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Digital Maker Networks. Benefits, barriers and opportunities for re-localised UK manufacturing for the future

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Abstract: From craft, to industrial revolutions up to current global concentrations of specialisms and virtual firms, the way we make has evolved dramatically over time (Mourtzis & Doukas 2014, Allen 2006, Eugene et al 2005). This research looks forwards and asks in light of new technological developments such as 3D printing what are the new production models of the future. Through literature review this paper explores how manufacturing developed historically. Following a summary of a primary research study titled Digital Makers, a feasibility study for rural maker centres based in the Highland and Island region of Scotland, the paper goes on to present a concept for a digitally enabled manufacturing network of the future. Concluding with a discussion on the implications for future research. The research connects to the authors work researching distributed manufacturing networks for rural and island communities and enabling innovation for manufacturing. (Smith 2015: Smith & Mortati 2017).

Keywords: digital fabrication, networks, future industry, additive manufacturing, local manufacturing

1. Introduction: status and drivers

Since the industrial revolution production of goods has become ever more sited in specialised regions spread globally (Mourtzis & Doukas, 2014). Financial and legislative levers have enabled this to establish as the most popular and widespread mode of production. Political events such as the UK exit from the European Union and threats to trade partnerships (Independent, 2016) invite governments to re-think or enhance their strategy for material goods. Other external pressures such as environmental concerns, theories such as the circular economy gaining popularity (Hobson, 2015; Ellen McArthy Foundation, 2012; Policy Connect, 2016), and publics becoming more aware of global impacts of current strategies are putting extra scrutiny on our current methods of production and consumption. Levers such as policy measures and fund incentives aim to develop regional small

manufacturing at the local level. Particularly there is a focus on creative industries as potential to make a positive contribution to the economy (UK Government, 2016 & Create UK, 2012), with reports of contributions of value £10 million per hour from the creative sector. The majority of the contributions come from film, music and games and more is needed to boost manufacturing sectors (craft, products and design). There is also a focus in the UK on innovation at all scales and across all sectors to boost the economy and deliver better goods and services for UK citizens.

“It must have the right fundamental building blocks, from a solid skills base to a dynamic research environment that fosters new inventions and commercialises them into successful businesses.” (Policy Connect, 2016)

The current situation for production of primary and intermediary goods favours large manufacturers using specialised regions for supply and manufacture. Access to new technology favours those who can afford to invest leaving smaller companies out of the loop, despite smaller companies often being more flexible and experimental. The issues of local production, supporting and boosting design and craft industries, enhancing the contribution design and manufacturing can make at a regional and national level is not just a UK issue. The economic, social and environmental benefits of innovating the way we make things are concerns that should be at the forefront of global strategies for manufacturing.

This paper through an analysis of secondary research and the synthesis of primary research presents a vision for a digitally enabled manufacturing network of the future with localised production at its heart. The secondary research consists of literature review of the evolution of manufacturing and associated models. It goes on to explore examples of burgeoning models of production, their motivations and impacts. The primary research consists of two ‘pop up’ experiments in two Hebridean Island communities. The experiments prototype a rural ‘maker centre’ and engaged with the local community and businesses through events and interviews, the aim was to explore the potential for a local production centre. A summary and synthesis of the research is presented in this paper. The aim for this research is too explore what lessons can be learned from historic and current practices of producing material goods, the key topics in manufacturing today and in combination with the insights from primary research to propose a speculative model for a future manufacturing network and highlight areas for further research.

2. Historic manufacturing

In a pre industrial age the design and manufacture of goods happened close to the site of consumption, using locally sourced material and energy (Urry, 2014). Labour was rarely divided and individuals with specialised skills made products. This was the way in which material goods were manufactured and carried on until new practices began to co-ordinate production into organised manufacturing. Technology developments made a defining shift in manufacturing history, yet before a centralisation of tools into factory settings, cottage industries and the workshop system represented a de-centralised mode of production that evolved from individual independent manufacturers.

“almost all of the contractors manufactured parts or fitted them through a highly decentralized, putting-out process using small workshops and highly skilled labor…the "workshop system" rather than the "factory system" was the rule” (Hounshell, 1985)

This workshop system 'put out' work to networks of producers each of who contributed one or more elements of a process to make the whole product. Research on the Leicester hosiery industry offers a comprehensive description of how co ordinated distributed manufacturing worked, where material was distributed from a central owner and equipment often on loan to individuals who worked at home (Head, 1990). Despite central control many cottage industries as well as being highly skilled were collaborative and developed collective models to compete.

"work was outsourced to small-scale artisans working at home who at times ran cooperatives when scale economies were important" (Mokyr, 2000)

Connected networks, coordination between individuals and by a central manager were defining characteristics of put out systems. This proto industrial era, occurring just before the industrial revolution of the 19th century, developed prior to centralised industrialisation (Hudson, 1990) (Mendels, 1972). The proto industry could be characterised by many small manufacturers, producing low volume, distributed traditionally in rural locations. This manufacturing network could be scaled laterally by adding additional small producer 'nodes' to the network making it a resilient system that could stretch and contract.

3. Centralisation: skills and tools

Industrial models that followed the workshop system extolled the centralisation of tools into factory locations and the housing of labour, removing ownership of tools from individuals (Rifkin, 2014; Hugh, 2013). The industrial revolution is often regarded as a technology revolution but it was as much a response to economic opportunity that drove technology development as technology pushed the revolution (Allen, 2006). Inventors saw an opportunity to develop products that could be exported as well as sold at home profitably, which in turn drove the industrial revolution, although this is of course not the only factor. In UK especially energy became cheap and labour expensive and therefore owners pushed to invent machines that would substitute labour with energy and capital investment. Innovation at this time was also largely centralised, product and system innovation was the property of a few individuals. Markets opened up to more people, innovations could be manufactured and sold to populations thanks to distribution networks and cheaper goods. With time manufacturing distanced further from consumption and material and energy resources were increasing brought in from 'other' locations. Divisions of labour that came next, and movement of manufacturing to a globalised network took advantage of computerised processes to monitor and make goods on a globally distributed scale.

4. Modern global concentrations: offshoring production

In a typical contemporary mass manufacturing model large-scale producers organise themselves by locating production in advantageous geographic locations (Dunning, 2001) and product is shipped to regional distribution in a make and move model using large complex distribution (Urry, 2014). Since the industrial revolution shipping of finished goods from central production to markets was the

dominant theme (Mourtzis & Doukas, 2014). More recently the industry assembles intermediary goods closer to the local market rather than shipping wholly finished goods. This network approach allows for local needs and sensitivities to be taken into account when assembling finished goods, essentially enabling a level of customization close to the source of use. Firms design complex supply chains, the chains bring in intermediary products, bought in or manufactured through intra or inter firm networks, assembled centrally and distributed or, as mentioned, increasingly assembled close to markets in line with regional needs and taking advantage of local assets (Coe, et al, 2004). These Global Production Networks (Henderson et a, 2002) situated in a competitive global market have transformed local economies and are driving constant innovation of manufacturing systems. The new 'ways' of making material goods are working at different geographical scales (Dickens at al, 2001) taking advantage of regional specialisms, global supply and distribution and access to free markets. Even at the small scale micro enterprises can have global supply and global distribution networks but their location strategy is usually less flexible.

The technology, social and political changes over the decades have contributed to the 'evolution of manufacturing paradigms systems from craftsmanship to automation and decentralisation' (Mourtzis & Doukas, 2014). Now again social and technology shifts are driving new emergent models of how material things are made.

5. New manufacturing networks

Enabled by digital fabrication technologies, new models of production promise to distribute manufacturing, produce locally potential at the individual scale, and negate the need for massive physical global supply chains. These are the emerging digital manufacturing models of the future. There are currently examples that put the theory of these networks into practice. Open design networks are collaborations between designer networks to develop goods (Koren et al, 2013), or they are mechanisms for the free distribution of design data geared toward local production (Tooze, et al, 2014). Open innovation networks combine open collaboration and free distribution channels to design and then distribute products with the intention that they are made near the point of consumption. Home fabrication uses small-format digital manufacturing technology to 'make' things at the individual scale.

Movements like the Fab City project (FabCity, 2016) are imagining the future paradigm for manufacturing, one where local production and networked nodes drive an alternative economic model. There is an ideological imperative that puts sustainability and innovation at the heart of the model and underpins the operation. The Fab City prototype in Poblenou is an experiment for a designated makers' district (Nesta (a), 2016; Nesta (b), 2016), and similar projects are starting up in Amsterdam and Paris. The areas are designed to build small digitally networked manufacturing 'nodes' at the local level. Open innovation projects such as the e-nable network use digital networks to move data ad manufacture at the super local level using digital manufacturing technologies (Smith 2015). Recently, the IKEA design team visited the Barcelona Fab Lab to experiment with new forms of making and distribution (Nesta (a), 2016). The idea of alternative mechanisms for manufacturing is not just theoretical research but is being adopted by industry, regions and individuals.

6. Rural maker centres: a prototype for manufacturing networks

To trial the idea of a new manufacturing network a series of ‘pop up’ manufacturing nodes or ‘maker centres’ were set up to explore the idea of local manufacturing bases connected to a wider network of supporting manufactures. Two main sites in the Highland and Islands region of Scotland were chosen for the trials. Both sites were situated on Islands off the west coast of Scotland, one based on Lewis and one based on North Uist. Island sites were chosen because of their remoteness from the mainland and their thriving creative industries of makers. At each site we partnered with a local arts centre as the physical site for the ‘pop ups’. On Lewis we partnered with An Lanntair arts centre and on Uist we partnered with Taigh Chearsabhagh arts centre, for both sites we set up our mini maker centre for 2 days, bringing with us 3D printers, 3D scanners, design software, laptops and a design team. Our aim was to explore how maker centres could function in rural and remote communities and how people would actually experience them on a civic and commercial level.

Our objective was to engage people in the centres through an open door policy, twilight talks about technology and ‘surgery’ sessions where slots could be booked to work on specific projects and opportunities. We named the open access time 3D print cafes and encouraged anyone to drop in and experience the technology and speak with the research team about potential applications for them. Visitors who were willing agreed to a short interview with the research team that allowed us to gain some insight into how local residents and businesses might experience a local manufacturing center, and what it would mean for the community. The 3D printing cafes, surgeries and talks took place at both sites and attracted a variety of interested attendees form the local area curious about the technology and what it could mean for their practice and for their community. Included in the visitors were a group of local artists, a group of ceramicists studying at the arts center studios, photographers, a local filmmaker, two architects and two local historians and some curious locals.

Amongst the things we made during our time on Uist was a 3D print of a 3D scan of a local site of historic interest that was used at a local lecture about the site. We produced a 3D printed version of a local artists 2D sketch work, created using 3D surfacing software. Using the same software we made some 3D prints of textures to be used as tools for a local ceramicist. For one resident we even made a 3D print of a broken dishwasher part using our desktop 3D printer. Since we visited the sites we have begun two design research projects with two local businesses that are experimenting with digital manufacturing technology in their practice.

The ‘pop up’ centers were limited in their technical capabilities, as we had limited space and mobile equipment. We learned that there are many applications for local manufacturing from the citizen level in terms of manufacturing for subsistence, spares and repairs of products, to the commercial level in terms of product or process innovations. Local manufacture can dramatically shorten supply chains for certain household items and respond to the local needs quickly especially important in remote regions. They can be sites for experimentation and access to new technology and ideas to innovate current industries, or equally places to manufacture tools that sustain other ways of production. Where technology was not available we sourced from other maker spaces, for example we have since been working with MakLab maker space in Glasgow city to develop new products conceived in the pop up centers and a broader network of 3D printing labs across the UK for access to specialist materials and equipment.

7. The concept

Based on the secondary and primary research conducted for this study we propose a concept for a digital makers network of localised manufacturing. The concept is a reflection of the insights from the literature in this study, the technological developments already impacting on current production processes we have identified in the research, the historical evolution of production in light of new developments, and the insights from the field studies. We recognise that the network model is an early attempt to describe an emerging concept and needs further study. This is something we discus in the conclusions.

Figure 1 is an illustration of the digital makers concept, showing the elements of the network and the interconnections between each.

Within the diagram there are at the base level dispersed domestic nodes of 'home fabrication', these are ad hoc networks of personal fabrication. These nodes would produce for the citizen at the individual scale or for industry as in house manufacturing. They could also serve as overflow and serve as additional capacity in the network if required, much like cottage industries (Mokyr, 2000).

There are local manufacturing nodes with flexible systems that can provide for local needs (micro industries), located in community centres offering services to citizens and businesses for goods, services and training. These nodes would offer service where there is no domestic fabrication, or domestic fabrication is not suitable. They would generally be more advanced and well equipped than domestic nodes. Local nodes can develop local competencies and evolve based on local need and resources.

Major regional hubs would exist outside of small regions and generally be more advanced in their equipment, servicing local needs of many local nodes, supporting more critical product innovations for key sectors (oil and gas, aerospace, healthcare). Major hubs will scale up innovations from the local level and support critical innovation for key sectors.

In our concept nodes are digitally connected and engage in file sharing through open repositories (Koren et al, 2013), innovations at the local citizen level that are not for profit are shared and can be downloaded, adapted if required and manufactured in local nodes.

The main tenets of the network concept are: local serving at citizen and commercial level; capacity sharing across local nodes where volume or technology deficiencies require external support; and connections to main hubs for critical manufacturing, scaling of innovations and advanced services.

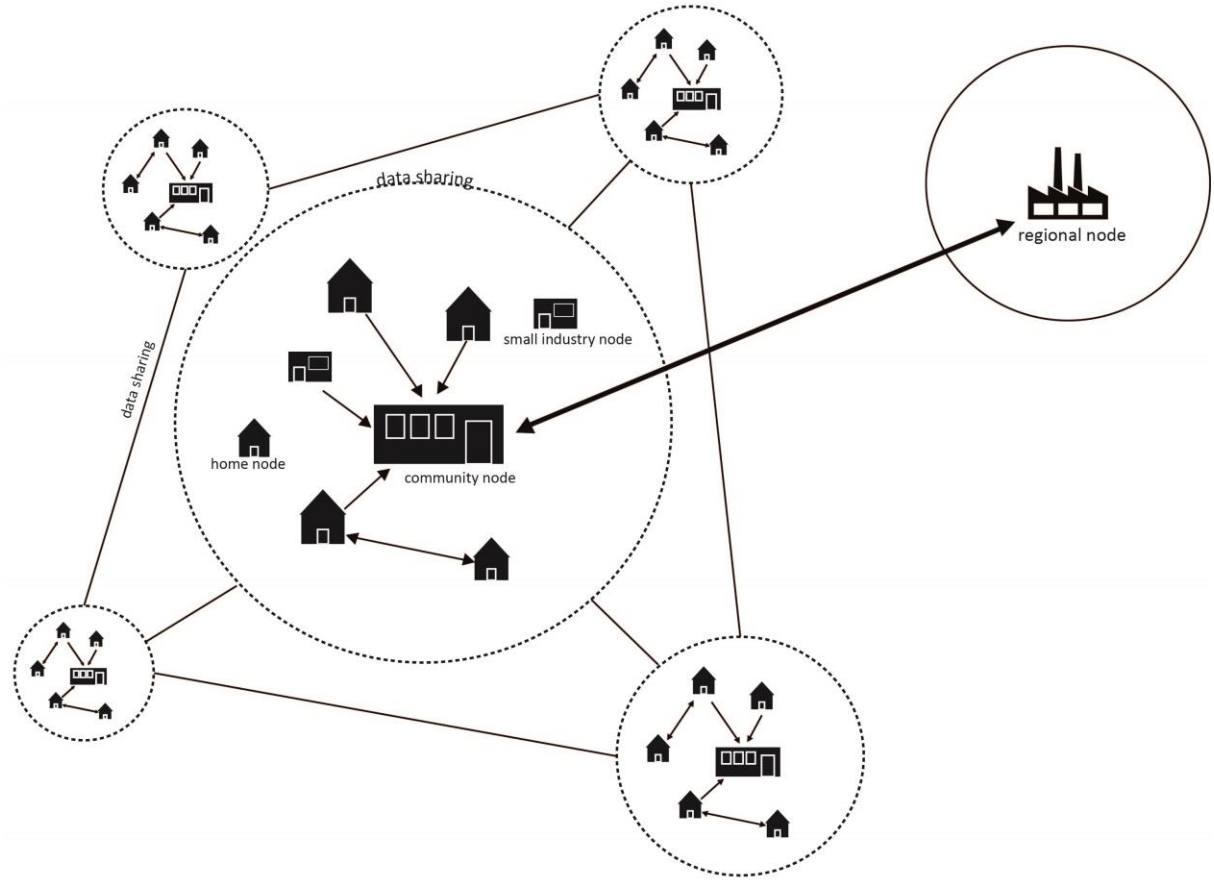

Figure 1: network diagram

8. Discussion: Theory into practice

Insights from the primary and secondary research informed us that citizens and local businesses can benefit from access to manufacturing technology and services in a way that bypasses current production and supply models. In order to exploit new technology individuals need to understand it initially and to get to grips with what is possible. It's not necessarily needed on site to be utilised, accessing technology through a network with some expert support is enough to support at the citizen and industrial scale. There is a lack of understanding from a business perspective of where to go to access new technology, what new technology is available, what it can do and what skills are needed to use it. The citizen perspective is interested in the application of technology and what it can do for them in terms of sustaining their lives in a very direct supply and demand way.

In terms of impact on product and service innovation, making at or close to the source of use puts producer and customer closer together shortening supply chains and producing on demand. Iteration of products is more likely especially if production is tied to flexible systems that require no initial investment except set up and material costs. The scope for design development on an almost daily basis is possible if innovations are opened up through digital networks. In the pop up experiments a spare part was re designed on site to make improvements on the original.

Nodes can be added and nodes can update so the network has more chance of keeping on the cutting edge of technology. As technology updates there can be a ‘second’ hand market for equipment as it moves form critical main nodes to regional nodes and personal nodes.

Local nodes can work at scale, servicing citizens, micro industry and SME. Everyone can access main critical nodes through local nodes and other local nodes. Domestic nodes can connect to digital networks to enabled ‘home’ fabrication of non-critical products.

9. Further work

The primary and secondary research poses some interesting questions and directions for further research.

Historically and in current global manufacturing networks regions have developed specialisms and become centres for particular types of production. In our field research that took place across two sites we encountered varying needs and demands for what a manufacturing centre should provide. In the scenario of localised manufacturing networks would regions develop regional competencies as a reflection of local needs and resources? Would industry requirements, academic interests, citizen needs, material resources, regional policy, educational needs, all play a part in the scope of local centres?

What are the legislative arrangements for distribution of IP across borders, how are financial remunerations generated and monitored? How are governments and societies impacted by localised production?

In the scenario where local centres support product innovations at citizen, micro enterprise level, what could regions do to support this? What products can be distributed at citizen level at cost, what open source hardware is likely to become available?

What are the social benefits of local production, what are the environmental benefits of local production?

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