Investigation on Additive Manufacturing as an enabler for reshoring manufacturing activities

MORADLOU, Hamid, SAWHNEY, Rapinder, BACKHOUSE, Chris J. and MOUNTNEY, Sara <http://orcid.org/0000-0002-9806-1228>

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Investigation on Additive Manufacturing as an enabler for reshoring manufacturing activities

Hamid Moradlou (h.moradlou@shu.ac.uk)
Sheffield Hallam University, Department of Engineering and Mathematics

Rapinder Sawhney
University of Tennessee, Department of Industrial and System Engineering

Chris J Backhouse
Loughborough University, Wolfson School of Mechanical, Electrical and Manufacturing Engineering

Sara Mountney
Sheffield Hallam University, Department of Engineering and Mathematics

Abstract
The recent phenomenon known as re-shoring, has gained momentum among developed countries. It is also evident that the new generation of technologies such as Additive Manufacturing (AM) and intelligent robotics can affect the manufacturing location decision. This study aims to investigate how AM can help companies to re-shore manufacturing activities. Three in-depth case studies are conducted where AM is used as primary manufacturing approach to reduce the number of suppliers and shorten the supply chain. The results show that companies can reduce transportation, lead-time, inventory and substantially improve customisation, meanwhile accommodate product changes as well as process changes in production.

Keywords: Reshoring, Additive Manufacturing, 3D Printing

Introduction

Relentless globalization has put tremendous amount of pressure on manufacturing sectors since they are obliged to operate within a complex international supply chains. This is whilst a product is manufactured in one country which is then shipped to an offshored location for further processing such as assembly or packaging (Arlbjørn & Lüthje 2012). This was initially started as the businesses moved the production overseas primarily to access cheap labour, raw materials and local technological resources. This is also known as offshoring strategy where the companies target new markets and ensure their global presence. However it is evident that the offshoring trend has slowed down in the last five years. Despite the scale of offshoring strategies implemented every year, the survey conducted by Herath & Kishore (2009) shows a lower success rate than expected with various offshoring strategies. Fine (2013) states that “the big names at the end of the chain have come to realize that the lowest price can mean highest risk – and highest risk can mean high total costs". Hence the manufacturing sector is witnessing a gradual change in the global supply chain configuration as some companies have repatriated their production to the countries of origin

As a result, new trend for reshoring manufacturing activities has emerged in which companies decide to bring once offshored production, back to their home country (Gray et al. 2013). Similarly Ellram et al. (2013) define reshoring as 'moving manufacturing back to the country of its parent company'. New studies show that the jobs being brought back to developed countries are not essentially the same jobs that were previously offshored (Lawrence 2015). According to Moradlou & Backhouse (2016a), re-shoring can provide a platform to utilise the new generation of technologies through Postponement strategy. It is believed that the only way for a long lasting and a sustainable reshoring strategy is through a fundamental transformation of the current industrial environment (Lawrence 2015; Bailey & De Propris 2014, Moradlou & Backhouse 2014). Meanwhile study done by Moradlou et. al (2017) indicates that the lack of production and delivery responsiveness is the primary reason behind the reshoring phenomenon. This indicates the potentials to utilise new technologies to overcome the issues related to responsiveness.

Therefore manufacturing sectors are required to adopt modern technologies such as AM, intelligent robotics, big data and Internet of Things, by which industries will ensure their competitive position in the market (Lawrence 2015). It is believed that the "upcoming industrial revolution will be triggered by the internet, which allows communication between humans as well as machines in Cyber-Physical-Systems (CPS) throughout large networks" (Brettel et al. 2014). In other words this is also called the fourth industrial revolution (Industry 4.0) in which virtualization, decentralization and network building could change the manufacturing landscape. A report published by TATA Consultancy Service (TCS) recommends seven mega trends that need to be adopted as a new direction for manufacturing industries.

1. "Consumerization of manufacturing.
2. Virtualization and digitization for all – global collaboration from product design to customer service
3. Supply chain network economy for better management of B2C aspiration.
4. Complexity reduction and modularization of business.
5. Product design, material science and sustainability.
6. Next-generation technology – hybrid crossover solutions.
7. Evolution of the manufacturing model" (TATA Consultancy Service 2013).

The above trends indicate the necessity of implementing new technologies that can transform the supply chain configuration. Moradlou & Backhouse (2016b) have stated that reshoring companies can employ technologies such as AM to shorten supply chains and enable the companies to adjust their businesses according to the above trends. Hopkinson & Dickens (2001) defines AM as a manufacturing process in which a part is made from a 3D model data by adding layer upon layer, as opposed to traditional subtractive manufacturing method. Another more commonly used term to refer to AM is 3D printing (Eyers & Potter 2015). According to number of studies, AM technologies can be seen as one of the revolutionary production approaches (Deloitte 2014; Dujin et al. 2014; Bechtold et al. 2014). It should be noted that the advancement of AM technologies has gone a long way since it initially started. It was started as a prototyping technique, which was mainly used in product development stage of the lifecycle. But the improvement has not stopped ever since. Tuck et al. (2007) state that "the use of AM will have particular impact on supply chain management paradigms such as lean and agile and has particular strategic fit with mass customisation". Hence this technology can be a feasible approach for mass customisation of products. This study aims to investigate the impacts of AM on the supply chain and the reshoring phenomenon. The following is the methodology adopted in this paper.

Methodology

This research highlights the AM impacts on the supply chain of reshoring companies by conducting three in-depth case studies (See Table 1). The selected companies utilise AM technology as a primary manufacturing approach to reduce the number of suppliers and shorten their supply chain. For the data collection process, highly ranked informants with broad knowledge of supply chain management were selected. To examine the research question established in this study, an appropriate framework was developed. After looking at the operational research literature, five operations performance factors were chosen which are the quality, speed, dependability, flexibility and the cost. These factors were adopted from the study done by Slack et al. (2013) which illustrates the connection between the performance factors and their external and internal effects. It provides a suitable platform to collect the required information by performing semi-structured interview. As a result, six semi-structured interviews were performed to collect the required data. Once the relevant data were transcribed, thematic analysis approach was selected using manual coding technique. Then a comparison study between the data gathered was conducted.

Table 1, Case studies

Case studies	Engineering Segment	Location	Number of employees	Respondent	Number of Interviews
Company A	Automotive	US	<99	Production Manager	2
Company B	Automotive and Aerospace	US	100-499	Senior Supply Chain Specialist	2
Company C	Electrical Goods	UK	<99	Managing Director	2

Findings and Discussion

As mentioned in the methodology section of this paper, the data collection is conducted based on five operations performance factors, cost, quality, speed, flexibility and dependability. Followings are the finding obtained after conducting the interviews.

Cost: The reason for selecting the cost, as one of the main themes in the data collection was to understand how AM technologies influence the cost of the production. In other words how does AM compares to the traditional methods of manufacturing. Series of factors were identified throughout the interviews. The first two aspects of the cost saving was related to the labour costs and transportation of goods. It was clear that the on-site production at all three companies led to a significant cost reduction on the transportation from the supplier as well as delivering to the customers. The following quote was recorded at Company A:

> *"We won't need a lot of labour in comparison to a large scale car m*anufacturer. We have machine operators. There is a single person operating at least two sets of machines at minimum. Two sets of AM machines and milling machines. You have also shipping reduced since we are currently dealing with only small number of suppliers that mainly provide the *feedstock for our machines." (*Company A)

And on the transportation side:

> *"We don't have cost related to the transportation and all the requirement for the protections* and insurance cost around it to get these vehicle to the destination including the overseas *situation the cars are produced on site and on location." (*Company A)

Similarly the interviewee at Company C believed that:

> *"Another component of the cost is the labour. How much am I paying for people, that* machine is *sitting there, doesn't really care. The machine will work regardless if the light in the room are on, doesn't need air conditioning and you don't need humidity control. All it need to control is inside that built chamber. "(*Company C)

Hence the reduction of labour cost and transportation cost are the main two factors under the cost operations performance. However another aspect to the overall production cost is the energy consumption. This plays an important role when the production is located in the western countries such as the UK and USA since the energy cost is normally higher than that of the low-cost countries such as China and India. According to a study done by Company B, the energy cost can be reduced through the optimisation of the manufacturing processes by considering the energy as a variable rather than accepting it as a cost of doing business. Following is also another point where AM technology can facilitate the energy saving during the production process.

> *"Metal additive manufacturing techn*ologies can significantly improve manufacturing energy efficiency by increasing material utilisation and minimising scrap material associated with *component fabrication." (*Company B)

The cost of utilising AM technologies in production can be driven by different factors. In other words AM can only be used in certain types of production where it offers its main advantages. As the following quote indicates, it is important to identify the range of products that can be manufactured using AM and then determine if it is economically viable to employ such technologies in production process.

> *"So really what I am getting at is what cost of products and processes are most driven by an* aspect that can be affected by AM. So that would be either material. If it is an area if you have a high scrap, additive would make sense. If it is a labour issue additive make sense. If it is a significant transportation issue additive would make sense. And another one at least from my perspectives would be the tooling. Where you have *such a … tooling and prototyping. So those* become the areas where additive make sense, for mass production additive does not make *sense." (*Company B)

<u>Quality</u>: Once the cost aspect was covered the interviewees were asked about the quality of the product they manufacture using AM and compare it to that of traditional ones. This is while the quality standard in the additively manufactured product is one of the mostly debated aspects of these technologies among the researchers (Ahuja et al., 2015; Atzeni & Salmi, 2012; Khajavi et al., 2014). Some scholars suggest that the quality of the AM products is still not sufficient according to the standards required in the market (Hague et al., 2003). Conversely Petrovic et al. (2011) believe that with the advancement in the AM technologies the quality of this approach is now at the

competitive level. Comparison between the additively produced component and conventional approach to manufacture the same component shows that in certain areas the quality of the product does not differ. In fact it can also offer advantages such as weight reduction and increase in the strength of the structure. The following quote states the quality aspect of AM technologies at Company B.

“Elimination of geometrical constraints associated with conventional manufacturing technologies such as casting and machining can result in components that fulfil all of the functional requirements but weigh significantly less than those of conventional design.” (Company B)

It also offers the capability of infrared thermography for further inspection of the quality.

“With additive manufacturing the goal is to be able to use infrared thermography where you can look at layer by layer and see where you got imperfections and heat rises and stress built up looking at them layer by layer by layer. So I’ve got a complete history of how it was done. If I start block of metal I don’t know what is exactly inside it. So from the quality stand point, theoretically yes I can get better information about that material and part. So from quality stand point I don’t know if there is going to be much of a difference with traditional methods.” (Company B)

Despite the viewpoint in the last paragraph, Company A believes that the traditionally manufactured products have better quality than AM products, while pointing out the significant potential in coming years for the quality aspect of AM products.

“The quality I think that it is at today’s stages it is lower no doubt that the quality of your traditional method of manufacturing your components and cars. Em …. That’s were a lot of people stepping into the game, mostly in OEMs they look at it that’s not and will never be to the same level of quality that we produce now, but I say that is narrow way of thinking and again like 10 to 20 years working on this everything can drastically change, and change the game. I think that is a narrow-minded way of thinking. I can see why they would think that the way they see it now, but we are more ambitious company we can vision” (Company A)

Speed: The third operations performance factor mentioned during the interview was the speed of the production. All the participants in the study had the optimistic vision on the future development of the technology and increase in the speed of production in coming years. With the advancements these technologies witnessed since the start, there is still number of ways to increase the printing speed in terms of deposition rate and material properties. Another aspect to speed is the overall production speed. This depends on the complexity of the processes and the stages involved in making the product by the reduction in set up, changeover time and number of assemblies.

“When you look at the speed, there is a lot of aspect to speed. There is with making the part that would be depending on how many steps are involved. If it is something that is a simple part and I can program CNC machine and put it there it is good to go and it is not a big deal. But if it has to go from station to station to station, intermediate steps and all these kind of things then additive would make more sense because you are not handling it as much time. You don’t have so much inventory level in the pipeline throughout that just reducing the intermediate steps where you have more time to move from one process to another. And then speed also is to making the part or getting the part delivered customer.” (Company B)

The speed of AM has been improving with a rapid space and will continue to enhance over the coming years (Tuck et al., 2007). The Company A has targeted to reduce the production of the body and chassis combination from 24 hours to 12 hours, which is mainly done by focusing on the material deposition rate. It should be noted the first car built at Company A required 44 hours of printing that was reduced to 24. However this process is continuing to further reduce the time required for the printing stage.

*"Our target is to print the body of the car in 12 ours but the way I see it in 5 years' time that 12 hours' time I see being muc*h less. Some could argues that in different way that I think it as a functional choice of investment really like whether or not like a companies investing on increasing the speed of deposition rate that put the material faster and more precise. It is just the technology is on the way, it is just money and time to develop the process really to increase that. If you could imagine you are putting down 80 pounds material per hour and you could make that into 160 pounds per hour obviously you doubling your speed *on that." (*Company A)

Flexibility: Flexibility is one of the strongest aspects of AM technologies. The capability of manufacturing parts regardless of the geometrical complexity has made this approach an unprecedented technology enabling businesses to produce parts which are not possible with any other manufacturing methods. In fact once the digital file of the product is developed in 3D format, the printers can produce the object straightaway. The adoption of such technology has enabled the Company A to accommodate the unexpected changes in the production system as well as the last minute changes in the product design. It also allows for more product iterations during the product development stage.

"There is a difference in manufacturing time now obviously the big companies have lined up for high reproducibility if they ever have to stop their production line they can be down for three month sometimes to make the whole production change or different thing depending on the extent. But us there is virtually no time required for that. We can change the design and hit the print there is no cost to *tooling at all. "(*Company A)

"The flexibility in AM is well documented. It is a technology where there are almost no design boundaries. This allows us to design and make parts which are light weight and o*ptimised in design."*(Company C)

As a result of the flexibility, more customisation in the product can be achieved. This is through closer communication with the customers. One of the strategies implemented at Company A is the involvement of the customers in the product design process. By doing so the customers can design their own vehicle and include the features they like.

Dependability: The last operations performance factor covered in the interviews was the dependability. This criterion or in other words the on-time delivery of the product to the customer can be seen as a result of improvement in speed and flexibility of the processes. The fast speed of the production combined with the ability to accommodate unforeseen changes in production and products can allow the company to meet the delivery objectives and be on-time when it comes to ensuring reliable delivery of the products. The following two quotes relates to the company's performance regarding their on-time delivery to the customer.

"If I make thing in the place that I will be using it, there is more chance of reliable supply goes way up. If I count on the thing coming from overseas lots of things can happen. A lot of things can be happening to it. But the transportation time, containership and all the other stuff. *Reliability or dependability can be compromise if I make the produce where I need it."* (Company C)

"At Company A we deal with the customers directly. They can come over here to order and pick up their products. Therefore the dealerships are also eliminated. It is like a shortcut which *it makes the process a lot faster and saves costs…. I would say we are quite strong in this factor (Dependability) thanks to 3d printing" (*Company A)

As it can be seen above the capability of producing the products in the same location where the end customers are, is the main factor that improves the delivery of the goods. After looking at the data gathered from the interviews, Figure 1 was developed to show a simple comparison between the conventional manufacturing e.g. CNC machining and AM production. This Figure is based on the 6 interviewees performed in three companies, where the participants were asked to provide their viewpoint on the comparison between AM and traditional manufacturing. The result is illustrated in five scales, one being the weaker side and five being the stronger side (note that the average was taken).

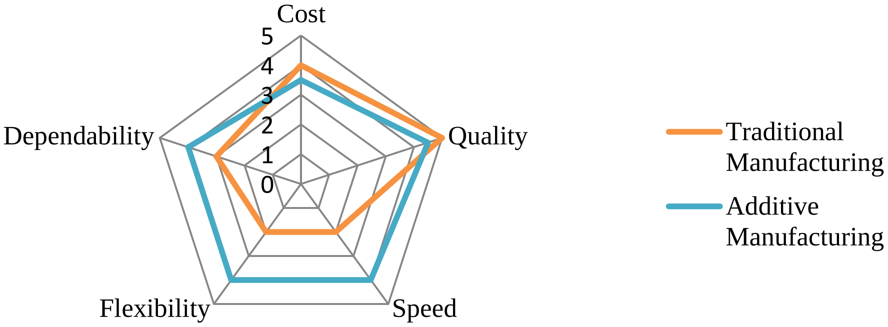

Figure 1, Comparison between traditional manufacturing and AM

TCS Seven Mega Trent

After analysing the three in-depth case studies conducted, the implications of AM were also compared to the 7 mega trends developed by TCS (TATA Consultancy Service, 2013). Consequently, several points were outlined as most significant impacts that AM technologies have in the context of supply chain management. In order to remind the 7-mega trend, the following points are included.

Consumerisation of manufacturing. In other words, shifting the focus from Business-to-Business (B2B) to Business-to-Business-to-Consumer (B2B2C): This involves establishment of customer-centric business system using interactive websites, digital marketing channels, Point-of-Sale (POS) systems, and e-commerce. Such trend can be addressed by engaging the customer in the product development stage. This is currently being done at Company A with the help of AM technologies where customers are involved in designing the body and the internal features of their future cars.

Virtualisation and Digitisation: This comprises the utilisation of software to simulate, visualise, and virtualise the product behaviour and performance under virtual scenarios. Hence it enables the companies to achieve more products testing iteration in a shorter time resulting in a quicker time-to-market. The Cloud technologies can be considered as one way to initiate such collaborations. With the use of AM, products can be tested going through number of iterations. For instance, at Company B, customers are able to view their designs prior to the actual production by using CAD software.

Connected Supply Chain: This is a network of interrelated supply chains that can also provide high visibility from suppliers to distributors. This would allow the companies to develop an agile production plan and maintain minimum inventory. In the case of AM technologies, the company can be integrated with its network of suppliers and customers to create value for firms. At all the case studies, supply chain has been shortened due to the reduction in number of parts used in the products. Meanwhile this has made the supply chain members more accessible since the number of suppliers has been also reduced. However it should be noted that the well-integrated online platform is much more than individual physical mechanisms. It needs some standards for the integration of data, applications, and processes to be negotiated and applied in order for real-time connectivity between the stakeholders (Rai et al., 2006).

Complexity Reduction and Modularisation of Business: Modularisation can be applied in various aspects of the business, products as well as processes. For instance by adopting standardisation and harmonisation, companies can ensure component economies of scale since similar components across product families will be used which also facilitates product updating. Moreover it increases the product variety and also reduces the order lead-time due to fewer components. One of the strong aspects of AM technologies is the ability for the customisation. The case studies performed in this study shows that the companies are able to offer unique products to each individual customers based on their specification.

Product Design, Material Science and Sustainability: This trend investigates the application of the new generation of materials with higher performances, lower costs and environmentally friendly. Moreover, companies are also obliged to consider the carbon footprint from supply perspective by intelligent sourcing and shortening the supply chains. According to the Company A, the material used in the body of the product made can be fully recycled. The material can then go back to the cycle of production after it has been made into a feed stock again. It was also mentioned that there are significant potentials in discovering new materials that can be used in AM.

Next Gen Technology: This includes the utilisation of embedded electronics, telematics, mobility, telecom services, and conventional engineering systems. A range of opportunities have been identified to use embedded electronics in some of the AM technologies. An example of with is in the "Sheet Lamination" or "Ultrasonic Consolidation" process (Li et al., 2015; Monaghan et al., 2015). Note that this study does not aim to investigate the technical side of AM technologies.

Evolution of the manufacturing model: This indicates the requirement for a shift from large centralised companies to a network of smaller modularised businesses that offer their core competencies and are closer to the end customers (TATA Consultancy Service, 2013). With the use of AM technologies, the local suppliers (possible small size companies) can engage in a larger supply chains (Tuck et al., 2007). This was evident at the Company A and C where the company had moved some suppliers from overseas and replaced them with the local suppliers in their countries.

AM Impacts on Re-shoring	
	1. More Customisation
	2. Less Transportation
	3. Accommodating Product Changes
	4. Less Inventory
	5. Accommodating Process Changes
	6. Shorter lead-time

Figure 2, Aspects of AM enabling reshoring companies to be more responsive

After carefully analysing the findings and the results in this investigation, six areas (See Figure 2) were identified where AM can make the most contributions in terms of responsiveness in the supply chain of re-shoring companies. These factors are; better customisation, less transportation, shorter lead-time, less inventories, accommodating product and process changes. By adopting AM technologies in the production, companies will not only be able to accommodating changes in product and processes but also achieve shorter time to market in introducing new products. Customers interface with the production system within Company A also allows the company to develop significant amount of variation in the product designs, making customisation possible. This collaboration and information sharing can also trigger innovation along the supply chain (Brettel et al., 2014). However there are also some indirect factors that AM technologies can have which influence the supply chain management. For instance the geometrical freedom, multi-material manufacturing and reduction in material waste can reduce the amount of operations and the suppliers involved in the production. This ultimately reduces the manufacturing lead-time and shortens the supply chain.

Conclusion

This study contributes to the existing knowledge by focusing on the operational challenges and bridges one of the emerging technologies, AM, to reshoring phenomenon. It provides a detailed explanation on how AM technologies can impact the supply chain performance of companies who are repatriating their manufacturing activities to their home countries. As a result of this investigation, author identified six areas that can be significantly improved with the help of AM technologies and facilitate reshoring decision. The companies can reduce their transportation, lead-time, inventory and substantially improve their customisation capability, meanwhile be able to accommodate product changes as well as process changes in the production. It should be noted that this study can benefit from conducting more case studies in terms of obtaining a more generalizable results.

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