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IMPACT OF 3D PRINTING TECHNOLOGY ON SUPPLY CHAIN IN CHINA

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Abstract
The 3D Printing (3DP) industry has been receiving increased public attention. Many companies are seeking ways to develop new means of creating and disseminating 3DP content, in order to capture new business opportunities. To date, however, the true business opportunities of 3DP have not been completely uncovered. This research explores the challenges posed in the development and deployment of 3DP, and focuses on China which is still the main manufacturing hub in the world. By means of empirical semi-structured interviews with 3DP companies in China, the current application of 3DP technology in the industry and the associated challenges are investigated. Although many companies can see the benefits of 3DP, its potential has not been delivered as promised. Several areas have been identified that could be improved further. The interviews with 3DP companies are used to learn about the gap between the 3DP technology in depth, and 3DP industrial applications which can further improve the growth of the 3DP industry.

Keywords:
3D Printing, Manufacturing, China, Interviews.

1 INTRODUCTION

The development of 3D Printing (3DP) technology can be traced back to the 1980s, and it is now being affordable for mass customisation and large-scale applications [1-2]. Despite the merits 3DP can potentially offer, it has not yet delivered its full capability to the industry [3]. 3DP is not a technology to replace traditional manufacturing methods, at least in its current form from an operating cost perspective [4]. Arguably, energy consumption may pose an issue from a sustainability point of view, which is estimated to be 100-fold higher in 3DP processes than in traditional manufacturing processes [5]. This assertion is subject to debate as some other studies proposed the opposite (e.g., [6-7]).

There are lots of research studies that have investigated 3DP technology, especially in the material engineering domain. Nevertheless, such effort would become a waste if the technology cannot be deployed successfully in the industry. Although 3DP is a popular topic in recent years, the application of 3DP in the industry is still very limited. There are obvious obstacles that restrict 3DP from having a larger scale application. The technology itself is fairly mature, which indicates that the application side could be the source of hurdles. This paper aims to explore the challenges from a manufacturing and supply chain point of view when employing 3DP technology. Since this is an emerging topic, an exploratory qualitative approach is employed. Semi-structured interviews were conducted.

The rest of this paper is organised as follows: Section 2 reviews relevant literature. Section 3 summarises the research method employed in this study, whereas Section 4 discusses the findings from 28 qualitative semi-structured interviews. Finally, Section 5 concludes this paper.

2 LITERATURE REVIEW

If we have started a new industrial revolution (inter alia digital manufacturing, Industry 4.0), 3DP is definitely part of it and is considered as a game changer [8]. With 3DP production can be started on a made-to-order basis [9]. This will reduce the amount of inventory stock up along a supply chain [10]. In other words, the excessive inventory stocking up due to uncertain demand along a supply chain, known as the famous Bullwhip Effect [11], should accordingly be reduced. If the Bullwhip Effect is a critical problem in any supply chain, would 3DP be the solution?

There are lots of studies discussed the impact of 3DP on manufacturing and supply chain. The majority of these studies point to customisation [12-14]. One extreme of the spectrum is, of course, to produce a quantity of one single unit. This was coined by Petrick and Simpson [15] as “economies of one,” in contrast to economies of scale for mass production. Undoubtedly most companies will fall between the extremes of this spectrum. The implication, however, is that with the 3DP technology, the configuration of supply chain and hence the associated business models would inevitably be changed. Customisation will allow product differentiation easier than the traditional supply chain models, and also allow companies to make production in small quantity. Both features will change the way the traditional supply chain operates. One simple effect is that the number of suppliers can be reduced drastically due to the flexibility 3DP can deliver. In an extreme scenario, the only supplier would be the materials supplier for the 3DP process during the production phase [16]. The focus will be leaning more towards the customer end [17].

Since the 3DP production can take place with minimum amount of labour involved, labour cost is less of an issue in view of the overall product cost. The location of production thus becomes less sensitive and there could be a re-shuffle of production facilities. For example, some factories may move back to the source of consumption, as with many developed countries [6, 16, 18]. At least the existing outsourcing models may change accordingly. This may also create a new paradigm of distributed manufacturing [19].

Another potential advantage of 3DP to the supply chain is that the technology can simplify some production processes (e.g. a module can be printed in one 3DP process rather than by assembling several components which may require different supply chains). In this sense, the level of complexity of a product or a supply chain can be reduced, and consequently the operation of the supply chain is more efficient [20]. This efficiency can also be complemented by the increased quality level that the 3DP process can achieve compared to traditional labour intensive operations.

Rogers et al. [3] provided a comprehensive review regarding the implications of 3DP on supply chain. Therefore, the authors will not elaborate that point further and readers are referred to Rogers et al. [3] for more details. The interesting findings from the literature is that the benefits of 3DP on manufacturing and supply chain management have been discussed widely, but there is limited evidence to demonstrate that successful mass scale applications of 3DP has already taken place. In this connection, this research aims to explore this issue in order to uncover the challenges in deploying the 3DP technology in practice.

3 RESEARCH DESIGN AND METHOD

Based on the review in Section 2, the main research question to be investigated in this paper is the current application of 3DP technology in the industry and the associated challenges. In order to address above research question, empirical qualitative data are required. It is because the problem is exploratory in nature, and hence qualitative type of research is more appropriate at this stage. In April 2016, 14 semi-structured interviews were thus conducted, each of which lasts for around 1 hour. Another 14 semi-structure interviews were conducted in August 2016.

The sample frame of these interviews is chosen to cover companies that are related to various 3DP stakeholders. They could be printers, manufacturers, or so. The natures of their business are: (1) Chinese 3DP manufacturer and 3DP distributor of foreign brands; (2) 3DP and scanning software supplier; (3) 3DP material supplier and material institution; and (4) 3DP solution provider. The business area of the majority of the companies covers rapid prototyping and moulding of fashion products, mass customisation of spare parts in ships, jet engine, aerospace, and for education science training. The companies interviewed are located in major industrial areas in China including Beijing, Shanghai, Hangzhou, Ningbo, and Guangzhou. The interviewees are either general managers or technical managers who have good understanding on the 3DP business in China.

4 FINDINGS AND DISCUSSIONS

Our initial questions are related to the application of 3DP in the manufacturing and supply chain sectors. This serves to confirm the potential capability of 3DP to the industry, and to explore the challenges faced by the industry. Generally, the responses about the application of 3DP are positive. In particular, three focus areas can be identified which are discussed further in the following sub-sections.

4.1 R&D and design

Although material costs and operating costs of the 3DP process may still be higher than traditional manufacturing process, it is generally agreed that 3DP can help reduce the development cost of products. Interviewee 2 stated that "*3DP does have some significant impact in some industries. It is mainly because with 3DP technology, it will improve efficiency and significantly lower the cost*". In addition, 3DP can shorten development time drastically. It is because, according to interviewee 22, "*traditionally you have to design the machine and mould based on what you like to produce, but 3DP changes the old way so that you don't have to design them*". Interviewee 18 supplemented this, by stating that "*it is a waste to develop a prototype and mould by using conventional method. 3DP can stand out and give you an economic solution*" in this aspect. This is also the early utilisation of 3DP, i.e., rapid prototyping.

One of the interviewed companies, interviewee 5, provides such service to foreign trading customers. When the company receives a physical sample from the customers, they scan it and then 3D-print it out. It is even easier if the customers can provide the company with a digital file. This is a new business model than can provide fast turnaround time to the eventual customers without any tooling. This business model enables the customers to modify the design based on the 3D-printed samples and can get the revised version very quickly. With such physical samples, the customers can minimise the risks in the product design process. They can also order a number of samples with different design options for testing the same time at an affordable effort – back to the concurrent engineering concept. Interviewee 7 mentioned that a WiFi device required half a year to complete the tooling fabrication and testing phase, not mentioning the high tooling cost involved. 3DP can also reduce both development lead time and the associated costs.

The main implication of this area is that it is easier to produce a new product in smaller quantity with relatively affordable capital with 3DP technology. It is also easier to build a new brand in the market, and this is particularly favourable to small and start-up companies. Companies can then move from Original Equipment Manufacturing (OEM) or contract manufacturing to Original Design Manufacturing (ODM) with the assistance of 3DP. This is exactly what the 'Made-in-China 2025' initiative would like to achieve in China. Of course, how such small companies, normally with limited resources, can protect the IP and ensure that the design is clean from infringement is another challenge that we will discuss further in later section.

4.2 Manufacturing and supply chain

Notwithstanding the cost benefit 3DP can bring in the product design process, the shortcoming of 3DP aligns with the reported studies that the unit manufacturing cost is still significantly higher than the traditional counterpart. This is still the major barrier in achieving the full potential of 3DP. In other words, there is a pressing need to incorporate additional value in the 3D printed parts or components to compensate for this high cost. For example, 3DP is (almost) mould-free. This characteristic of 3DP can reduce the maintenance cost and tooling cost of moulds, which can bring some benefits to some industries. The next question is of course how to leverage various cost, such as economy of scale from mass production, according to interviewee 22. This is also echoed by interviewee 18 that in some industries "*current moulding is quite convenient and we can make it cheap and nice*".

One way to counteract the aforementioned barrier is to employ 3DP in a different manufacturing or supply chain mode. Mass customisation has unanimously been considered the merit of 3DP in manufacturing and supply chain in the literature. Interviewee 16 and interviewee 21 both confirmed that small batch production is more feasible with 3DP, especially when the demand is uncertain. 3DP allows product differentiation. Interviewee 2 gave an example of car headlights in her production line. There could be six options that mean the companies needed to stock up inventory for six stock-keeping units. It is costly and timing consuming to design and manage the corresponding moulds. With 3DP, interviewee 2 can take just one week to finish this task.

Based on the interviews, 3DP can not only reduce cost and time of product development and manufacturing, but help counteract the uncertainty of demand since the supply chain can be more responsive utilising the 3DP approach. This is because, to an extreme extent, production can take place at a unit quantity level. Manufacturers do not need to stock up different types of materials but the materials for 3DP, which can be used to produce different types of parts and products. Effectively, there is no need to manage the supply chain in this sense.

Demand for the materials is aggregated by the technology itself even if the demand information is not available to the manufacturers and the suppliers. To achieve this paradigm is of course not easy and currently the industry is still far from this. However, the ability of introducing customisation can help manage the demand uncertainty of the supply chains. This is especially important with the current pace of technological development that leads to fast changing customer demand.

Another obvious barrier to apply 3DP in the industry is the recognition of the technology to some industries. This is somehow related to the cost of 3D-printed parts, and the material in relation to printing. Industries with high value products such as medical, automobile are easier to incorporate 3DP in their manufacturing process. Some interesting industries, such as glass production, do not require tooling anyway. Therefore, the added value of using 3DP technology would be very much dependent on the time and cost to print a product or parts.

4.3 Data management

Coupled with the customisation capability, good data management can facilitate 3DP, and vice versa. It is because the value behind the customisation is customer preference and behaviour. Interviewee 15 worked with her customers, in that data from those customers who, in turn, obtained scanned data via the cloud, are synchronised. This allows interviewee 15 to work on the data and revise the design. This can allow Interviewee 15 to make sure that the design is truly customised and would not infringe other designs in the database. Obviously this links to the IP issues that will be discussed in the subsequent section. Regardless of the IP issues, this way to exchange information is not restricted to the product design for printing. For example, interviewee 18 also incorporate patients' information so that the medical products produced by them can be easily customised for next generations of products. This aligns with the recent big data research and analysis trend. This can help companies to trace 3D-printed contents along the supply chain, according to interviewee 19. This can further assist mass customisation mentioned above because this really can achieve the no-supply-chain utopia.

5 CONCLUSIONS

It is still too early to conclude that the mass production era has been replaced by the mass customisation era. In fact, the opposite is probably more accurate according to the interviews. 3DP has created a lot of "hopes" but at this stage 3DP has still not fully delivered its promise. That being said, 3DP, among other technologies and technological development, enables the transition. The authors do not assert that the mass production type of methods will be entirely phased out, but it will be complemented by the mass customisation demand. This is in fact supported by interviewee 21: "I don't think it (3DP) can replace the traditional manufacture". However, many interviewees predict that as more 3PD service providers or manufacturers will appear in the market, 3DP that is easier to achieve can be incorporated in various manufacturing and supply chain applications. One way to further enhance the productivity of the 3DP industry could be to set up a service centre for 3DP. Interviewee 12 stated "this centre will serve the local enterprises to enhance their competitiveness".

One limitation of this study is that we don't focus on a particular target industry. The implications deliver from this paper is rather generic and hence cannot cover the specifics of some industries. The medical industry is a classic example that requires special attention. In addition, 3DP for metallic components is also an emerging issue in the industry. Another future research direction is thus to pinpoint such specialised industries and try to retrieve their distinctive characteristics and challenges. There is no one-size-fit-all strategy or business model.

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