DEVELOPMENT OF 3D PRINTING BUSINESS MODEL IN CHINA

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ABSTRACT

3D printing is an industrial revolution that brought revolutionary advancement in the manufacturing sector. China is leading in the traditional manufacturing sector, but the disruptive technology of additive manufacturing has provided developed economies with an opportunity to leapfrog to the front. Thus there is a need for a comprehensive business model for the 3D printing industry of China. The explorative study extensively reviews the existing literature on 3D printing and business model. The methodology is based on qualitative research design, and snowball sampling technique is used for data collection. In-depth recorded interviews were conducted from 5 enterprises operating in the 3D printing cluster of Weinan Science Park, China. In order to examine and record patterns within the qualitative data, the study executes various analysis tools such as thematic analysis, word frequency query, text search query, word tree and group query. Research findings suggest that business model for 3D printing industry consists of six internal components, namely financial, marketing, technological, competitive advantages, corporate social responsibility, and supply chain, while government support, R&D, and globalization constitute external components.

Keywords: 3D printing, additive manufacturing, business model, research and development, supply chain.

1) INTRODUCTION

Increased reliance on rapid manufacturing is shifting the focus from traditional manufacturing to additive manufacturing. 3D printing is also known as to additive techniques, additive layer manufacturing, layered manufacturing, freeform fabrication or something along that line (Conner et al., 2014, Mellor et al., 2014). 3D printed product is three dimensional item that is produced by a method in which consecutive coats of materials are set over each other till the item is formed. Malleability of additive manufacturing for practical reflection focusing on number of applications

and future development are directed by this technology. The manufacturing industry started to use this disruptive technique to eliminate the use of tools, production lines and curtailing supply chains. In a relatively short span of time, 3D printing is witnessing the transformations of rapid prototyping, rapid tooling and distributive manufacturing (Bak, 2003). The application and utilization of 3D printing in distinctive fields offer different advantages to the industry and customers i.e. quick prototyping, cheap prototyping, decreased lead times, quick assembly lines, diminished overhead, mass-customization, large scale manufacturing, utilization of special materials, configuration opportunity, and minimize waste and destructive chemicals (Ivanova et al., 2013). Though 3-D printing benefited the industry and consumers, there are also some industrial problems aroused due to this new technology, for instance, constrained objects measurements, lessened variety of materials, lower exactness, restricted quality (Janssen et al., 2014). Additive manufacturing is inherently different from traditional manufacturing, which is characterized by subtractive manufacturing. AM has the potential to disrupt traditional manufacturing and is already redefining competition. The developed countries, such as USA, are relishing a lot of benefits from 3D printing technology, while this technology is a double-edge sword for fast developing economies, like China. With respect to traditional manufacturing, China emerged as manufacturing giant and accounts for 21 percent of the world's total manufacturing value, surpassing the America's 19.4 percent in 2011 (Gang, 2012), however 3D printing poses threats to China of being the manufacturing powerhouse (D'aveni, 2013). Popular media reports (Gang, 2012) suggest that USA is making all out efforts to regain its lost share in manufacturing and enhance jobs through exploiting additive manufacturing. Thus there is a need to explore 3D printing businesses operating in China and suggest a technology-specific business model.

1.1) Research Synthesis

Previously, many studies have been conducted on additive manufacturing and product designs (Thomas and Gilbert, 2014, Moilanen and Vadén, 2013), its implementation in different countries and sectors (Kianian et al., 2015) and technical aspects of the products in different sectors (Tomasello et al., 2016, Wu et al., 2016), but little research (Rayna & Striukova, 2014, 2016) exists with respect to the business models of 3D printing industry. However, 3D printing is challenging the existing business dynamics and business models (Hämäläinen and Ojala, 2017). Mellor et al. (2014) designed a framework of internal and external factors for the implementation of 3D printing, but the study lacks generalizability on a wider scale because it is based on a single case study. This relatively naïve revolutionary industry needs an innovative business model in order to overcome the obstacles and enable further technology commercialization. In China, there are emerging 3D printing enterprises and the primary purpose of the study is to explore the components that can potentially enrich 3D printing sector and thereby propose a business model for the relatively nascent Chinese 3D printing industry. In order to achieve the main objective, the qualitative study seeks to answer the following research questions: (a) what are the factors of business model for 3D printing industry of China? (b) Why customers prefer 3D printing technology over traditional manufacturing? (c) What are the issues in adoption of 3D printing technology, and the future prospects of 3D printing technology in China? Second section thoroughly reviews the relevant literature on 3D printing technology and business model, and also provides tabular description of the components of business model by various authors over the period of last five years. Third section elaborates research methodology, theoretical framework and numerous qualitative analyses techniques. Fourth section explores the results of the study by answering the research questions that we set forth in the first section. Last section of conclusion extrapolates the key findings of the study, and consequently suggest recommendations for the betterment of the industry and for future studies.

2) LITERATURE REVIEW

2.1) Additive manufacturing and its implications for the Chinese economy

Often touted as the third industrial revolution, additive manufacturing is necessarily the digitization of manufacturing and an exemplar of mass customization (Berman, 2012). By solidifying material in layers, 3D printer acts as a computer controlled machine that can cobble up physical objects (Moilanen and Vadén, 2013). 3D printing is also known as an additive manufacturing technology, for the reason that it stores material in the form of layering through use of a print-head, much an inkjet printer. The printhead passes beside the X and Y axis, and on the Z axis the printed material

passes back and forth, progressively building a three dimensional layered object (Tomasello et al., 2016). It is also known as rapid prototyping because 3D objects are quickly made on a machine connected to a computer containing blueprints of the object (Bassoli et al., 2007). Additive manufacturing is necessarily different from traditional manufacturing because it makes product by successive deposits of material rather than using exclusion or forming methods. AM has now become a rather preferable choice for manufacturing customized components and smallscale production (Scott and Harrison, 2015).

The disruptive technology offers benefits to almost every sphere of life, be it medical and dentistry sector (Janssen et al., 2014), surgical instruments (Ikram et al., 2016), automotive and aerospace, architecture industry (Bogue, 2013), construction industry (Wu et al., 2016), food industry (Godoi et al., 2016), textile (White et al., 2015) and education sector (Walters and Davies, 2010). Importantly, the technology is capable of producing complex components which might not be possible to manufacture with conventional methods (Berman, 2012). The advent of relatively economical 3D printers, like desktop 3D printers, is enabling faculty, students and industrialist to conceptualize their ideas. Schools, especially of developed countries, are progressively procuring 3D printers, so as to stimulate students' interest in disruptive technologies. This practice not only enables pupil to determine which field of study to follow, but also spark the highpoints of fields, such as engineering and magnetics (Bull et al., 2015). Captivatingly, the disruptive technology of 3D printing can also be used to produce custom 3D textiles and fabrics, with the help 3D printing oriented technique of electro-spinning (White et al., 2015). The technology of 3D printing has the potential to revolutionize the way physicians and clinicians presently treat bone injuries and defects (Jariwala et al., 2015). As organizations are increasingly using additive manufacturing technologies, there comes numerous supply chain implications. Scott and Harrison (2015) explored the impact of additive manufacturing on supply chain strategies and proposed optimization model to help the manufacturer decide whether to go for additive manufacturing or persist with traditional manufacturing; it was suggested that magnitude of demand is the actually the primary driver in the aforementioned model and that 3D printing adoption process can be facilitated by the decrease in cost of materials. There is even greater need for a 3D printing oriented business model as the revolution-cum-evolution of additive manufacturing occurred in four

successive stages, namely rapid prototyping, rapid tooling, rapid manufacturing and home fabrication (Rayna and Striukova, 2016).

3D printing is challenging China's position as manufacturing dynamo, while offering opportunities to developed countries like USA to regain their lost share, because additive manufacturing is potentially re-shifting the manufacturing to consumer countries (Gebler et al., 2014). Although China has played a vital role in the traditional manufacturing industry and is now undoubtedly a global manufacturing powerhouse, the nascent industry of additive manufacturing is facing numerous challenges (Anderson, 2013). It can be attributed to multifarious reasons, for instance, China's intellectual property laws might not be as favorable to the growth of revolutionary technology as in other nations (Ang et al., 2014). However, government support and university-industry collaborations are facilitating the nascent industry of 3D printing through expediting technology commercialization (Anderson, 2013). By integrating the Technology Acceptance Model and Innovation Diffusion Theory, Wang et al. (2016) conducted a survey of 256 participants to determine the factors influencing adoption of 3D printing systems by consumers, and suggested that younger consumers are more prospective early adopters of 3D printing systems, while the intention of aged people to use 3D printing systems can be boosted by improving their perceptions of usage.

2.2) Business Model

Teece (2010) defines business model as the framework enabling a company to provide value to consumers, persuade consumers to compensate for value, and transform those compensations into profit. In the words of Amit and Zott (2001), the business model represents "the content, configuration, and control of transactions aimed at creating value through the management of business opportunities". Apparently transactions link events, Amit and Zott (2012) modified the definition to theorize an organization's business model as "a system of mutually dependent events that exceeds the pivotal firm and extents its boundaries". Sorescu et al. (2011) state that a business model is an ostensible classification of synergetic events, processes, and structures that facilitates a company to create a sense of value-creation for its consumers and generate value for company and its supply chain partners. Broadly speaking, business model is a procedure of organizing business actions through processes, and strategic designing of internal and external resources of the company (Pereira and Caetano, 2015). Table 1 gives a brief chronological viewpoint

of scholars (Thomas and Gilbert, 2014, Huarng, 2013, Bohnsack et al., 2014, Reim et al., 2015, Paiho et al., 2015, Engelken et al., 2016, Massa and Testa, 2011, Rayna and Striukova, 2016), considering the time span of 2011 onwards, on the components of business model.

Author (Year)	Components of Business Model
Massa & Testa, 2011	Infrastructure management, product (value propositions), customer, and financial aspects
Huarng, 2013	Innovation, resource, market, value, cost, revenue, profit
Thomas & Gilbert, 2014	Factors related to the offering, market factors, internal capability factors, competitive strategy factors, economic factors, and personal/investor factors
Bohnsacka et al., 2014	Value proposition, value network, revenue & cost model
Reim et al., 2015	Value creation, value delivery, value capturing
Paiho et al., 2015	Customer Segments, Value Proposition, Channels, Customer Relationships, revenue streams, key resources, key activities, key partners, and cost structure
Engelken et. al., 2016	Value proposition, financials, infrastructure management, Customer Interface
Rayna & Striukova, 2016	Value proposition, value creation, value delivery, value capture, and value communication

Table 1: Components of Business Model

3) RESEARCH FRAMEWORK

3.1) Methodology

The study was conducted to explore the factors of China's 3D printing industry and propose a business model. For this purpose, qualitative research design and strategy of grounded theory was used to analyze the 3D printing companies in Weinan City. A grounded theory is a systematic qualitative approach used for the theory generation on a wider theoretical level (Corbin and Strauss, 2014). **Figure 1** depicts the theoretical framework of the preliminary business model for Chinese 3D printing industry. Since extensive interviews are requirement of this particular explorative study, we had to go for reference-based respondents or referral sampling. So snowball sampling technique was used to collect data from five 3D printing companies of Weinan Science Park¹, China through in-depth recorded interviews lasting more than 1 hour each.



Figure 1: Theoretical framework depicting preliminary business model for Chinese 3D Printing Industry

¹ The five focal companies that we selected for in-depth recorded interviews are: (1) Weinan Hi-tech Zone Torch Technology Co., Ltd (2) Shaanxi Lutong Precision Aluminum Industry Co., Ltd. (3) Weinan Ding Xin Technology Co., Ltd (4) Xi'an Bright Laser Technologies LTD (5) Shaanxi Hengtong Intelligent Machine Co., Ltd.

Open-ended interview protocol was designed on account of previous literature and opinion of the experts in 3D printing industry (see Appendix A). Owing to language constraints, interviewer was accompanied by Chinese interpreter. Though it is qualitative based study, efforts were made to ensure data validity and reliability in a non-statistical sense. Upon completion of study, research findings were endorsed by the respondents and concerned academia of Xi'an Jioatong University, China, which has developed industry linkages with many of the companies in this particular high-tech cluster. The practice of cross-examination ensures credibility, dependability and triangulation (Guba and Lincoln, 2005). The recorded interviews were then translated from Chinese to English and exported to QSR NVivo 11, where we execute thematic analysis, word frequency query, text search query, word tree and group query.



Figure 2: Word Frequency Query

3.1.1) Thematic Analysis

It is a technique for identification, exploration, and reporting themes of data collected through interviews. Thematic analysis manages and arranges collected data in detail in order to interpret the research study and draw inferences (Guest et al., 2011). Corbin and Strauss (2014) advocated that qualitative data can be coded in three phases. Accordingly, data was coded in three phases through creation of theme nodes in NVivo 11. A theme node is a collection of references about a specific theme by 'coding' sources at the node (Bazeley and Jackson, 2013). In the first phase, open coding of data was done for identification, categorization, analysis, and making it more measurable. In the second phase, axial coding of data i.e. more conceptual coding than open coding, was done for further categorization and sub categorization. In the final phase, more categorized nodes were prepared through selective coding for generating themes.



Figure 3: Text Search Query 'Manufacturing'

3.1.2) Word Frequency Query

The examination of 'word frequency query' was executed in qualitative software of NVivo to find the most recurrent word or concept in sources and nodes. **Figure 2** of 'word tag clouds' shows that most recurring words have big sizes. The extracted themes are manufacturing, products and services, cost, customers, company, equipment, rapid prototyping, employees, personalization, marketing, research and development.

3.1.3) Text Search Query

Text search query was run to find all occurrences of a theme or a word. It is found that the word 'Manufacturing' is the main theme of the study (Figure 2) and thus asks for further scrutiny. Hence, in **Figure 3**, word tree illustrates different views of interviewees about the word 'Manufacturing', and the extracted theme states that '3D printing is a rapid manufacturing technique and will replace traditional manufacturing in future'. Second most recurring word in word tag cloud was 'cost'. The extracted themes suggest that 'the main cost associated with additive manufacturing is machine acquisition cost, cost of hiring skilled employees, and research cost' (**Figure 4**).



Figure 4. Text Search Query 'Cost'

3.1.4) Group Query

Group query explore the nodes that are used to code responses of interviewees and to find the nodes that are associated with nodes of other respondents (Corbin and Strauss, 2014). The analysis of group query is imperative as it suggests relevant factors of 3D printing business model. Convergence points advocates agreement among majority of the respondents. Following convergence points were found from our qualitative investigation:

- 1) Major issue in adoption of 3D printing technology is immaturity of technology (see appendix 1B);
- 2) Government is providing financial support to 3D printing industry, and the disruptive technology of additive manufacturing will widen its spectrum to more fields in the days to come, as customers prefer customized products. (see appendix 2B);
- 3) To resolve the supply chain issues, industry must focus on their customers. Moreover, experienced and skilled employees are the most important part of the industry and constitute a major sub-factor the organizational component of business model. (see appendix 3B);
- 4) Marketing aspect is the major component of business model for 3D printing industry. (see appendix 4B);
- 5) Additive manufacturing is allowing provision of personalized products through which industry creates value for its customers. Thus technology commercialization and value proposition are important components of business model of 3D printing industry. (see appendix 5B).

4) RESULTS AND DISCUSSION

We now extrapolate the key findings to answer the research questions that we set forth in the introduction section and draw inferences for the business model: (a) what are the important factors of business model for 3D printing industry of China? (b) Why customers should prefer 3D printing technology over traditional manufacturing? (c) What are the issues in adoption of 3D Printing technology, and the future prospects of 3D printing technology in China?

4.1) Business model for 3D printing industry

The research study was primarily conducted to explore the components of business model for 3D printing industry of China and propose a new business model for Chinese 3D printing industry. Research findings propose that there are numerous internal and external components contributing to business model of 3D printing industry. As per the proposed model (**Figure 5**), internal factors are financial (I1), organizational (I2), marketing (I3), supply chain (I4), technological (I5), corporate social responsibility (I6), and competitive advantages (I7), while globalization (E1), government support (E2), and research and development (E3) constitute external components. Table 2 describes the potential components of business model for 3D printing industry of China, as derived from our fieldwork visits and qualitative analysis.

Internal components

4.1.1) Financial Components

One of the main contributing components to business model is financial component. 3D printing industry incurs numerous expenses, cost of acquisition of 3D printers, purchase of raw material, spare parts, online platform, research on additive manufacturing, hiring of skilled employees, research & development fee. There is an urgency on the part of practitioners of 3D printing industry to restrict the production cost. An interviewee narrates,

"We mainly focus on cost i.e. machine acquisition cost and material cost. We also create online platform that is our core resource. As the customer needs are unique, so online platform is playing a vital role to satisfy our customers by fulfilling their needs. On the other hand, we try our best to reduce the production cost, make better products and provide you with best service."

In the words of another interviewee,

"For cost structure, the major considerations are machinery and equipment because we use the professional-grade and industrial additivemanufacturing systems that are very expensive. So, we have collaborations with Weinan Hi-tech Industries Development Zone, and by the aid of the platform which it provides for us, we can save a lot of cost..."

3D printing industry also emphasizes on revenue generation from sale of 3D printer and rendering services, revenue from new product development, horizontal projects, and provision of outdoor talent training programs. Companies are also making investments in research & development to enhance their products and services and to promote 3D printing technology. It results in a financial structure that is based on cost aspect, reduced production cost, and revenue structure. Another interviewee says,

"Our key resources are high-quality talent. We have 80 full-time post graduate and doctorate employees and also employed 30 professors from School of Mechanical Engineering, School of Electrical Engineering, and Energy and Power Engineering School of Xi'an Jiaotong University. Lu Bingheng is not only the Board Chairman of Shaanxi Hengtong Intelligent Machine Co., Ltd., but also cherishes many academic designations, such as Director of National Engineering Research Center of Rapid Manufacturing, Leader of Mechanical Engineering Subject Appraisal Group of the State Council Degree Committee, Dean of Mechanical Engineering School of Xi'an Jiaotong University, and Vice Chairman of Chinese Mechanical Engineering Society. So by the aid of talent resource, we do a lot of research on 3D printing, including product sales and services, NPD, horizontal projects, talent training, and transfer of scientific& technological achievements and generated revenue from these areas."

4.1.2) Marketing Components

Marketing factors also constitute an important component of business model for 3D printing companies. As 3D printing is an emerging technology so there is a need to promote it and create awareness among people. The industry is creating value for their customers by providing mass customized and unique products according to their demand and delivering that value to customers through online platforms and also providing them customer care services for their ease. An informant argues:

"Xi'an Bright Laser Technologies Ltd., founded in July 2011, is the largest provider of complete solution for metal additive manufacturing in China. We almost have 30 advanced equipment sets for laser additive manufacturing and repairing... The Company's business includes 3D printed personalized product, strengthen the expansion of 3D printing technology and services, the company has independent 3D printing platforms-YunZhi that provides online 3D printing services for customers and renders services to product designer." The companies attract their customers by product differentiation, product segmentation, and customer relationship management. Product differentiation contributes towards business model by creating unique products according to the customer requirements and blend it with their personal information. The product segmentation is discussed by the respondent as:

"I think the most important marketing factor to attract the customers is segmentation. First, we provide unique materials: high quality alloy powder, powder components meet the relevant industry standards, national military standard, ASTM, AMS etc. and powder cover various particle size ranges. Second, customized products: in the fields of lightweight structure, manufacturing complex inner structure, the overall function integration, the rapid development and rapid manufacturing, component manufacturing and repair and remanufacturing. Third, technical services: technology advisory service, design optimization service, reverse engineering services, software customization service, personnel training services, equipment leasing services, spare parts services and equipment upgrading services."

An interviewee discusses customer relationship as:

"The most important marketing factors to attract the customers is customer relationship, the relationship is embodied in term of their requirements. We can fulfill their requirements with the use of 3D printing."

Therefore, marketing components contributes to business model for 3D printing industry. The major contributing components are value proposition and product segmentation. Value proposition further includes value creation and value delivery. Some other components, such as product differentiation and customer relationship, also play an important role in marketing strategy of 3D printing businesses.

4.1.3) Competitive Advantages

The most valuable component of any business is to gain competitive advantages. In 3D printing business, companies gain competitive advantage through product differentiation and new product development.

3D printing industry is producing mass customized products that traditional manufacturing does not produce. The speaker deliberates:

"Company gain competitive advantages by providing customers the complete solution of metal additive manufacturing and remanufacturing, including technical service, customized products, equipment, materials, repair and remanufacturing... Company gain competitive advantage by development in 3D printing machines and equipment, for example, HTP600 Metal Spraying Machine, RMS Three-Dimensional Surface Scanner Machine, Industrial Digital Close-Range 3D photogrammetry System, XJTUDIC 3D Digital Speckle Measurement System, Selective Laser Sintering Machine, SPS250J Rapid Prototyping Machine and so on."

Therefore, the foremost components through which 3D printing companies gain competitive advantage is product differentiation and other the component is new product development (NPD).

4.1.4) Supply Chain Components

The 3D printing companies are dealing in rapid prototyping and manufacturing, remanufacturing, metal rapid manufacturing, and subsidiary of research center of 3D printing. So, they are directly dealing with their customers, suppliers, product designers, research facilitators, and logistic. 3D printing companies acquire 3D printers from other companies, purchase raw material from suppliers with the use of online sources, built an online platform for customers, suppliers, and product designer, and also appoint third party to deliver 3D printing product to customers. After that companies give feedback to the supplier of machinery and raw material about the features, quality, reliability, and operational functionality of 3D printing machinery and also receive feedback from their customers about the features and quality final product. An interviewee explains his supply chain as:

"Company purchases 3D machines from Shaanxi HengTong Intelligent Machine Co., Ltd. and also from other companies, and purchase raw material from online sources and giving them feedback on features, quality, reliability and operational functionality of its new 3D printing technology. Company built a new business model to create value for customers. In order to supply products to customers, build an online platform to produce the personal product for the makers, enthusiasts and so on... We are mainly engaged in two areas. First, conduct research in domain of 3D printing technology that needs a lot of money, so company establish a good collaboration for the mutual benefits and high efficiency of the Government of China and the Northwestern Polytechnical University. In 2014, Weinan Hi-tech Zone, Weinan Hi-tech Zone Torch Technology Co., Ltd. and Xi'an Bright Laser Technologies LTD (BLT) jointly established a Research Institute, for this Government provide enough research grant to support the Company. Second, we collaborate with down-stream enterprises positively to continue our efforts to provide customers with better products and services."

Some of the 3D printing companies are also dealing in research, so for this purpose they have collaboration with Government and University. 3D printing companies have collaboration with other enterprises to promote the 3D printing technology and to facilitate, gain and to retain their customers. 3D printing industry is resolving their supply chain issues by cooperating with their customers and key partners. Companies are providing after sales services to their customers, customers get 80 percent to 100 percent same as new product after repairing and remanufacturing. As per one of the respondent:

"... We resolve supply chain issues by the cooperation of our customers and key partners because we have enough resources and equipment. So, by taking advantage of these resources, we satisfy our customers' needs. For this, we establish the good relationships with many firms that enable us to create "win-win" position in market. We resolve many supply chain issues by the aid of National Engineering Research Center of Rapid Manufacturing, which has 40 demonstration center all over the country."

Therefore, 3D printing supply chain includes customers; key partners i.e. supplier of 3D printing technology, supplier of raw material, research facilitators, distributors, government; and key resources i.e. online platform and highly skilled employees. 3D printing industry is an emerging technology and enrich with resources so, resolve its supply chain issues with the cooperation of customers, suppliers and research facilitators.

4.1.5) Organizational Components

The highly experienced employees, researcher, and the highly skilled trainers are those provide training to their employees are the key partners of company. They are working efficiently to enhance the effectiveness organizational processes and to promote the 3D printing technology all over the world. As this industry is newly introduced in market so, the organization size is small to better control its operations in an effective way and to maximize its probability of survival for long time spam. The main key resources are online platform through which company can communicate with its customers and key partners. An informant says:

"... Our key resources are high-quality talent. We have 80 full-time post graduate and doctorate employees and 30 professors from School of Mechanical Engineering, College of Electrical Engineering and Energy and Power Engineering College of Xi'an Jiaotong University."



Figure 5: Proposed Business Model for 3D Printing Industry

4.1.6) Corporate Social Responsibility

Every organization is bound with society and for their sake, they are performing social activities. Corporate social responsibility is a prominent component of business model and has positive impact on businesses (Naseem et al., 2017). 3D printing industry is also performing CSR activities. Industry is mainly focused on education sector by providing it 3D printers and 3D printing services in classrooms, to educate students so they may get primary knowledge about technology. Companies are also organizing events for creating awareness of 3D printing among people. In the words of respondent belonging to 3D printing of metal products.

"We perform CSR activities. First, we cooperate with the government, and help the government to bring 3D printing technology and 3D printer into the classrooms at primary to high school level. Second, we organize many events so that the public can learn more about 3D printing...We organize many events that raise public awareness about 3D printing and communicate about the principles of green design, green production, green services that is our program guide action."

Companies dealing in metal additive manufacturing are much concerned with the environment because the usage rate of raw material is high. So, companies are contributing in the development of green production to make the environment healthy. Therefore, corporate social responsibility is an element of business model because 3D printing industry is now paying attention on CSR activities i.e. provide 3D printers and services to education sector, public awareness events, and development of organic products.

4.1.7) Technological Components

3D printing is a technology used for rapid prototyping and manufacturing. The biggest challenge to industry is immaturity of technology due to which companies are facing problems in its commercialization. The high cost of its spare parts and raw material is one of the main obstacle in market commercialization of technology as well as in technological development. Industry is also facing problems in technology diffusion as the companies have enough resources and transferring 3D printing technology with the cooperation of government to education sector and universities has number of experts in research but they do not know complete mechanism of 3D printing technology and they are less aware about market demand. A mechanism for 3D printing technology will be established to enhance the ways for development and transfer of 3D printing technology to support country-specific adaptation and mitigation efforts. As informant discusses:

"We established good relationships with Northwestern Polytechnical University, and we can transfer technology from university to industry easily, but how to collect the requirement of market is our main concern. We're not doing right in this aspect. There is U-I collaboration but due to the lack of market commercialization, universities cannot work in accordance with the market need... Company is a subsidiary of National Engineering Research Center of Rapid Manufacturing and an industrial entity of Rapid Prototyping & Manufacturing, so the biggest problem is to do a better technology mechanism or a machine. We do a lot of research with the aim to create cost effective and efficient product in shorter time."

3D printing is an immature technology but industry is continuously making its efforts to improve the technology mechanism, focusing on technology development, and trying to cope with issues in technology diffusion by providing 3D printers at primary and high school levels to educate the students for creating better understanding about technology. On the other hand, industry is providing complete technical solution to customers.

External Components

4.2.1) Government Support

Government support is not an in-house capability of the company therefore it is considered as an external component of business model. The Provisional Government is strongly supporting 3D printing industry by providing different subsidies i.e. financial aid, relaxation in taxation, subsidiary on electricity, land and supported infrastructure, sponsored research projects and facilities, research and development funds, and other incentives. 3D printing companies are also facilitating education sector with the collaboration of government. As respondent suggests:

"At present, company covers a scientific area of 900 square meters and a plant area of 2500 square meters. A modernize and intelligent scientific area of 40000 square meters is expected to be completed by the end of 2016,

located in Xi'an High-Tech Zone. We have also built good relationship with Weinan High-Tech Zone. The government gives special favors in aspects of process transactions, land and supported infrastructure, and doing number of projects about 3D printing with the aid of government."

4.2.2) Research & Development

Research and development is a most important component of business model because 3D printing industry is mainly exploring and promoting this technology through research. Government is very much concerned with research & development and heavily investing through research grants and sponsored research projects. Industry pay attention on hiring of expert professors from universities. So, they can make their contribution in research.

4.2.3 Globalization

Nowadays, globalization comes as an inherited phenomenon for almost every business. 3D printing companies are also doing globalized business to promote the technology and to earn the name of country in all around.

"Company is developing and supplying complex precision die casting aluminum parts of automobile engine, generator and industrial air conditioning applications for the global enterprises. Co. has created six kinds of products for BMW with the help of 3D printing, producing spare parts for automobile industry, producing appliances for global enterprises."

4.3) Preference of additive manufacturing over traditional manufacturing

The main reason to choose 3D printing technology rather than tradition manufacturing is cited as unique and customized products. 3D printing Industry provides mass customization according to the requirement of customers. It has efficient and short manufacturing cycle with better productivity, high utilization rate of raw material, multi-material manufacturing, high forming accuracy, properties of new product after repair, and provide products at lowest cost. Unique products also include 3D printers, spare parts, and 3D printing services. An interviewee states:

"We create unique product by the aid of technical abilities i.e. Laser Solid Forming: short manufacturing cycle, high utilization rate of materials, similar mechanical properties as that of the forgings; multi-material gradient composite manufacturing; Selective Laser Melting: complex shape and structure; high forming precision; similar surface smoothness as that of the precision castings; Laser Forming Repair: dense metallurgical bonding, little deformation of the components, over 80 percent or nearly 100 percent of the mechanical properties of the new products after repair." Another informant says, "Company provides unique products (include the machines and equipment) and services that other company cannot provide. As a professional engaged in the 3D printing industry leader in all aspects of service, is actively research and development of medical industry, and set up medical rehabilitation center, to push forward China's medical out of a force."

4.4) Adoption of 3D printing technology and future prospects

In this study, issues and hitches pertaining to adoption of 3D printing technology are also discussed. The major issue is the immaturity of technology due to which industry is facing problems in technological development, technology diffusion, difficulty in availability of 3D printer's spare parts, and limited application in different fields of work. From customer's point of view, the major concern is the lack of public awareness with respect to this disruptive technology due to which companies are facing difficulties in promoting products. Despite having the transitory problems, 3D printing technology has bright future because it is mainly focusing on personalization or mass customization that is the thirst of this era. It is fair enough to say that 3D printing will compliment traditional manufacturing in future. It improves and reinforces the scientific research environment and the main goal of this technology commercialization is to expand its application in more fields of work. In the words of one of the interviewee:

"Future of 3D printing is very bright because we have studied the manufacturing paradigms. In the past 200 years in course of development, the manufacturing industry has evolved through several paradigms. Overall, manufacturing paradigms has experienced from craft production, mass production to mass customization, and are moving in the direction of personalization. The 3D printing technology is tougher than other technologies because it has large data, cloud computing, involvement of internet that plays big role here."

5) CONCLUSIONS AND RECOMMENDATIONS

Manufacturing industry witnessed a paradigm shift as traditional manufacturing is gradually transforming to additive manufacturing. Prior researchers primarily focused on the technical aspects of 3D printing, we take business perspective and commercialization aspect of the technology into consideration. The exploratory qualitative study not only discusses the components of business model for 3D printing industry in China, but also highlights the issues and future prospects in adoption of 3D Printing technology. With respect to business model for 3D printing industry, the study provides seven internal components and three external factors; internal components consist of financial, marketing, technological, corporate social responsibility, supply chain, competitive advantages, and organizational components whereas external components are government Besides support, R&D, and globalization. offering policy recommendations, the theoretical contribution is expanded practice of qualitative research. Regarding adoption of 3D printing technology, China is suffering from the immaturity of this disruptive technology and other related issues, such as lack of customer confidence, lack of public awareness, lack of resources, difficulties in product promotion, difficulty in availability of 3D printer's spare parts, and problem in technology diffusion. On a positive note, customers are going to prefer 3D printing technology because it is providing customized product in considerably short time period. This assertiveness is consistent with the proposition of Wang et al. (2016) that youngsters are perhaps the most prospective adopters of the 3D printing technology.

Based on the field-work surveys and in-depth interviews, the study suggests recommendations as well. New proposed business model is supposed to strengthen 3D printing industry mainly by emphasizing on the CSR activities, reducing production cost, investing in R&D, and state patronization. There are still some issues in adoption of 3D printing technology that need to be addressed by provisional ministries and government. With the collaboration of university-industry-government, 3D printing technology can be promoted among students. Technology diffusion is a challenge for the industry because it often faces difficulties in enlightening potential customers regarding benefits of the disruptive technology. The issue can be overcome by enabling a vigorous triple-helix model of university, industry and government. Moreover, there is a need to build customer oriented marketing strategy on the basis of their preferences to use 3D printing technology. The study has few limitations as well. First, results and findings are not quantified or based on empirical finding, only theory was induced. Second, the sample of this study was limited to five 3D printing companies of Weinan Science Park, and thus results might not be generalizable on a wider extent, but they do offer the perspective of emerging high-tech clusters and science parks. Though efforts were made to enhance the internal validity, however the findings might not be externally valid, as they might not be applicable to the context outside Weinan Science Park. Future researchers are advised to empirically test the proposed 3D printing business model. Longitudinal study can enhance the generalizability aspect of the study. Moreover, there has been so much talk of green supply chain, so corporate social responsibility can be studied in connection with 3D printing industry.

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Appendix A

Interview Protocol

Interviewee's Name / Designation: _____

Company: _

- 1. Major components of business model for 3D printing industry;
 - a. How 3D printing facilitates the industry?
 - b. What financial factors are involved in your Company?
 - c. What are the marketing factors to attract the customers?
 - Pricing
 - Segmentation
 - Distribution channels
 - Customer Relationship, etc.
 - d. How to get Competitive advantages in 3D business
 - e. How does your organization resolve supply chain issues?
 - f. What kind of technological factors are involved in 3D printing industry?
 - Commercialization (How to market an idea)
 - Technology Diffusion (Transfer of Technology) from University to industry
 - g. How to deal with the organizational factors?
 - Culture
 - Structure
 - Size
 - Employees experience and skills, etc.
- **2.** Why should your customer purchase from you rather than traditional manufacturer?
- 3. How 3D printing can support traditional manufacturing industry?
- 4. How is the government supporting you?
- 5. What are the main issues that you are currently facing?
- **6.** How does your company cope with CSR (Corporate Social Responsibility)?
- 7. What are the future aspects of the 3D printing in your industry?

Appendix B

Appendix 1B: Connection Map showing Convergence Points

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Appendix 2B: Connection Map showing Convergence Point 2, 3 & 4



Appendix 3B: Connection Map showing Convergence Point 5 & 6



Appendix 4B: Connection Map showing Convergence Point 7



Appendix 5B: Connection Map showing Convergence Point 8 & 9

