved regions. By leveraging adaptable contracting models and digital tools, DM networks can improve cost efficiency, reduce environmental impact, and boost local economies. However, challenges such as quality assurance, role clarity, and legal considerations need further attention and exploration.

This report concludes with recommendations for further research, collaboration, and funding to develop scalable and sustainable DM systems. By advancing digital contracting and supporting makerspaces, the proposed framework can accelerate DM adoption globally, especially in sectors like healthcare and humanitarian aid.

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1. The Distributed Manufacturing Approach

In its 2023 report [A Framework for Scaling Distributed Manufacturing in the Global South](), produced in collaboration with [Frontier Tech Hub](), [Manufacturing Change]() seeks to clarify what distributed manufacturing (DM) is and to develop a framework of strategies to scale it in the Global South.

*"There is no generally accepted definition of Distributed Manufacturing (DM). We understand it as a decentralized approach to production that enables **smaller-scale manufacturing** much **closer to the end-user**, often leveraging recent **breakthroughs** in production and infrastructure technologies. In this model, products are designed, produced, and distributed through a **network** of local or regional manufacturers, rather than being manufactured at a centralized location and shipped to customers" (Manufacturing Change, 2023, p. 3).*

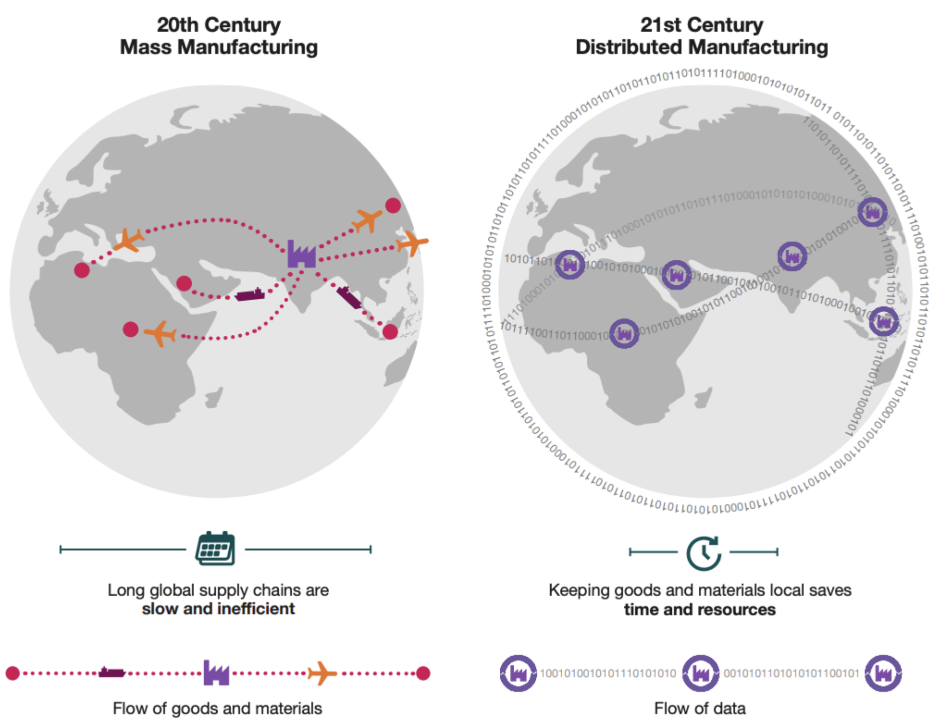

Figure 1. Mass Manufacturing vs Distributed Manufacturing
Source: Manufacturing Change (2023), p. 3

The evidence is that DM is more complex than traditional manufacturing, as mentioned previously. There are different types of DM. The models differ based on:

- **Product Variety,** or how flexibly a workshop can produce different items
- **Network Type**, or a typology of nodes and networks built around them
- **Degree of Coordination**, or how closely coordinated the different nodes are

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Many large-scale manufacturers use DM as an approach—in order to move production closer to where items will be needed. It can be argued that manufacturing at various production sites owned by a multinational corporate actor is a form of DM, whether or not the actor uses this term itself. In many cases, such actors are can be said to be following a narrower definition (than the one, cited above, as proposed by Manufacturing Change) of DM, with DM in this multinational corporate context denoting use of flexible manufacturing technologies such as 3D-printing, laser-cutting, and computer numerical control (CNC)-machining. Spare part production is by far the most prominent area where actors in the private and defence sectors use decentralised manufacturing—instead of stocking them or waiting for them to be shipped, spare parts are being produced on site, in the Global North and South alike.

DM organisations face growth challenges, often internalising costs like workforce-training, custom designs, and navigating procurement policies, which would be more efficient if addressed at the ecosystem or global level. Sustainable scaling requires collective efforts within ecosystems of stakeholders—spanning industries, governments, and local communities—focusing on partnerships, standardisation, skills development, supportive policies, and holistic approaches to address social, economic, and environmental goals, especially as crises increasingly act as catalysts for DM growth.

2. Contracting in Distributed Manufacturing

2.1. Mapping the Ecosystem

In the scoping exercise Report 1 produced by the Internet of Production Alliance (IOP) and Sensorica, entitled *Mapping and Building Understanding: Means to align agencies in material peer production, to increase its dependability*, the contrast between traditional production models and distributed production models is made clear, including the fact that contracting for DM is more complex.

The organisations and individuals participating in distributed production are all intertwined. They can share agents, share resources, and even mutualise processes. They often have a large degree of openness and their interactions are complex. For example, if we look at the mAkE Open Catalogue of Business Models (OCBM), a makerspace could engage and be contracted as a machine and material provider, for product development, for manufacturing, and/or for quality control.

Interviews[1] and workshops were held to build an understanding of the different distributed manufacturing and contracting processes.

Contracting involves agreements between people and organizations engaged in production, where flexibility and adaptability play a crucial role in navigating challenges. This report underscores the added complexity of contracting in DM compared to traditional models.

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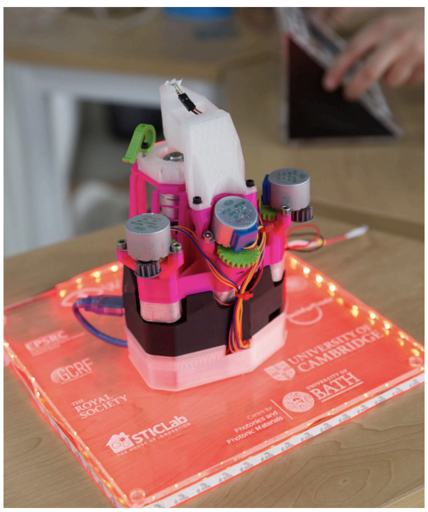
2.2. Distributed Manufacturing of Open Hardware

The *Distributed Manufacturing of Open Hardware* report, compiled by the Open Hardware Distribution & Documentation Working Group and published by NYU (Weinberg2021), explores the challenges and opportunities of achieving truly distributed hardware production in the context of openly licensed designs.

"Open hardware promises to combine open, distributed design with localized, distributed manufacturing. While the open and distributed design promise of open hardware has been realized time and time again, the goal of truly distributed manufacture of hardware has proven harder to achieve." (Open Bio Economy Lab, University of Cambridge)



The report draws on the work of the Open Hardware Distribution & Documentation Working Group (2020-2021), which focused on creating the commercial, legal, and manufacturing infrastructure needed to support a global network of local manufacturers for the OpenFlexure Microscope. **The report contains valuable insights in the context of developing a contracting system, as it reflects on research into the differences between contracts for traditional centralised manufacturing and contracts for DM.**

Picture 1. OpenFlexure Microscope

Developing a contracting system for DM, as exemplified by the OpenFlexure Microscope, must account for the distinct challenges of hardware production and distribution. While the microscope was already a "functional design reproducible by individuals"[1], scaling it to batch production required significant transformations, including addressing the complexities of manufacturing infrastructure, material costs, and quality assurance. A contracting system needs to accommodate these factors, ensuring consistent quality across manufacturers, navigating international logistics and regulations, and supporting the coordination of diverse entities involved in the production and distribution process.

This highlights the importance of designing adaptable, scalable contracting frameworks tailored to the specific demands of hardware manufacturing.

[1] Distributed Manufacturing of Open Hardware - a Report of the Open Hardware Distribution & Documentation Working Group (2020-2021).
https://www.law.nyu.edu/sites/default/files/DistributedManufacturingofOpenHardware.pdf

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2.3. Distributed Contracting

Contracting in distributed manufacturing shares many of the same principles as contracting in other scenarios, particularly concerning quality assurance, insurance, logistics, delivery, materials, and responsibilities. These core issues remain consistent regardless of whether the manufacturing process is centralised or distributed.

However, **what distinguishes distributed manufacturing from traditional centralised manufacturing is the allocation of roles and responsibilities.** In a centralised setting, the manufacturer typically handles a wide range of tasks, shielding the buyer from many of the complexities involved in the process. The contract generally involves a direct relationship between the buyer and a single manufacturer who assumes most of the roles and responsibilities.

In contrast, **distributed manufacturing involves multiple entities, each potentially taking on different roles within the manufacturing process.** This dispersion of responsibilities means that the buyer might need to engage more directly with aspects of the process that would otherwise be managed by the manufacturer in a centralised setting. As a result, the contractual landscape becomes more complex, with the distribution of roles among various entities leading to **multiple variations in how responsibilities are assigned and managed.** The complexity in contracting arises from the need to clearly define and coordinate these distributed roles to ensure a cohesive and effective manufacturing process.

The complexity of contracting in distributed manufacturing is further compounded by the numerous permutations in how roles and responsibilities can be allocated among the various entities involved. Unlike centralised manufacturing, where roles are typically consolidated within a single entity, distributed manufacturing requires a more adaptable contractual framework to accommodate the diverse ways these roles can be distributed.

This **flexibility is essential** because the distribution of roles may vary significantly depending on factors such as the availability of local facilities, the specific skills and expertise of each entity, access to materials, and the unique know-how that different participants bring to the table. Each of these factors influences how a particular role within the manufacturing process might be executed, necessitating a contracting ecosystem that can account for and adapt to these variations.

To effectively manage this complexity, contracting in distributed manufacturing must be designed with a high degree of flexibility, allowing for different configurations of role distribution while still ensuring clarity, accountability, and cohesion across the entire process. This adaptability ensures that, regardless of how responsibilities are divided, all parties involved can work together efficiently to achieve the desired outcome.

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3. Evaluation of Existing Contracting Systems

3.1. Field Ready Smart Contract Simulation

In 2017, Field Ready ran a simulation trial of a DM contracting system. As part of the Frontier Technologies Livestreaming programme, Field Ready and DFID Nepal tested the hypothesis that:

"The 3D printing sector in Nepal is currently underdeveloped as an industry, but increased organisation, decreased costs and better customer engagement could significantly develop the sector to the point where regular-use items are ordered from suppliers in the sector as standard" (Pushing forward 3D printing in Nepal, Britton B. 2018).

Picture 2. Products such as this 3D-printed model of an earthquake reconstruction house are in demand in Nepal's humanitarian aid sector.

At the beginning of 2017, Field Ready identified a significant number of organisations working with 3D design and 3D-printing in Nepal. They started the process of registration for a 3D-printing association, named the Forum for Digital Manufacturing. At the same time, Field Ready was developing a minimum viable product (MVP) code for MakerNet. The objective was to combine a network of small-scale manufacturers (using 3D printers) with smart contracting based on blockchain technology and automated online cryptocurrency payment systems (Ethereum, in this case), so as to enable customers to procure multiple items from a network with the same ease and costs that they would experience procuring from a single supplier.

Smart Contracting prototype trial

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The MVP developed for MakerNet was founded on the idea of a blockchain-based smart contracting system facilitating automated Ethereum cryptocurrency payments to suppliers, which would theoretically make it as easy for a customer to deal with a hundred suppliers as it is to deal with one. It also allowed buyers to provide suppliers with some up-front working capital.

Smart-contracting for DM is one means that Field Ready Nepal has identified to enable humanitarian organisations, and other customers, to source portions of a large order from multiple, small-scale, local manufacturers. The specific element of the MakerNet system tested was the acceptable quality level (AQL). The AQL specifies the quality expectations of the product, in this case a 3D-printed wrist brace. The AQL was controlled by a third party and its inputs onto the blockchain automatically triggered approvals and payments to the suppliers.

Components of the MakerNet trial system

- Distributed manufacturing payment
- Contracting
- Quality assurance
- Smart contracts run on Ethereum to test the blockchain.
- Ethereum Ropsten platform automates the administration of a DM order between three suppliers
- Each customer order has its own unique smart contract
- As the order progresses, actions are automatically triggered, thus driving the process forward

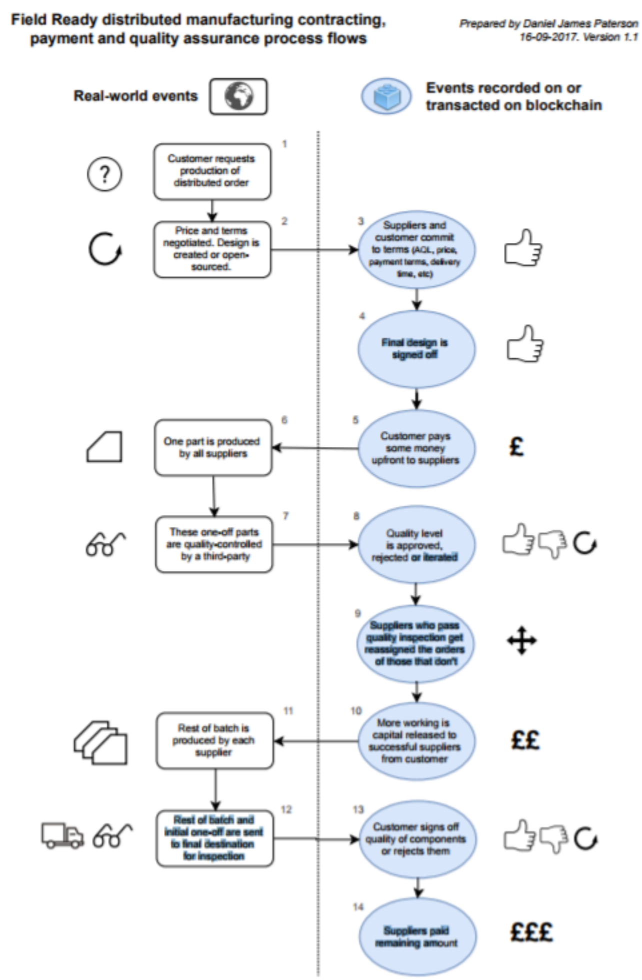

Figure 2. MakerNet trial flow chart

Main functions

- Approval of supplier contract and design onto a blockchain
- Accepted quality approval inputs automatically trigger payments

The smart contract simulation engaged with organisations and individuals, and was run with 8 participants: 1 customer, 3 suppliers, 1 quality controller, 2 simulation observers, and 1 simulation support person. One supplier was assigned (in secret) to deliberately fail the full batch during quality control.

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The trial demonstrated the potential for distributed contracting systems to streamline interactions between customers and multiple small-scale manufacturers, enabling efficient procurement of parts or products from diverse suppliers. It also showed how the use of blockchain-based smart contracts could help simplify the process by automating payments, approvals, and order progress based on predefined triggers such as quality checks. However, challenges related to blockchain adoption were revealed, including the technical knowledge required to implement and manage smart contracts and the costs associated with blockchain transactions (e.g., Ethereum gas fees).

These findings provided a strong foundation for refining distributed contracting systems and exploring their broader applicability in various industries and regions.

3.2. Distributed Manufacturing Trials

The Innovative Manufacturing in Africa (IMA) project was a 12-month sister project to the mAkE project, implemented by Distributed Manufacturing Limited with funding from the Research and Innovation Systems for Africa (RISA) Fund. DM trials, supported by the IOP, were held as part of the project between October and December 2023. The aim of the trials was to test a system that allows multiple makers to participate in distributed production of goods for local use.

Three trials were conducted with makers in Ghana, Kenya and South Africa, to produce 1,125 products, with nine selected IMA makerspaces (three in each country) conducting quality control checks on the products. This distributed production effort was significant with makers in three countries completing the same steps at the same time. Additionally the production needed to ensure defined quality standards in order to be distributed.

As part of the experiment, distributed contracting for DM was tested in the following scenarios:

- One single maker
- Several makers at a single makerspace
- Several makers at several makerspaces

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Picture 3. Quality inspection of the produced writing aids at DTI Makerspace, Accra (Oct. 2023)

From October to November 2023, makers in Ghana, Kenya and South Africa were to make:

- 100 simple devices (writing aids) for the 1st trial
- 20 simple products (test tube racks) for the 2nd trial
- 5 complicated products (tibial fracture fixators) for the 3rd trial

Three engineering experts participated in the selection of open hardware to be produced. They provided the technical specifications and documentation, as well as the quality inspection brief.

Testing distributed production across three levels of complexity and value provided insights into contracting and quality systems.

<u>The Process</u>

The scenario for the distributed manufacturing trials was as follows:

1) The buyer sent out a call for producing predefined products
2) The call was shared with the maker communities in Ghana, Kenya and South Africa
3) Manufacturers (makers) examined the product specifications and sent in offers
4) Makers submitted their quotes
5) The buyer selected the makers to participate in production, and contracts were signed
6) The buyer processed the payment, to the makers, for the production, in line with the contracts
7) The products were manufactured by the makers
8) The products made were delivered to the affiliated makerspace for quality inspection
9) Once the products passed quality inspection, makers received the final payments for the production
10) Final products were donated to local healthcare facilities

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A process workflow was designed to identify each role covered by the participants. Each swimlane corresponds to an entity and the actions he will have to make in the process.

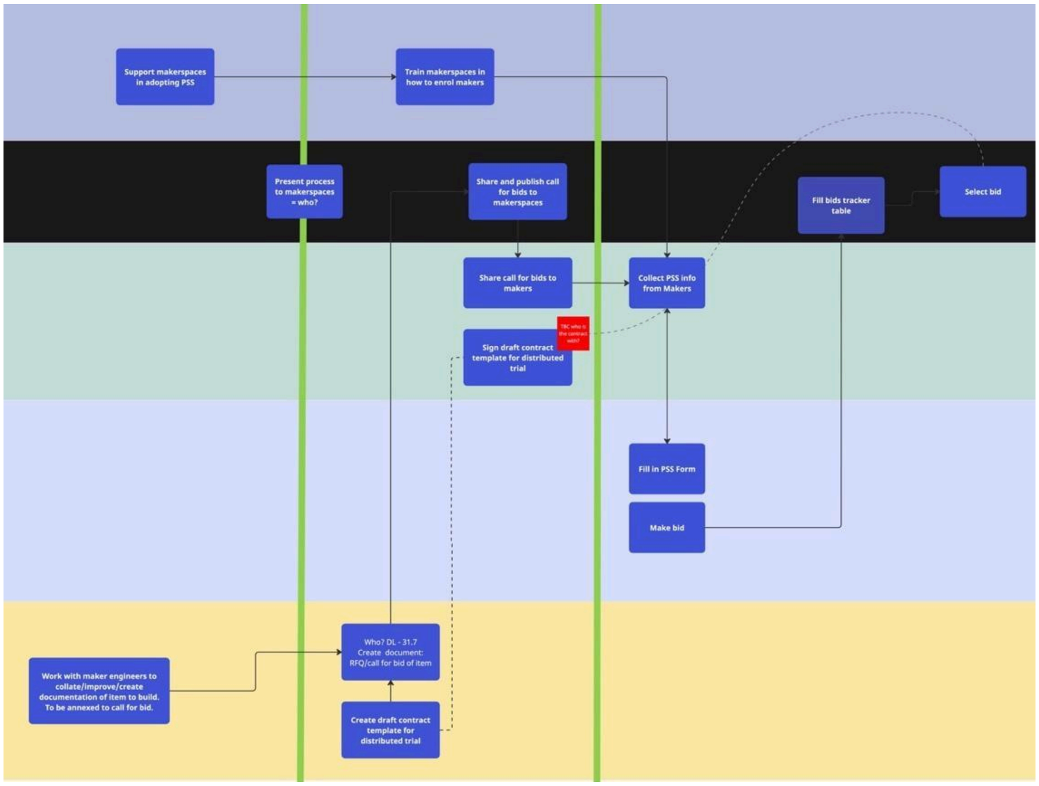

Figure 3. IMA project: Process workflow for distributed production trials (2023)

The Contract

A [Contract & Quotation template]() was shared with the makers to help them submit a quotation. It highlighted the minimum required information that needed to be in the quotation. The maker could also add additional information to their bid, such as a portfolio, customer feedback, background, pricing for different quantities.

In the contract, the maker was required to specify:

- the machine(s) used for the production
- that the maker in charge of the production has a Maker Passport[2]
- minimum and maximum quantity they were committed to produce, and the price for it: "*The total price per item must include all costs related to production including material, energy, labour, quality assurance, marking and/or packaging, handling and delivery costs. International shipping of the items was not required and (...) not included in the price.*"

[2] Part of the initiatives developed within the mAkE project, the Maker Passport aims to enable participating makers to communicate experience and skill levels automatically for ease of navigation through the ecosystem of Digital Innovation Hubs (DIHs).

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What was *not* part of the contract used in these trials:

- Warranty
- Insurance

The Payment

The makers were asked to define their requested payment schedules:

- 0%-100% before production begins
- 0%-100% during production
- 0%-100% upon delivery
- 0%-100% after completion of quality inspections.

In this experiment, the colour and the material used for the production were left at the choice of the makers. All the expenses related to the raw material, and machine use was at the charge of the manufacturer.

The Quality Inspection

The nine IMA makerspaces participating in the project were asked to play the role of quality inspector and receiver of the produced items, with the ultimate aim being to deliver the items manufactured to health care facilities as donations. The makers had to sub-contract the makerspaces for the quality inspection, and (where production occurred at the makerspace) for use of the machines and the materials at the space.

We observed that when the production happened in the makerspace, the items were generally more compliant with required quality levels than when the production occurred externally.

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Picture 4. Quality inspection of tibial fracture fixators produced at FabLab Winam, Kisumu, Kenya (Nov. 2023)

Results & Learnings

Between August and November, 27 makers locally produced a total of 1030 items, out of the 1,125 initially planned: 825 writing aids, 159 test tube racks, and 46 tibial fracture fixators. A total of 97 items did not pass the quality inspection and 56 had to be remade after being considered defective at the inspection.

Having the makerspaces involved in the quality inspection succeeded technically, financially, and in terms of building the spaces sustainability. The nine participating makerspaces provided valuable technical insights on the production throughout the process (when the production was happening in-house). The spaces also ensured standardisation of packaging and labelling. In addition, the spaces were able to increase their financial sustainability by renting their machines for production, and their overall sustainability by training members on new skills, and providing guidance on production of high-quality products. The experiment created traction for the spaces with new makers and their local communities, who saw the opportunity to use the makerspace and their machines as tools for production and not only for training and prototyping.

Among the things we learned from this experiment was that **there is not one scenario for DM and, therefore, for contracting of DM.** Each makerspace has its own business model, expertise, and priorities. Another scenario surfaced from these trials where the makerspace play the role of project manager for a production and act as the liaison between the buyer and the manufacturers, taking care of all

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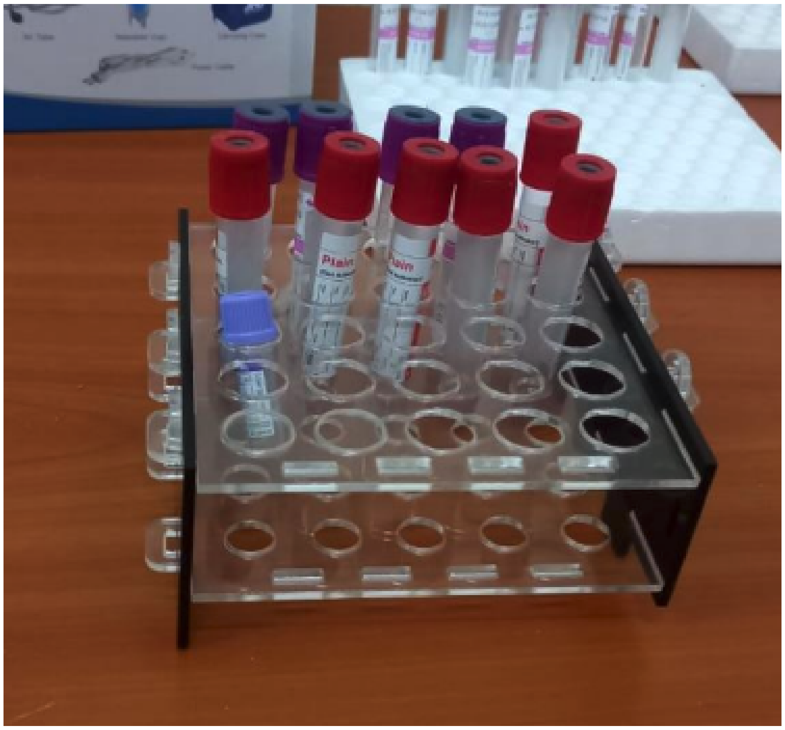
documentation, sharing the order, controlling the production until the delivery of the production to the client.



Picture 5. Test tube racks produced at I.O.Me254, Lamu, Kenya (Nov. 2023)

4. Digital Contracting System

4.1. A System-of-Systems

In distributed manufacturing scenarios, the management of contracts and contractual relationships must reflect the variety of roles and role distribution. Since there is no single method of production within the distributed manufacturing ecosystem, any system that helps people manage contracts and contractual relationships must be able to reflect this variety.

We need to take a system-of-systems approach to this, where different parts of the process that are carried out by entities fulfilling the different roles, need to have the flexibility to allow these entities to use tools that are best suited to their own needs. These tools may be related to quality inspection, payment systems, document management systems, or the manufacturing process itself.

This system-of-systems approach will help ensure that the different entities taking part in a distributed manufacturing workflow are able to adapt these systems to their assigned roles and their unique needs while still maintaining the ability to operate effectively within this process.

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A good starting point for this is to have a system that enables participants in a distributed manufacturing scenario to assign specific roles to the relevant entities involved, and based on their respective responsibilities within the process, integrate the necessary tools into the process as needed.

We are proposing **a system that enables participants in a DM scenario to assign specific roles to the relevant entities involved.** The assignment of these roles is informed by the framework developed for key DM roles. Once participants designate which entities will handle each role in the scenario, the system **recommends the appropriate contractual relationships needed between these entities.** This ensures clear delineation of responsibilities and accountability throughout the DM process.

The system is designed to clearly explain and define the roles, ensuring that those who are new to DM, or less familiar with it, can easily understand the responsibilities associated with each role. This helps to provide clarity on how accountability and responsibility are distributed in the specific scenario chosen by the system's users, while also outlining the relationships between the participating entities.

The system generates a set of recommended contractual relationships between the entities identified by the user[3] along with suggestions for the key responsibilities, accountabilities, and deliverables that each party must address. These suggested relationships can then serve as a foundation for the entities to negotiate the specific terms of their contracts, ensuring that all relevant aspects of the distributed production process are properly considered.

While we anticipate that this could eventually lead to the creation of libraries of standard clauses tailored to different jurisdictions, potentially even utilising generative AI to assist in producing contract templates, the current focus of our system is not on generating contract content. Instead, **it helps users identify the necessary contractual relationships based on their specific DM scenario, guiding them in ensuring that the right agreements are in place.**

4.2. The Roles in DM

In her article Roles in Distributed Manufacturing, published on *Medium*, Lowe (2022) lists the essential roles that need to be considered to contract for distributed / decentralised manufacturing.

[3] The user here is the contractor who commits and begins the contract.

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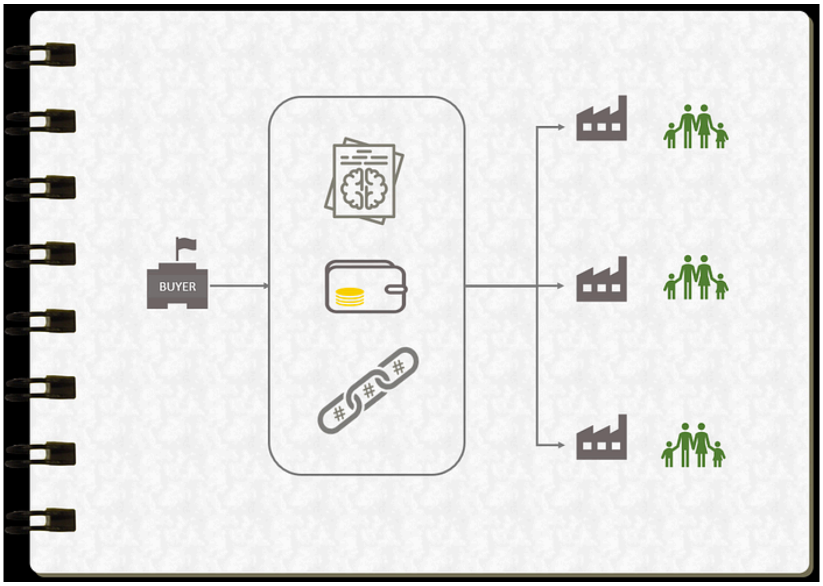

Figure 4. Contracting process for DM

Each role can be played by a person or an organisation. Also, there could be multiple entities for one role, and/or one entity to perform multiple roles. The roles identified by Lowe (2022) are:

Demand-side roles

a) **Buyer** - Enters into the contract to purchase items and commits to pay for them (or ensure they are paid for).
b) **Specifier** - Takes on responsibility to properly specify what the product needs to be or do in order to be acceptable, thus approving the design and the quality criteria. Even if this role is done by reference to a standards body (see *independent roles*, below), there is still a demand-side role needed to confirm which standards are required in order for the product to meet the buyer's need.
c) **Recipient** - Receives the product and completes any delivery checks and formalities.
d) **Payer** - The entity that pays for the products. Even if there is only one buyer, the actual money may come from several legal entities, accounts, or budgets.
e) **User** - Actually ends up using the product. Where this person is not also performing one of the other buyer-side roles, they tend not to be a party to the manufacturing contract—but finding ways to incorporate their views can offer ways to improve quality or reduce waste.

Intermediary Roles

f) **Demand & Supply Matching** - Entity/person performs the service of matching demand and supply or helping buyers and sellers to find each other.
g) **Logistics -** Entity/person moves and/or stores the items between seller and buyer, without taking ownership title to the goods.

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h) **Quality Inspection –** Entity/person verifies whether or not the products meet the defined quality criteria. Often done by the buyer, but we may see it commonly performed by an independent entity in DM situations.

i) **Transaction Finance Provision –** Entity/person provides cashflow or risk reduction to cover the period from when inputs to the manufacturing process have to be paid for to when the delivery is complete and the contracted fee is due.

Supply-side Roles

j) **Manufacturer/maker –** Enters into the contract to supply the items and takes responsibility for the manufacturing process (even if they do little of it themselves). This is the seller and the entity that stands by the quality of the products.

k) **Designer –** Has created or developed the design to which the products are made. The role is listed as supply-side because it is needed to create the product, but there are many situations where the entity that performs the role is the buyer.

l) **Input owner –** Provides some input to the manufacturing process. This would most commonly be a supplier of parts or materials, but could also cover provision of anything from labour to a machine to a building in which the manufacturing takes place. Typically there is a separate purchase contract between this supplier and the manufacturer making the products (the buyer of the input), but there are a number of factors unique to DM that mean there is sometimes a need for them to be included in the same contract for the final goods.

m) **Production Coordinator –** Manages the coordination of the manufacturing process, such as by making sure components and machines and labour are available at the right times.

Independent Roles

n) **Reference Owner –** Owns or maintains information that the contract refers to—for example, national product quality regulations, standardised specifications, hardware licenses. A designer may also fall into this category in some circumstances. Typically this entity would not be a party to the contract or play a role in its execution, although they need to be considered because their work may be essential to the way the contract can be executed by others.

4.3. The Scenarios

Thus, developing a contracting system for DM began with defining the roles, which not only helped us describe various DM scenarios and their production processes but also allowed us to identify areas where automation could enhance the connections between entities and improve process efficiency.

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Scenario C (IMA 2023)

- One buyer contracting with many makers
- Each maker contracting with one makerspace for materials, tools, and machines
- QA performed by makerspaces
- Items delivered by makers to Recipient

Roles

	IOPA	Maker-spaces	Makers	Recipient
Buyer	✅			
Specifier	✅			
Recipient				✅
Payer	✅			
User				
Demand & Supply Matching	✅			
Logistics Coordinator				
Quality Inspection		✅		
Transaction Finance Provider	?			
Manufacturer / Maker			✅	
Designer	✅			
Input Owner		✅		
Production Co-ordinator	✅			

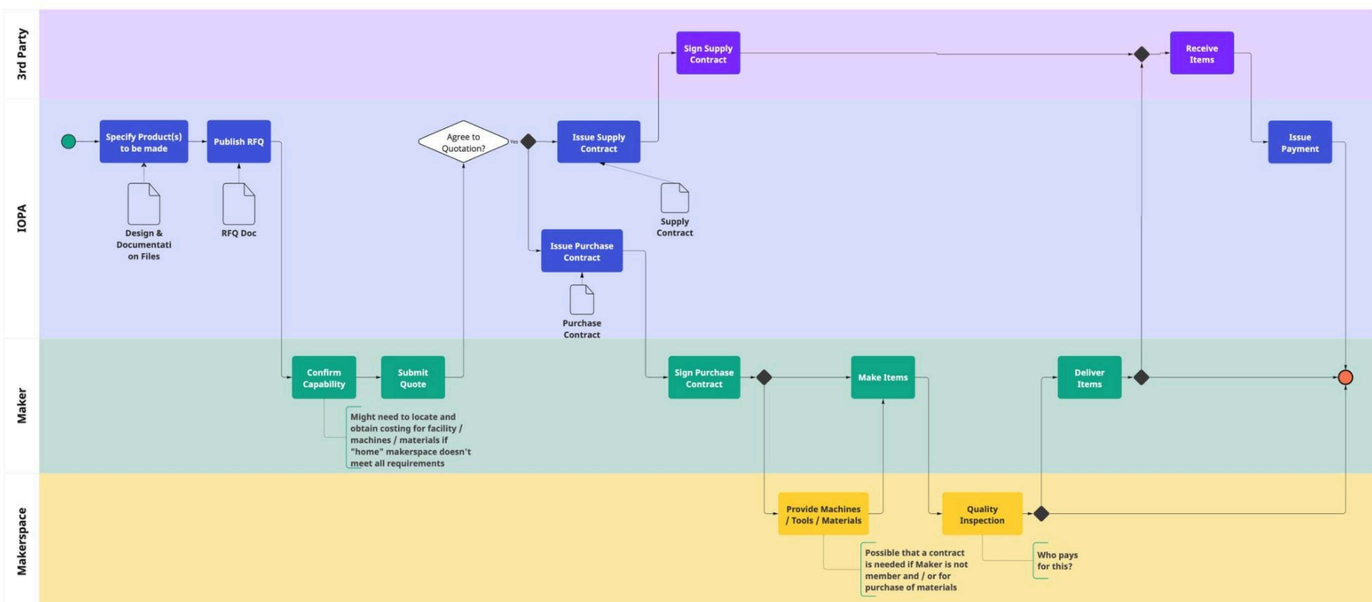

Figure 5. DM workflow – [Scenario C (IMA trials)]

For this research, we developed DM workflows, based on the discussion and trials run with the community. Just by looking at the different scenarios, and the roles implicated in the production, it is clear that it is not possible to draw a unique model for DM. Each swimlane represents one entity who will play one or several roles in the production process. The configuration of which roles are being played by which entity leads to a need for a specific set of contracts or agreements.

4.4. Testing of Contracting System Prototype

The prototype tested during the virtual trials was a demonstration of the workflow for a DM contract. A particular scenario was chosen based on the research of the ecosystem. This scenario was not

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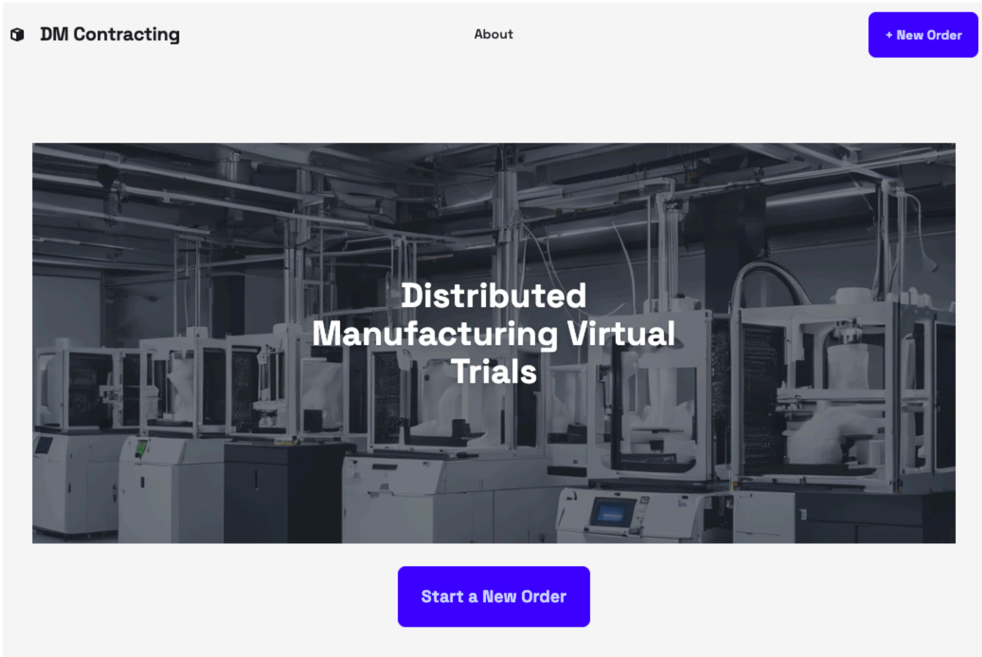
representative of all DM models. It was but one scenario of DM that allowed testing of the automation of a DM process. The goal was to understand how automation can help the whole process or part of it.



The virtual trial scenario that was tested involved:

- The initiator of the contract, who takes on multiple roles including buyer and the entity contracting for the production of a specific quantity of an item. In this scenario, the initiator is also the end receiver.
- Many manufacturers whom the manufacturing is distributed across.
- The quality assurance, carried out by a single entity.

The process tested is as follows:
The initiator requests the production of a number of items by multiple makers.
Each manufacturer will need to manufacture a single item as a prototype.
The prototype will be evaluated by the quality inspector.
If the quality inspector is satisfied that the manufacturer is capable of providing the item to the required standard, the contract for manufacturing the remainder of the items is assigned to that manufacturer and the manufacturer will move forward.

This scenario is meant to replicate a use case that is typical of scenarios such as humanitarian aid organisations wishing to distribute the manufacturing of an item across multiple manufacturers in a location where the buyer does not have prior knowledge of the capabilities of the manufacturers that are being contracted.

The trial format: A presentation of the trial is shared to introduce the simulation and start the process. Roles are assigned to each of the participants. Each action of the process triggers an automation sending a request.

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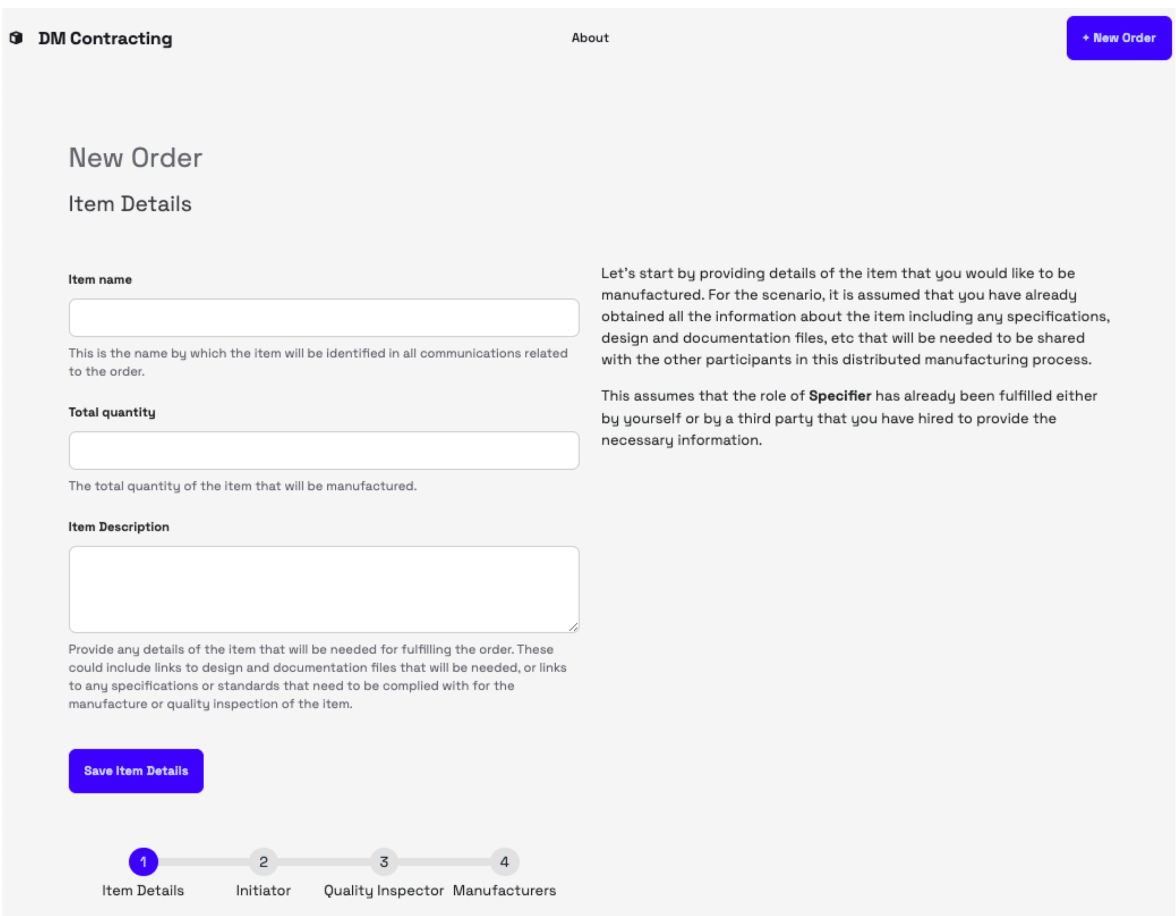
The platform: https://distributed-orders.fly.dev

The source code for the front end of the order management system is openly licensed (MIT licence) and available at this repository: https://github.com/iop-alliance/distributed-contracts-trials

Many parts of the workflow automation were implemented using the open source ActivePieces platform. The workflow used in the virtual trials are available at this repository for others to utilise: https://github.com/iop-alliance/activepieces-flows

4.4.1. Send an Order

The first step is to start providing details of the item to be manufactured.
For the scenario, it is assumed that the initiator already has all the information about the item (specifications, design and documentation files, etc) needed to be shared with the other participants in the DM process.



In this scenario, the initiator of the order is responsible for providing the necessary information and contact details about the person/organisation sending the order, so that other participants can receive and send updates.

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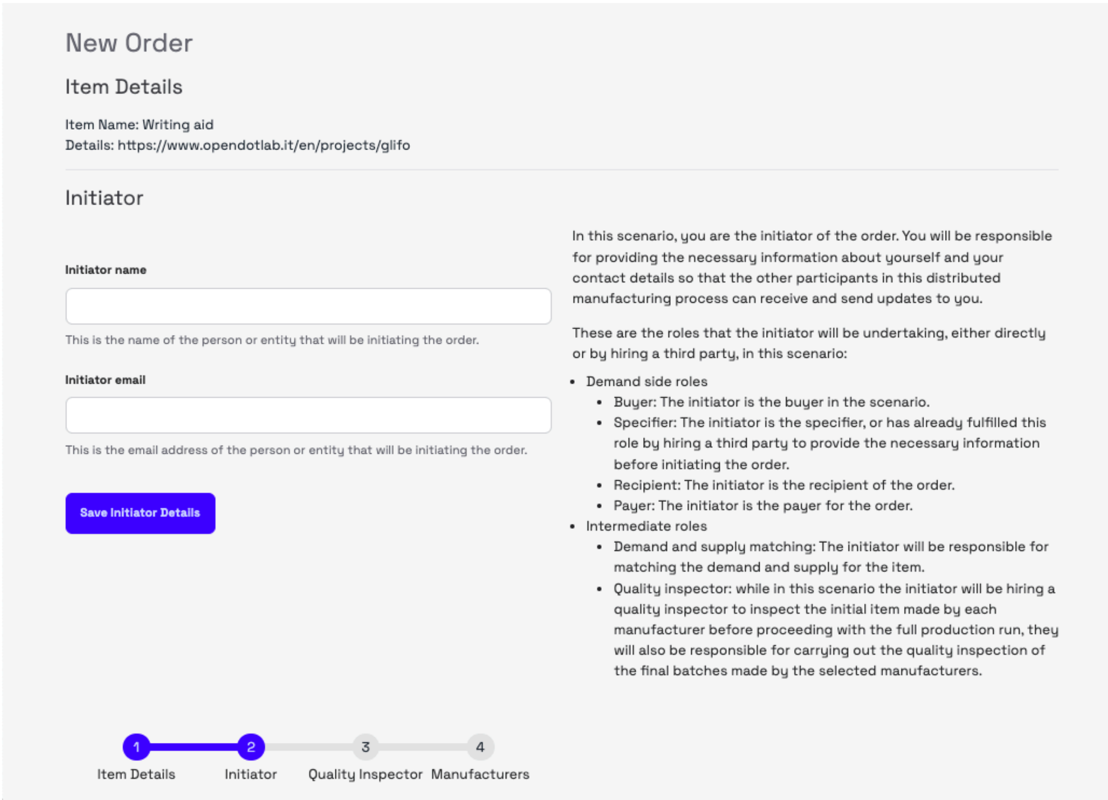
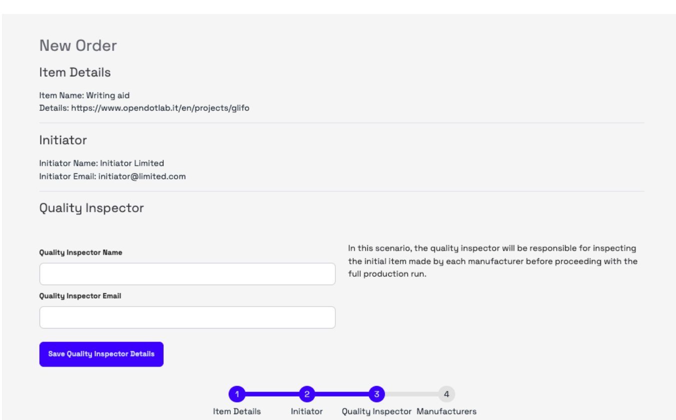
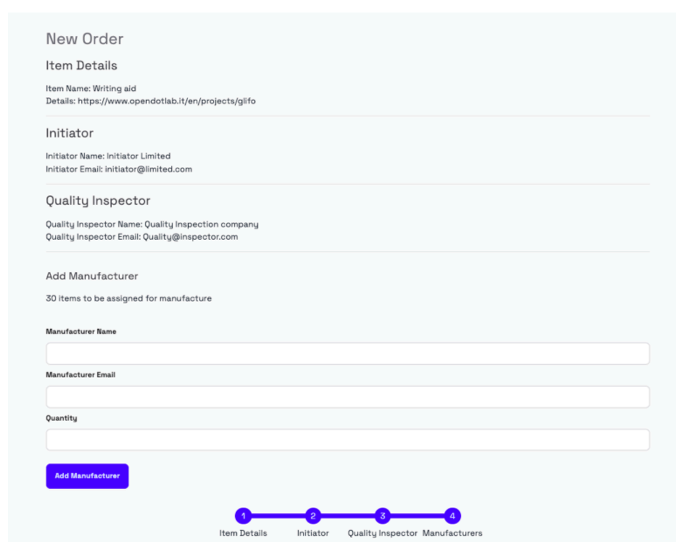
Here the initiator is undertaking the role of the buyer, the specifier, the recipient, the payer, the provider of demand and supply matching, and the provider of the final quality inspection for the whole production manufactured by the selected makers.



The initiator then appoints a quality inspector person/organisation to conduct the quality control of the initial item/prototype before the initiator approves the full production run. Then the manufacturers are assigned production of a certain number of items.





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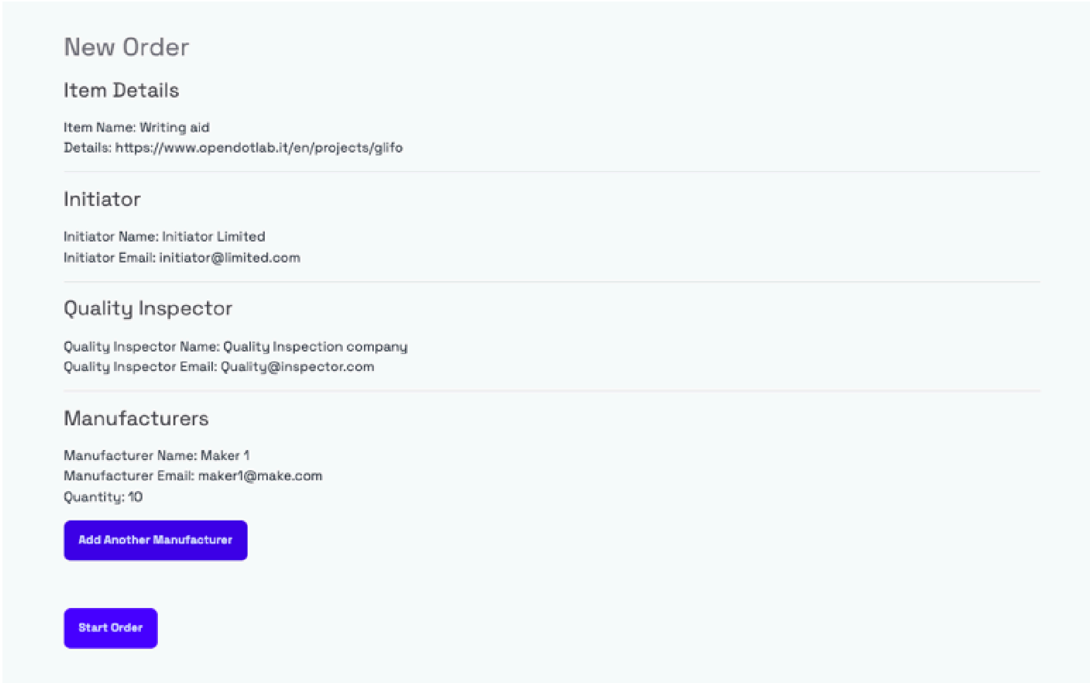
Once a manufacturer is assigned, the initiator can add as many manufacturers as they want to add to the distributed production, and can assign the number of items to be produced by each manufacturer.



4.4.2. Start the Order

Starting the order kicks off a series of actions.

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Through the back-end process-flow implementation specific to this scenario, each of the participants receives a series of emails and has to click links to progress the order flow.

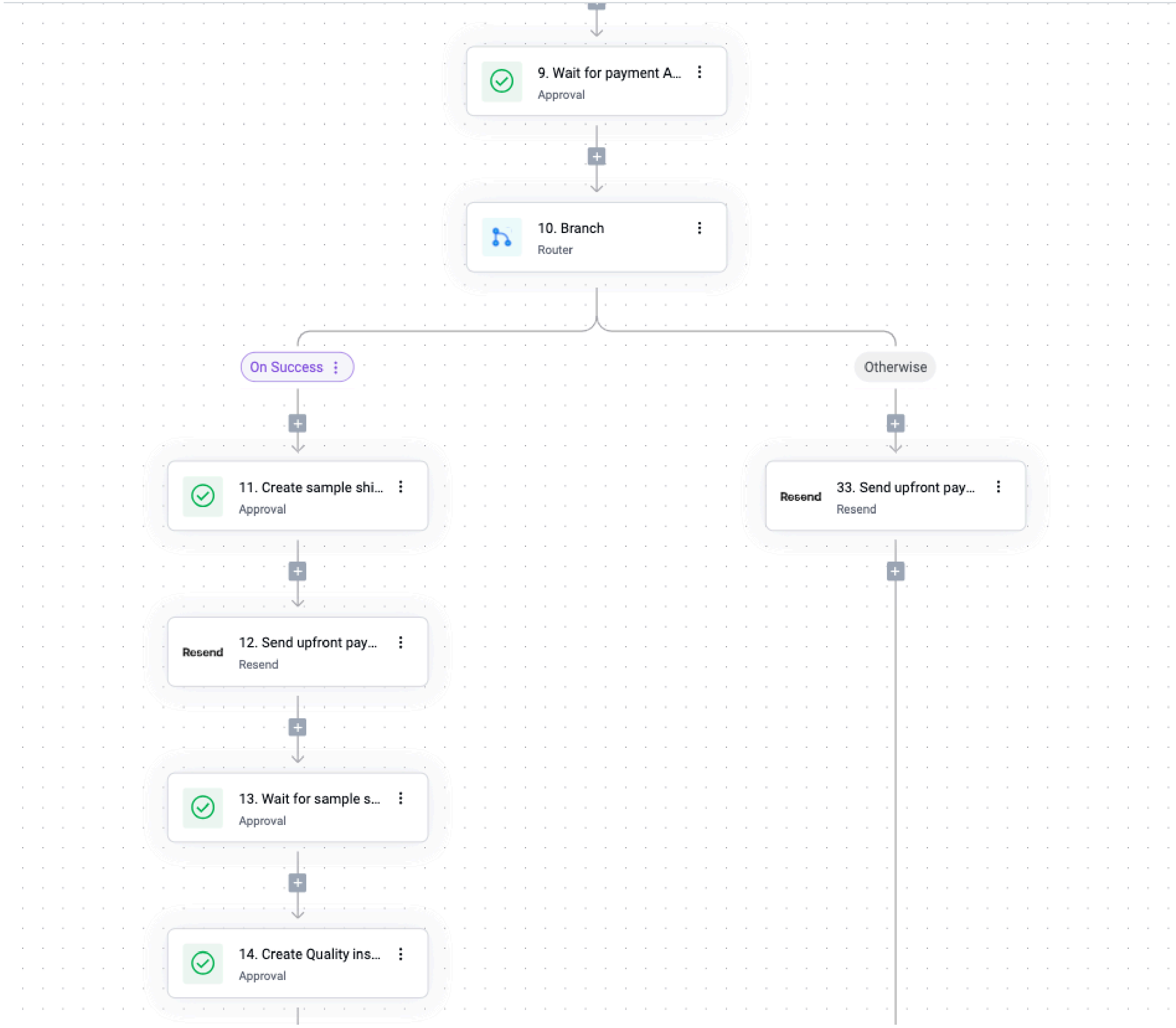

Figure 6. Screenshot of part of order workflow as seen in the back-end

The process is as follows, with the steps mentioned referring to the back-end order-work flow illustrated above:

1) Each manufacturer receives an email asking them to approve the contract for the order. In a real scenario, each email would include a docu-sign contract or a word contract document to sign.

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2) Each manufacturer approves the contract, and the initiator receives a request for the up-front payment. In this scenario, the payment is divided into 3 tranches:
    a) before production of the prototype;
    b) after validation of the prototype; and
    c) after the production is delivered to the client.
3) The initiator approves the payments by clinking the confirm link. The manufacturer can then start the production of the sample. There is one workflow per manufacturer.
4) The manufacturers send the samples to the quality inspection.
5) The quality inspection entity receives the items and approves the quality of the prototypes. The initiator receives the confirmation that the items have been approved and proceeds to transfer the second payment to the manufacturers.
6) The manufacturers produce the quantity of items ordered and send the items to the client. They confirm the shipping by clicking the confirm link.
7) The client receives the items delivered and proceeds with the third and final payment.

Below are a few examples of emails received by the initiator during the order process, with Chris A. as one of the manufacturers.

Chris A is requesting the agreed upfront payment of $X for the manufacture of Writing aid.

To confirm that the payment has been sent click this link:
https://cloud.activepieces.com/api/v1/flow-runs/GjkUuGR5TFGpoHrygp8JT/requests/bWMaSgUB0MXPNGdSVS9Dj?action=approve

To decline the request for payment, click this link:
https://cloud.activepieces.com/api/v1/flow-runs/GjkUuGR5TFGpoHrygp8JT/requests/bWMaSgUB0MXPNGdSVS9Dj?action=disapprove

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The manufacture of Writing aid (quantity: 2) by Chris A has been completed and the items have been shipped.

When the items are received and inspected, if they pass final quality inspection then click on this link to confirm that the final payment has been sent to Chris A: https://cloud.activepieces.com/api/v1/flow-runs/GjkUuGR5TFGpoHrygp8JT/requests/X-fYWGQjNnDRlbTolnJT1?action=approve

If the items do not pass quality inspection then click on this link: https://cloud.activepieces.com/api/v1/flow-runs/GjkUuGR5TFGpoHrygp8JT/requests/X-fYWGQjNnDRlbTolnJT1?action=disapprove

The sample item manufactured by Chris A has passed quality inspection.

The next step is to release the next payment tranche.

Once the payment has been made, click on this link to confirm: https://cloud.activepieces.com/api/v1/flow-runs/GjkUuGR5TFGpoHrygp8JT/requests/0SL3loBJcxxswpWHL2HG3?action=approve

4.5. Virtual trials

Virtual trial 1 – Online workshop

Date: Wednesday 30 October 2024
Location: Zoom
Participants:

- 1 initiator
- 1 quality inspector
- 3 makers
- 2 observers
- 1 simulation support

Among the participants were three members of the IOP, one supporting the simulation and leading the demonstration and two acting as observers, along with another member, from the Centre for Social Innovation (ZSI), a mAkE consortium member. Three participants were makerspace managers from South Africa, Ghana and Kenya, who participated in the IMA project's distributed manufacturing trials, and a co-founder and CEO of a social enterprise focusing on open source connectivity solutions.

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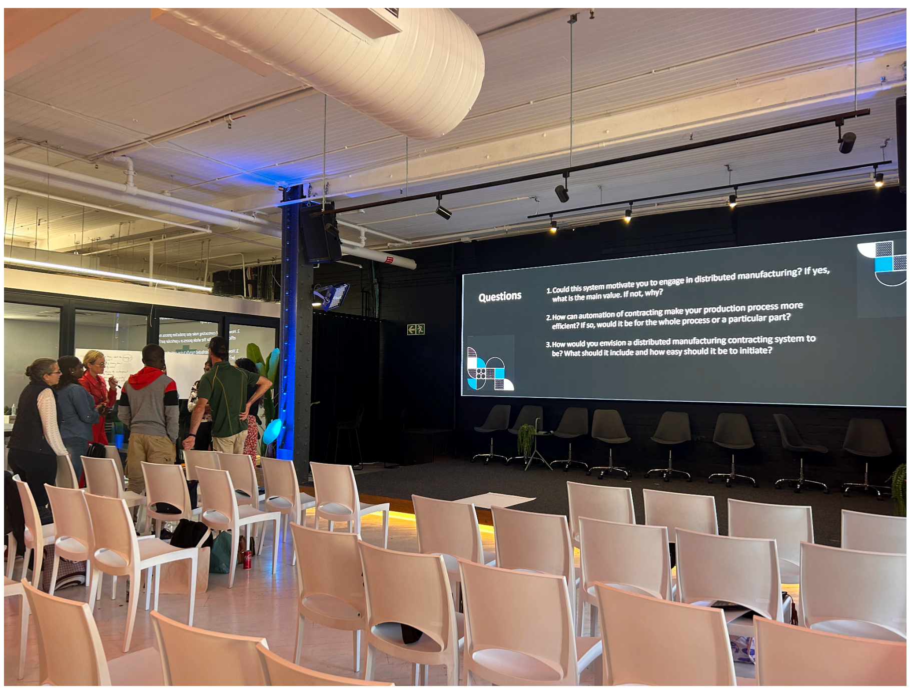
Feedback:

- Participants discussed DM quality inspection, highlighting several possible approaches, including centralising the inspection process with local representatives, allowing manufacturers to self-inspect with trust, or having makerspaces manage quality control.
- A key advantage of DM mentioned was the delegation of manufacturing to multiple subcontractors ("distributing the manufacturing") while centralising logistics and quality control.
- Automating the process was seen as valuable for improving efficiency, with the creation of clear briefs and visual workflows to enhance transparency and streamline communication among different entities.
- Additionally, pre-production quality inspections were suggested to avoid disrupting the production workflow.

<u>Virtual trial 2 – In-person workshop</u>



Picture 6. Contracting system demo workshop at A-MEG, Cape Town, Nov. 2024

Date: Wednesday 13 November 2024
Location: African Makerspace Ecosystem Gathering (A-MEG), Cape Town
+/-60 Participants divided into four groups. Each group assumed one of the four roles within the proposed scenario:

- initiator
- quality inspector
- manufacturer 1
- manufacturer 2

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The people who participated in this trial were mainly African-based makers and makerspace managers.

Feedback:

- The discussions across the four groups highlighted the potential value of a DM system, emphasising key areas such as trust, quality control, and automation.
- Groups saw the benefits of automation in improving efficiency and standardising production, but raised concerns about the capacity of makerspaces for large-scale production, the consistency of quality control, and the challenge of maintaining trust between purchasers and manufacturers.
- Additionally, there were discussions about logistics, currency differences, and the need for certification or training to ensure the reliability of makerspaces, with some suggesting the inclusion of additional actors or smaller organisations to support the production process.

Virtual trial 3 – In-person workshop

Date: Friday 22 November 2024

Location: Vulca seminar Erlangen, Germany

Participants: 16 people divided in four groups. Each group assumed one of the four roles within the proposed scenario:

- initiator
- quality inspector
- manufacturer 1
- manufacturer 2

The people who participated in this workshop were mainly European-based makers and makerspace managers.

Feedback:

- Participants in the workshop examined DM by focusing on the simulated production of a 3D-printed writing aid, emphasising quality assurance, resource management, collaboration, and the role of makerspaces.
- Ensuring consistent quality across decentralised makerspaces was a central challenge, with suggestions like shared quality assurance frameworks and data-driven approaches.
- Discussions on resource management highlighted the importance of clear workflows and collective purchasing strategies to address material-sourcing challenges.
- Collaboration was recognised as vital, requiring a balance between open-source innovation and financial sustainability, while makerspaces were seen as spaces for creativity, education, and community rather than solely production hubs.
- Finally, participants stressed the need to align production processes with end-user needs by incorporating user-centered design and feedback.

Note: The detailed feedback from the workshops can be found in Appendices.

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5. Progress

An important part of the mAkE concept is that it brings together and builds upon the work of previous initiatives by consortium members. The technologies that the mAkE concept calls for are already at high readiness levels with technology at least being validated in relevant environments (at technical readiness level (TRL) 4-5) by some project partners. The Internet of Production led and participated in multiple research on distributed contracting since 2017 when the smart contracting system from Field Ready was tested. A series of workshops and community calls were hosted to discuss contracting systems for DM, where different use cases were listed, existing systems were identified (Valueflows, Incoterms), so it could inform on the infrastructure, protocols, specifications and standards needed for an Internet of Production (more on the IOP forum).

TRL	European Union	Model Contract (taken from TRL2 to TRL7)	Digital Contracting System (taken from TL 5 to TRL 7)
2	Technology concept formulated	Concept based on the roles in Distributed Manufacturing	N/A
3	Experimental proof of concept	"Pricing for Production" workshop to present the concept of contracting for a distributed production	N/A
4	Technology validated in lab	Contract & Quotation template written by the Internet of Production	N/A
5	Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)	Contract & Quotation template shared with makerspaces participating in the distributed manufacturing trials	Field Ready Smart Contracting System (2017)
6	Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)	Contracts used by +20 makers for the production of 1030 items in 6 makerspaces.	Testing Distributed Manufacturing Contracting in Distributed Manufacturing Trials in the Innovative Manufacturing in Africa project (2023)
7	System prototype demonstration in operational environment	Distributed Manufacturing contracts with local payment systems demonstrated as effective	System prototype of Distributed Manufacturing Contracting (2024)

The contracting prototype has reached TRL 7. The digital contracting system, initially at TRL 5 (technology validated in relevant environments using the blockchain-based system from Makernet.org), was further

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developed to achieve TRL 7, based on the learning from previous systems tested, and from running real orders using distributed contracting. Similarly, the Model Contract progressed from TRL 2 to TRL 7, as detailed in the table above.

6. Recommendations

6.1. What a Contracting System Should Include

With the system prototype developed during this project, the elements of data-sharing and transparency and of flexibility and adaptability, and the roles and responsibilities, have been included in an automated system. It could easily be integrated with commercial payment platforms and independent or commercial contract-signing tools. A range of interfaces can be adapted to the system to offer more flexibility and adoption by a larger number of stakeholders (mobile, WhatsApp, online user interface possibilities).

A contracting system for manufacturing, especially in distributed or decentralised contexts, should include the following key elements:

Roles and Responsibilities: Clearly define the roles of each entity involved in the manufacturing process (e.g., suppliers, manufacturers, quality controllers, logistics providers, etc.). This should outline who is responsible for what in the production, quality control, delivery, and payment processes.

Quality Control Standards: Define acceptable quality levels (AQLs) and procedures for quality assurance. Specify who will be responsible for quality inspections (e.g., manufacturers, third-party inspectors) and how quality will be ensured at different stages of production.

Payment and Payment Terms: Establish how payments will be made (e.g., using cryptocurrency, bank transfers, or other methods), the conditions under which payments will be released (e.g., after production or upon approval of quality), and any penalties or incentives for meeting or missing deadlines or quality standards in the production process, as well as meeting or missing payments by the payer.

Intellectual Property (IP) and Confidentiality: Specify how intellectual property (e.g., product designs, proprietary processes, etc.) will be protected, especially when there is collaboration among multiple parties. Define ownership and usage rights for designs, prototypes, and other sensitive information.

Logistics and Delivery Terms: Define how and where the products will be delivered, who is responsible for shipping and handling, and how the delivery will be tracked and confirmed. This includes addressing potential issues related to international shipping, customs, and other logistical challenges.

Dispute Resolution: Include clauses for resolving conflicts or disputes that may arise during the manufacturing process, including third-party mediation, arbitration, or legal action.

Compliance and Regulatory Standards: Ensure that all parties comply with relevant legal and regulatory standards for manufacturing in the respective regions (e.g., labour laws, safety standards, environmental regulations).

Flexibility and Adaptability: Given the dynamic nature of DM, the system should allow for changes or updates to the contract as conditions evolve, such as in response to changes in market conditions, technologies, or production needs.

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Sustainability and Ethical Standards: If applicable, include clauses that promote sustainable practices and ensure ethical considerations are met, such as fair labour practices, environmental sustainability, and responsible sourcing of materials.
Data Sharing and Transparency: Provide protocols for data-sharing among parties involved in the contract, including data on production progress, quality control results, and financial transactions. This is important for maintaining transparency and trust.

These elements form the foundation of a comprehensive contracting system that ensures smooth and transparent operations in a DM environment.

6.2. To Consider

The final system should be flexible enough to allow any permutation of roles that the parties want, and not be limited to any particular scenarios.
The final system **should not:**

1. Overcomplicate the Process: The system should not create unnecessary complexity. Overly intricate terms or excessive bureaucracy can make it difficult for parties to understand and follow the contract, potentially causing delays or miscommunication.
2. Limit the Collaboration: It should not repress collaboration between the parties involved. A good system should facilitate communication, problem-solving, and adaptability, while a poor system might create barriers or foster isolation between different stakeholders.
3. Disregard Scalability: It should not ignore scalability needs. A contracting system should be designed to accommodate growth, allowing new parties to be added and new processes to be integrated as the manufacturing network expands.

Agreement vs Contract

In some cases, depending on the roles assumed in a distributed production, the use of the word "agreement" instead of contract would be more appropriate. Using the word "agreements" instead of "contracts" can be beneficial if the intention is to emphasise mutual understanding and flexibility rather than the formal, legal relationships often associated with contracts.

<u>Further development of the prototype</u>

Based on the interest shown, by members of the mAkE stakeholder community, in the DM contracting system prototype during the virtual trials, further development of such a system should be considered. While the system prototype offers opportunities for increased market access, standardised quality, and efficient contracting, concerns remain regarding manufacturer capacity, quality control, customer involvement, and the level of automation. Further work is needed to address these concerns and develop a system that effectively balances the benefits of DM with the need for trust, transparency, and quality assurance.

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What Could This Lead To?

One key question that arose was about the definition of DM and what it entails for makerspaces and makers. The development of a contracting system as an educational tool will help people understand the difference between DM and traditional manufacturing, and the benefits of adopting such a model.

Moving more of the world's manufacturing to the DM model requires those driving the demand side to gain a better understanding of DM and the different processes and scenarios involved, including the various contracting models that would be needed.

The system that we have been prototyping could, in part, be used as an educational tool to help buyers understand what choosing a DM model for the fulfillment of their contracts would mean and what the different scenarios would entail in terms of processes, relationships with various participants in the process, and any specific contracting needs that are relevant to DM.

It would be particularly helpful to develop ways of educating those who are already familiar with traditional manufacturing methods to understand what the differences would be between what they are used to with traditional manufacturing and what they should expect if they decide to place an order through a DM process or framework.

An example of such an educational tool that could be developed would be a catalogue of DM contracting models where the buyer would be able to choose based on a particular product that they want made, the quantities and locations they want, and what needs they might have in terms of the processes that they can choose from to implement such an order.

Further collaborations within the ecosystem

1. FabCityOS is, at core, an operating system–a set of tools–designed to empower autonomous FabCity communities to create and collaborate in distributed design and manufacturing value chains. FabCityOS uses a standard vocabulary, Valueflows, to describe the nature and relationships of these collaborative creations, which aims to facilitate coordination and resource flows in systems where multiple agents—such as people, organisations, and ecological entities—work together to meet shared needs like food, housing, and healthcare.

Partnering with FabCity for integrating Valueflows into DM contracting would provide a flexible framework for coordinating resource flows, agreements, and production processes across a decentralised network of independent producers, suppliers, and consumers. Additionally, Valueflows would facilitate scalable networks of small production units and promote collaboration through open-source design-sharing, driving efficiency and innovation in decentralised manufacturing systems.

Collaborate with others to develop distributed contracting systems that integrate with each other

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2. SeekMake is an online platform that connects people or businesses in need of custom manufacturing or product prototyping with local makers (such as small-scale manufacturers, fabricators, and makerspaces). It supports DM, where production happens locally rather than in centralised factories, making it ideal for small-batch production, prototyping, and customised goods. SeekMake fosters collaboration and helps users find makers with specialised capabilities like 3D-printing, CNC-machining, and laser-cutting, promoting sustainable, agile approaches to manufacturing.

As part of a DM network, SeekMake could be part of a broader economic ecosystem where makers collaborate to fulfil complex projects. Using Valueflows, the platform could enable collective planning where multiple makers contribute to different parts of a product or service. For example, one maker might focus on 3D-printing the prototype, another might handle assembly, and a third might be responsible for packaging and distribution.

Further recommendation for DM contracting

Exploring the diversity of contracts in DM

DM thrives on flexibility, and any contracting solutions must reflect this. These contracting agreements can range from simple transactional exchanges to complex, multi-party collaborations involving reciprocal contributions. Contracts may specify monetary payments, resource-sharing, or mutual service exchanges, making them adaptable to varying supply-chain requirements. They can also be structured to accommodate dynamic changes in demand, capacity, and resource availability.

Expanding Work in Distributed Quality Management Systems

Distributed manufacturing networks require robust quality management systems (QMSs) to ensure consistent product standards across diverse entities. These systems need to adapt to local capabilities while maintaining global compliance. Advanced QMS platforms can integrate real-time data from production units, monitor adherence to predefined standards, and facilitate collaborative troubleshooting.

Enhancing Traceability, Provenance, and Tracking of Manufactured Items

Traceability is a cornerstone of trust and efficiency in DM. Expanding work in this area means developing systems that can track every stage of an item's lifecycle—from raw material sourcing to final delivery. Advanced technologies like internet of things (IoT), radio frequency identification (RFID), and blockchain can create a comprehensive digital trail for each product, providing insights into provenance and ensuring authenticity. Such systems also help manage contract compliance, monitor supply-chain disruptions, and enable recalls when necessary. Innovations in this space should focus on integrating traceability tools with resource flow models, enhancing visibility across the entire manufacturing process while making data accessible to all stakeholders in real-time.

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- Internet of Production Community Forum on Business Models and Contracting. https://community.internetofproduction.org/c/initiatives-channel/bmc/11

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Contract & Quotation template

Basic terms

This document is a contract between [NAME OF MAKER] (referred to as the 'maker' in this document) and [NAME OF BUYER/CONTRACTOR] which is registered in [LOCATION].

The contract is for the manufacture of [NAME OF PRODUCT] as specified in the Request for Quotations and the related Specification Documents provided by [NAME OF BUYER/CONTRACTOR] (referred to as 'items').

The maker quotes that for a minimum quantity of [MINIMUM QUANTITY] items, their price will be [TOTAL PRICE PER ITEM IN UNITED STATES DOLLARS FOR MINIMUM QUANTITY].

The maker quotes that for a maximum quantity of [MAXIMUM QUANTITY] items, their price will be [TOTAL PRICE PER ITEM IN UNITED STATES DOLLARS FOR MAXIMUM QUANTITY].

Upon selection of a quantity and acceptance of the quotation by [NAME OF BUYER/CONTRACTOR], the maker will produce the quantity ordered of the items.

[NAME OF BUYER/CONTRACTOR] will pay the maker the price per item for the quantity ordered.

The maker will then deliver all the items to the [NAME OF PARTICIPATING MAKERSPACE] by [DELIVERY DATE] or latest by close of business on [END DATE].

The total price per item will include all costs related to production including material, energy, labour, quality assurance, marking and/or packaging, handling and delivery costs. International shipping of the items is not required and should not be included in the price.

Production requirements

The items will be produced using the following machines that have been added to the project's map of machines:

Machine 1	[NAME OF MACHINE]	[HAS THE MACHINE RECORD BEEN ADDED – YES/NO]
Machine 2	[NAME OF MACHINE]	[HAS THE MACHINE RECORD BEEN ADDED – YES/NO]
…		
…		

The items will be produced by [NAME OF MAKER] who has a Maker Passport created using this form.

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[NAME OF BUYER/CONTRACTOR] will not accept a quotation until it has confirmed that the machine record has been submitted to the project's map of machines and that a Maker Passport has been created for the maker. These records and passports will also be used to notify the maker of future production opportunities.

Quality requirements

Quality inspections of the delivered items will be conducted by [NAME OF PARTICIPATING MAKERSPACE] within 14 days of delivery. The maker must include the cost of quality inspections in their total price per item. [SELECT: The maker will pay for the quality inspections directly, and [NAME OF BUYER/CONTRACTOR] will check that these payments have been made. OR SELECT: [NAME OF BUYER/CONTRACTOR] will pay for the quality inspections on the maker's behalf, at a price of SELECT: PRICE IN UNITED STATES DOLLARS per item OR SELECT: % RATE PER ITEM FOR QUALITY INSPECTION per item.]

[NAME OF BUYER/CONTRACTOR] will inform the maker of any defects or non-conformities within 7 days of the completed quality inspection.

The maker will replace or repair any defective or non-conforming units at their own expense within 15 days of receiving the notification from [NAME OF BUYER/CONTRACTOR].

The maker should mark each item with a label and/or packaged showing: product name; maker or manufacturer's name; date of production; item number. Any item missing these markings will be considered as non-conforming.

[NAME OF BUYER/CONTRACTOR] may gather feedback from the users of the items regarding the item's performance and quality, and may share this feedback with the maker.

Payment planning

Upon selection of a quantity and acceptance of the quotation by [NAME OF BUYER/CONTRACTOR], the maker will provide the details for their preferred method of payment to [CONTRACTOR'S EMAIL ADDRESS] as part of a supplier on-boarding process. These details will be kept confidential and separate from the maker's Maker Passport record.

The maker requests payment by [NAME OF BUYER/CONTRACTOR] according to the following schedule (noting that the total of these percentages must be 100% of the total contract value for the quantity and price ordered, less any amounts made on their behalf for quality inspections):

- [SELECT: 0%-100%] before production begins [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] during production [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] upon delivery [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] after completion of quality inspections [IF NEEDED, SPECIFY FURTHER DETAILS].

If no payment schedule is selected, the maker will be paid within 15 days of delivery or latest [END DATE].

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[OPTIONAL: The maker requests payment to [NAME OF PARTICIPATING MAKERSPACE] by [NAME OF BUYER/CONTRACTOR] on their behalf according to the following schedule:

For use of machines provided by [NAME OF PARTICIPATING MAKERSPACE]:

- [SELECT: 0%-100%] before production begins [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] during production [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] upon delivery [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] after completion of quality inspections [IF NEEDED, SPECIFY FURTHER DETAILS].

For use of materials provided by [NAME OF PARTICIPATING MAKERSPACE]:

- [SELECT: 0%-100%] before production begins [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] during production [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] upon delivery [IF NEEDED, SPECIFY FURTHER DETAILS].
- [SELECT: 0%-100%] after completion of quality inspections [IF NEEDED, SPECIFY FURTHER DETAILS].

[NAME OF BUYER/CONTRACTOR] already has the payment details required for these payments.]

Warranty, Guarantee, Liability and Intellectual Property

The items will not be covered by any warranty or guarantee.

[NAME OF BUYER/CONTRACTOR] will inform the users of the items that the items are used at their own risk and neither it nor the maker accepts any liability.

The maker and [NAME OF BUYER/CONTRACTOR] will respect each other's intellectual property rights and confidentiality obligations regarding the item and its production.

[NAME OF BUYER/CONTRACTOR] expects high standards of health and safety and compliance with its policies, including on anti-slavery, safeguarding, anti-corruption and environmental impact. Copies of its policies are available on request and are also available from participating makerspaces.

Enforcement & Disputes

This contract will come into effect when the maker provides their bank details to [NAME OF BUYER/CONTRACTOR] and providing these details will be interpreted as acceptance of this contract and all of its terms.

The maker will inform [NAME OF BUYER/CONTRACTOR] using [CONTRACTOR’S EMAIL ADDRESS] immediately of any problems or delays in delivering against this contract, whereupon negotiation over new terms may be considered.

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Failure to deliver against this contract without informing [NAME OF BUYER/CONTRACTOR] will result in a breach of contract note being added to the maker's Maker Passport, and could therefore affect the maker's reputation and ability to secure future contracts.

[NAME OF ARBITRATOR] will act to resolve any disputes related to this contract, and can be contacted on [REFERENCE ARBITRATOR'S EMAIL ADDRESS].

This contract shall be governed by and construed in accordance with the laws of [COUNTRY].

This contract constitutes the entire agreement between the parties and supersedes all prior negotiations, understandings, and agreements between them relating to its subject matter.

Note: These contracts to makers were issued as part of a series of trials in distributed manufacturing and the role of makerspaces, from October to December 2023.

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[1]Questions for individual interview

Situate activities

- What is that you or your organisation do? What do you offer, produce or distribute or disseminate? How do you do it? Production of **what**, **where** and by **who**.
- What is the economic model that you are using? - extract economic model / pattern from answer.
- What do you need to agree on, or type of engagements, commitment or promises are important in order to be able to fulfil your operations? Agreement framework.

Describe circumstances

- Geographic, cultural, legal

Ecosystem mapping

- Who are the main stakeholders in your activities? What roles do they play?

Elements

- How do you recognize agency? (mandate, power of representation, influence, decision making or planning)
- How do you establish trust and/or accountability? Accountability framework? Measure responsibility?
- Documentation: Any documents respiratory? Data storage?
- Liability: Are there measures to mitigate mistakes, missteps, errors, damage?
  - Any framework that covers for accountability? Ex. if pull out of agreement, announce in advance, or find a replacement, use redundancy, rely on a long tail?
  - Incentives or punishments
- Do you plan? How do you plan?
- How do you assess risks?
  - Ex. transparency into data, processes, inventories, etc. Openness, which allows looking at past activities and monitoring.
- How do you assess costs?
- How do you assess quality, reliability, repeatability or reproducibility of deliverables? Standards
- What are the measures/assessment of satisfaction for you and for your partners / stakeholders? Ex. “how” is this done and delivered.
- How do you make agreements?
- How do you align interests and detect conflict of interest?
- What type of litigation mechanisms do you use? Conflict resolution.

Propagation

- Do you know other people or organisations that could contribute to this reflection?
- Can you suggest interesting literature related to this topic?

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Appendices

Virtual trial 1 – In-person workshop

13 November 2024, Africa Makerspace Ecosystem Gathering, Cape Town - South Africa.

<u>Notes from the workshop:</u>

Distributed Manufacturing in Africa: A Feasibility Discussion

This discussion centres on the feasibility of a distributed manufacturing platform in Africa, exploring its potential benefits and challenges. Participants representing manufacturers, a platform developer, and potential customers voiced concerns and suggestions regarding various aspects of the proposed system.

Motivating Manufacturers and Market Access

It was argued that the system would motivate manufacturers due to "possibility of getting contracts regardless of your production capacity," providing easy market access and customer exposure. Furthermore, the platform aims to "help you with standardisation of quality," incentivising lower-quality manufacturers to improve. However, questions arose regarding quality control—whether it should reside with the manufacturer or the customer—and the need for a system allowing manufacturers to communicate and agree on issues.

Automation and Contracting

The discussion then shifted to the automation of the contracting process. Some advocated for a fully automated system to save time, reduce complexity, and enhance transparency. A streamlined process was envisioned: initial request, proposal submission, prototype approval, and final production capacity determination. This automated system would provide clear information on approval status and production quantities.

Manufacturer Capacity and Concerns

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The manufacturers, represented by a group, expressed concerns about the system's suitability for their capabilities. They highlighted their expertise in prototyping but questioned their capacity for mass production, stating, "when it comes to 500 pieces, that's large scale production...So now we are thinking, are we repurposing?" They also raised concerns about maintaining quality standards, particularly in sensitive sectors like medical devices, where stringent regulations and certifications are required. The manufacturers emphasised the challenges of scaling up production, securing necessary materials, and managing equipment downtime. They also noted the potential need for additional equipment and tools to fulfil larger contracts. The group also highlighted the varying levels of commitment among maker spaces, particularly those affiliated with universities versus independent entities.

Customer Perspectives and Quality Control

The customer representatives expressed concerns about quality control and their limited involvement in the process. They questioned how quality would be ensured and how trust in manufacturers would be established. They stated, "How do we know about the quality? How do we know we can trust the maker spaces? How do we know we can trust the quality?" They desired greater participation in quality control, potentially including the ability to select specific manufacturers and verify consistent quality throughout the production process. They also raised questions about the cost of outsourcing quality control and the potential benefits of in-house quality checks. The customers also considered the value proposition of local production, emphasising the potential for faster turnaround times and the ability of maker spaces to respond to specific, niche needs. They suggested that some level of personal interaction might be beneficial, allowing for collaborative problem-solving and design adjustments.

System Automation and Certification

Finally, the discussion addressed the extent of automation. While acknowledging the benefits of automation for standardised products, the customers suggested that not all aspects should be automated, particularly those related to accountability and trust. They also raised the need for certification of maker spaces and a mechanism to address potential production failures.

Conclusion

The discussion revealed both the potential and challenges of a distributed manufacturing platform in Africa. While the platform offers opportunities for increased market access, standardised quality, and efficient contracting, significant concerns remain regarding manufacturer capacity, quality control, customer involvement, and the level of automation. Further work is needed to address these concerns and develop a system that effectively balances the benefits of distributed manufacturing with the need for trust, transparency, and quality assurance. The platform developer expressed willingness to collaborate further to refine the system based on the feedback received.

Virtual trial 2 - In-person workshop

22 November 2024, Vulca Seminar, Erlangen - Germany.

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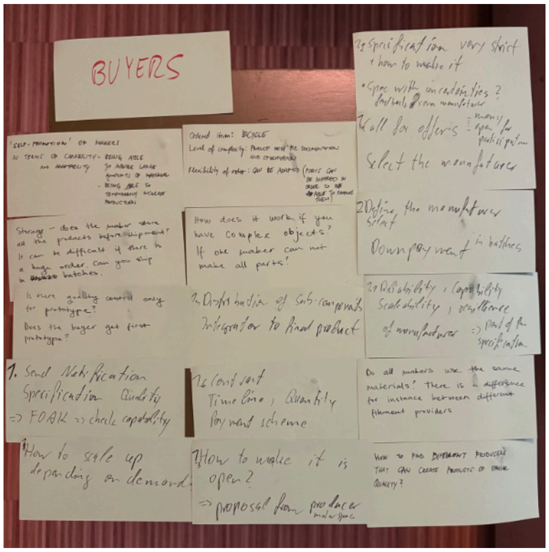

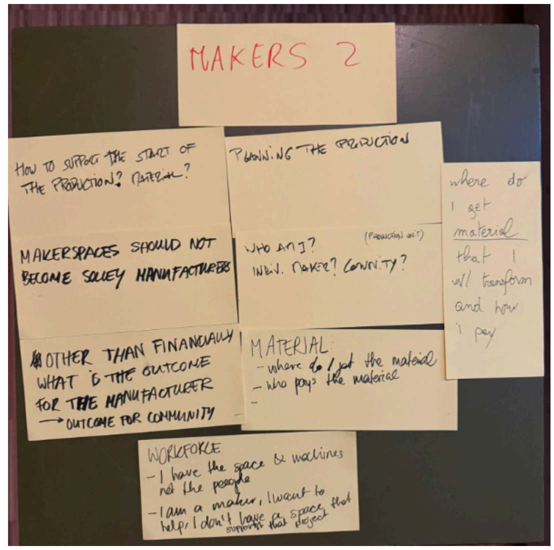

<u>Notes from the workshop:</u>

The workshop participants, role-playing as makers, buyers, and quality inspectors, explored various facets of distributed manufacturing, focusing on the creation of a 3D-printed writing aid. Across the groups, a few overarching themes emerged: quality assurance (QA), resource management, collaboration dynamics, and the role of makerspaces.

Quality Assurance and Risk Management

A major concern for all groups was ensuring consistent quality in a distributed manufacturing environment. Participants highlighted the importance of clear specifications, thorough testing, and robust quality control processes. Randomized checks, preparing prototypes for customer feedback, and setting up shared QA frameworks were common suggestions. However, the groups acknowledged the challenges of scaling QA across multiple makerspaces, such as increased costs and logistical complexity. There was also discussion about leveraging collective data from makerspaces to identify patterns and self-improve QA practices.

Resource and Material Management

Securing and managing materials was another critical area of focus. Participants questioned who should be responsible for sourcing and paying for materials and explored the logistical challenges of distributing resources across different production hubs. They emphasized the need for clear workflows for material acquisition and transformation. Some groups suggested the need for financial support systems or collective purchasing strategies to address these challenges.

Collaboration and Community

Collaboration emerged as a cornerstone of the maker process. Groups reflected on the distinction between individual contributions and the collective goals of makerspaces. Some participants advocated for open-source models to foster innovation, while others highlighted the need to balance

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community-driven efforts with financial sustainability. Makerspaces were envisioned not only as hubs for production but also as centers for learning, support, and collaboration. The importance of documentation, contracts, and clarity in roles and responsibilities was also emphasized to streamline collaborative efforts.

Makerspace Identity and Broader Outcomes

The philosophical role of makerspaces sparked deep reflection. Participants stressed that makerspaces should not merely evolve into manufacturing hubs but retain their core mission of fostering creativity, community, and education. They explored the broader non-financial outcomes of maker projects, including their social and educational impact on communities. This perspective underscored the value of makerspaces as environments for experimentation and shared growth, not just economic production.

Practical Feasibility and End-User Focus

While the groups tackled logistical and philosophical challenges, there was a recurring need for a stronger focus on the end user. Discussions were largely centered on production processes rather than the specific needs and preferences of the writing aid's target audience. Incorporating user-centered design and feedback into these discussions could align production efforts with practical outcomes.

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