Exploring the Essence of A Multidimensional Ecosystem for 3D Printing industry

-Evidence from Technology and Social Innovation

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Abstract

3D printing is the additive manufacturing which has unique features to transform a digital design file into a real physical product and is changing the world profoundly. The paper is to explore the essence of a multi-dimensional ecosystem by examining how the revolutionary 3D printing skills is reshaping the world from the perspectives of technology-oriented innovation and social innovation. We firstly identify and analyse then visible process of operation in 3D printing in the view of technology dimension (i.e. Dimension 1). The results from this analysis of Dimension 1 indicate that social innovation has played an essential role in the development of 3D printing technology which is always neglected. Also, enlightened by the Positive-Negative Framework, we then put forward a new framework after focusing on the investigation of the 4 sub-level dimensions, such as, Productivity, Biological Adjustment and Science Cognisance. Thus, we have contributed the linkage and the interaction recognition between technology innovation and social innovation based on the 3D technology development. Furthermore, the research shows a prospect of implication to explain the way how we could stimulate the network effect, promote and regulate the normal-growth technology when nurturing the development of the emerging 3D industry.

Keywords: 3D printing, multidimensional ecosystem, social innovation, technologies

1.0 Introduction

It is actually a reality today that we can download product data from a website, perhaps re-programme or personalise it to our own preference and taste, and have that information send to a desktop machine through which the product be fabricated and send to us on the spot. This way of operation can actually build for us very rapidly, a physical object. And the reason we can do this is through the emerging technology called additive manufacturing, or 3D printing. It is an interesting phenomenon that human society is being transformed from subtractive manufacturing to additive manufacturing. In ancient times, craftsmen worked on the targeted objects such as stone, jade, diamond and metallic materials, by measure of carving, digging, slicing to create the product that we do need and admire. This type of manufacturing, known as the industrial machine tools, which is composed of such technologies as lathe, bench work, plane, grinding tools, typically forms the traditional method to get the products [1]. On the contrary, the additive manufacturing, such as 3D printing, shows in a fairly different way. We would take data, like the data of a pen, which would be a geometric representation of that product in 3D, and convey that data with special material to a machine. And a process that would happen in the machine means layer by layer that product would be built. And we can take out the physical product, and ready to use. If the traditional method to produce, the subtractive manufacturing, is analogous to minus; 3D printing, the addictive manufacturing, goes to the other extreme, i.e. analogous to plus.

The features of 3D printing is outranged from these mentioned above. Cost savings play the key role in the industrial society, because each manufacturer is eager to reduce the leftover material from the process of subtractive manufacturing. In fact, the industrial society produces much waste. However, the situation occurring in the additive manufacturing goes to the opposite. During the 3D printing manufacturing process, the material is sprayed by the jet having already been calculated by the preoperative computer program which minimises waste. The advantage of additive manufacturing has drawn great attention from the industrial and technological fields, and it will profoundly change the whole world. Even some tycoons of industrial circle call it “the end of industrial times.” Our question is how the new emerging technology makes waves, and what the profound change to the human society is. These questions need to be addressed.

2.0 Literature review

Additive manufacturing/3D printing, has profoundly been changing our world and our lives. Almost in the fields of social science, research on 3D printing actually concentrate on the business models which could be the core of all systems. Marcel et al. [2] indicate that a consumer goods manufacturer can organise the operations of a more open business model when moving from a manufacturer-centric to

consumer-centric value logic. Meanwhile, the analysis of the business model components has become the trend of research. Cabirio et al. [3] emphasise the use of new 3D printing technology in design enterprises should be coupled with proper business model components. Besides that, 3D printing combines the industrial manufacturing with the structure of marketing, in which Jan et al. [4] referred that most manufacturing processes have been "subtractive" in that matter is removed (e.g. scraped, dissolved, turned, machined) from a substance in order to produce the desired product. 3D printing turns traditional manufacturing on its head in that it uses an "additive" process. In addition, without the feasible and practical business model, it will typically be a real barrier for the development of 3D printing. Thierry and Ludmila [5] figured out the pitfall situation made by the lack of effective business model, and they thought 3D printing technologies have the potential to change the way business model innovation, by enabling adaptive business models and by bringing the "rapid prototyping" paradigm to business model innovation itself [6]. Similarly, cost control, value capturing and the social cognisance like law and ethics have been the focused issues in the research. For instance, Christian et al. [7] identified AM enables the production of complex and integrated functional designs in a one-step process, and the adoption of AM allows a firm to increase profits by capturing consumer surplus when flexibly producing customised products. Meanwhile, legal issues, especially in the view of intellectual property rights, mainly occupied the dominant research fields in law [8]. Davis [9] pointed out that the DIY (do-it-yourself) community which consists of self-designed software programmes will be at the risk of infringing patent law and copyright law. Gerald [10] argued that the current arms control and transfer policies are adequate to cover 3D-printed guns, which proves that there is still "grey area" for 3D printing from the perspective of law and ethics. Social framework still needs to be refreshed or be innovative in order to meet the various requirements from different directions. Thierry et al. [11] in the first published paper regarding 3D printing initially proposed the new emerging technology provide a "presumption" framework and a typology of co-creation activities.

Building on previous literature in relation to the content, this paper will introduce the essence of additive manufacturing, not only from the view of technology revolution, but also relating to the social innovation framework. Beyond the business model, the other elements such as legal systems and social thought and consciousness are always fluctuating during the new ages.

3.0 Methodology

Based on interviews and empirical research, the paper adopted the comparative methodology based on the social and business ecosystem theory. Under the macroscopic background of the internet age, the additive manufacturing combined with the features and characteristics of IT, shows the total difference from the one by the conventional business pattern. In other words, the data-driven technology will impose great influence on the development of society and the technology itself. The comparative methodology displays several dimensions and categories throughout the paper coupled with the manufacturer-centric structure and

customer-centric structure, production en mass and small scale production, the ownership and lease of means of production, the difference of standard-settings, and so on. The comparison will reconstruct the current business model, legal system, even the social framework and the way of observing the world when the internet and the thought derived get involved (Figure 1).

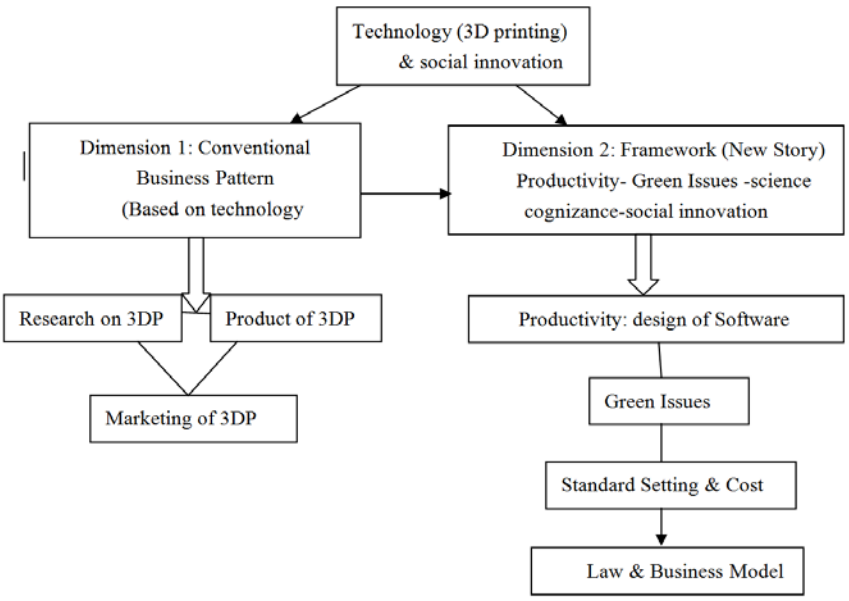

Figure 1: Reconstructed business model

Therefore, the multidimensional reconstruction of additive manufacturing, embeds in the system of internet network, reviews the conventional circulation by the traditional business pattern, and reorganises the potential framework which will happen in the future.

4.0 3D printing: from Technology-changing to Society-changing

The advance of technology leads our way to the future and success, although we humans hardly meet the rapidly growing requirements. Currently, technology has been embedded into the entire facet of industry, from the industrial design to the physical production. Both the capital investors and engineers try to make the effort to create a win-win business pattern for benefit sharing. Nevertheless, the social framework brought about in the technology-oriented change fundamentally has got changed as well, resulting in a veritable innovation.

4.1 The Conventional Business Pattern

The farming society far earlier than the industrial times, which are ranked as a "shortage" era, regulates its own discipline to adjust the objective conditions. With the coming of new ages, the industrial society had crushed down the old ones, and the mechanised mass production has exploded the potential ability of human beings.

For example, Foxconn Inc., the giant of manufacturer in China, has its own R&D centre factory with logistics system, container port, and distribution centre. One of many of its factories (located in Shenzhen, Guangdong Province), employs more than 300 thousand workers and only the canteen for workers will get profit of at least 1.5 hundred million GBP per year. The harvests of this one branch factory are 2400 international containers which will be loaded on board quickly and transported to other countries around the world.

This is a conventional story about how the industrial wealth has been made, how the capitalists and investors of big incorporation have got their savings leap to the upper class, and how the workers get their own payrolls to make a living. Approximately, Industry Age has been deporting the shortage and famine away from our daily lives.

It seems that the business pattern will go on forever. New technology is invented in the laboratory with the efforts of the scientists, and then technical transformation will happen in the factory to be a mass production without individuation. Finally, the products through the process of industrialisation will appear in the market with value label and be evaluated by the price. It forms the chain of "research-product-market" which is typically labelled as prosperous industrialisation; thereby the circulation of these three elements profoundly affects the contemporary industrial society. However, the emerging additive manufacturing, 3D printing, totally merge the producer and consumer into one entirety rather than splitting them when it often happens in the conventional business pattern.

4.2 A New Story

The reality has been achieved that a customer could sit at home, making an order online so as to acquire the commodity he wants. The internet has played a more and more important role in the human society, in which if the internet is inaccessible, life is not sustainable.

Compared with the current manufacturing and marketing, additive manufacturing is just based on the technology innovation, bringing about the unpredictable social innovation which actually imposes the great influence upon it. Obviously, the technology of 3D printing is still under the introduction stage of its life cycle, and markets are far more mature. During the incubation, the technology has to face the various challenges and barriers standing in its way. According to the previous technical revolutions, these requirements of being the qualified products in the

market will be met by the efforts of technicians and inventors in the future. Besides, additive manufacturing already appeared 30 years ago. However, as to why the investors and the masses concentrate on the development of additive manufacturing all the time, the answer may be different and thought-provoking.

It is the wide use of the internet that enables the close linkage and interaction between new emerging technology and business model for sale, marketing, communication. 3D printing is characterised as a revolutionary and practical technology which is admired by many titans and its market potential looks so promising so that the international capitals intensify the R&D. The medium propaganda is overwhelmed by any other wording, such as “this technology has a bright future, not least in rapid prototyping, but also in the manufacture of many kinds of plastic and metal objects, in medicine, in the arts, and in outer space.” This is based on the technology-orientation, rather than the social-orientation. In other words, the social science on the 3D printing has already lagged behind. We have no detailed and systematic research on the business model, biological protection, energy saving, etc. With the growth of additive manufacturing, the various social problems will follow. Especially, when the times of “Industry 4.0” are approaching, the IT (Internet Technology) has a profound impact on the ways how human beings produce. The gap between manufacturers and consumers will be eliminated, and many social issues will be changed. The social innovation which is neglected on the research fields should be refocused on. The new story has begun.

5.0 The Multidimensional in 3D Printing

In the following context, we will see the multidimensional contents regarding the essence of additive manufacturing, 3D printing in the current situation, or even in the future.

5.1 The technical Dimension: Visible or Invisible Process of Operation

The new 3D printing technology typically reads CAD data which is product design data created on professional product design programs. It could be an architect or a professional product designer who creates a product in 3D. Data collected will be sent to a machine through which data would be sliced into two-dimensional representations of that product, the same way as slicing a salami. That data, layer by layer, gets passed through the machine, starting at the base of product and depositing material, layer upon layer, infusing the new layer of materials to the old layer in an additive process. The material that is deposited either starts as a liquid form or a material powder form. And the bonding process can happen by melting and depositing or depositing then melting. Over time quite rapidly, actually in a number of hours, we can build a physical product, ready to take out of the machine and use. The products are ranging from shoes, rings that were made out of stainless steel, phone covers out of plastic, all the way through to spinal implants, for example, that were created out of medical-grade titanium, and engine parts.

What aroused our notice is that all these 3D products are very intricate due to the quite extraordinary design. With the application of 3D printing skills, we can actually create structures that are more intricate than any other manufacturing technology, or in fact, that are impossible to build in any other way. The 3D technology skills ban be applied successfully to produce moving components, hinges, parts with parts. So in some cases, we can abolish totally the need for manual labour. Today, architects could build the house which is almost three meters high by an architectural firm called Shiro. And it was built by depositing artificial sandstone layer upon layer in layers of about five millimeters to 10 mm in thickness slowly growing this structure. And on the other end of the spectrum, a microstructure could be created depositing layers of about four microns.

So, above all, what is the essence of additive manufacturing, 3D printing? We think the change of mode of production perhaps would not cover the features or traits of this technology while the combination with IT will give the new birth to the additive manufacturing. The process of the operation is visible because a consumer could stand aside the printing machine and watch the process of the production. Nevertheless, the spectators will not know about which essence is pushing the technology forward. Or, they could not distinguish the traditional manufacturing from the additive manufacturing. In reality, the essence is that 3D printing is digital-driven technology which is invisible for all of us. This feature proves that 3D printing is a bridge which links the human, information, wealth and physical world as together by the way of internet and a series of modern technology for materials and manufacturing. It is the technical dimension for 3D printing.

5.2 The Social Innovation dimension: the change of framework

The social framework is refreshed and changed with revolution and advancement of technology each time. In the view of human history, the invention of ironware totally changed the agricultural society, and the appearance of steam engine led Britain to the first Industrial Revolution. So it is for electricity and computer science. These revolutions of technology not only evolve their own process, but also take the human society into a different world. The means of production had changed, and division of labour had become more and more refined. In the thought of inertia, we may conclude that additive manufacturing, 3D printing will follow the revolutionary road to the higher industrial level. Although it is hard, we perhaps have to make the serious prediction that industrial times will be dismantled and overturned by 3D printing, due to the following reasons. The first is that means of production means nothing. And the second is that role of human lies beyond all.

5.2.1 Productivity: Design of software

Many scientists devoting to the additive manufacturing research are exploring how to enlarge the market of 3D printing, and then they regard the way of production en mass as a solution. However, this sometimes goes wrong and limits the potential of technology. The key to explain is that the needs of customised products have become the consumption trend in internet marketing. Compared with the

standardisation in the conventional pattern, customisation represents the trend catering for the target consumer group. As the design data of 3D transits via the internet, the productivity will be greatly released and enlarged.

5.2.2 Biological Adjustment: Green Issues

The additive manufacturing rather than the subtractive manufacturing, produces only the products without the waste. The role of human gradually forms the bridge which links the manufacturing and green issues. For example, 3D printing may inadvertently also help to achieve some of the most urgent environmental and resource goals facing the international community. The transportation and manufacturing carbon footprint of many products could be reduced as DIY designs by human, rather than products, are shipped around the world.

By significantly reducing waste in the manufacturing process, 3D printing also could enhance global "resource productivity"—that is, getting more "product" out of the same quantity of a given resource. This could ease the growing gap between supply and demand for non-renewable resources.

5.2.3 Technical Cognition: Standard Setting & Cost Control

Technical Cognition refers to the growing understanding which vastly depends on the development of technology and the application by the operator. Here the paper will clarify two issues, standard setting and cost control which fall into the category of technical cognition.

National standard and industry standard do always exist in the conventional industrial society, though how to make standard-setting has been the key focus of the 3D printing. With respect to the fixed standard in the old times, the standard setting in new times will be constantly flexible and diversified because of the human factor. It will soon prove that there are two levels of standard setting in 3D industry system which is apparently divided to fixation and flexibility. They are usually referred to as traditional standard and standard by DIY customisation.

In addition, the cost control in 3D printing will be much easier than in the conventional industrial manufacturing. That is to say, the means of production appears less important. For instance, it is hard to imagine that the student who would like to copy a book never goes to a printing plant on account of the cost control by the printer. As long as the industrial engine of printing machine starts, it will cause a money-loss resulting in no copy for the student anymore. On the contrary, in the circumstance of 3D printing, the customised products will never pass through the roaring machine, and they are just produced by the way of small scale production.

It is supposed that someone in Shanghai wants to buy a birthday gift for his friend who works in London now. This person could rent a 3D printer via online renting process instead of buying it. He can then customise the shape, colour or other

characteristic through the software design and make a request to the person who owns the 3D printer. The owner will accept all and send the finished gift to the customer's friend by logistics. For the customer, the 3D printer, means of production, no matter how expensive or cheap it is, is just a lending for hours or even a few minutes.

5.2.4 Social Cognition: Law & Business Model

Social cognition refers to the superstructure such as law and business model which are based on the technical cognition, productivity and biological adjustment. The additive manufacturing has the potential to be as disruptive as the personal computer and the internet. The digitisation of physical artifacts allows for global sharing and distribution of designed solutions.

Of course, the social framework with such disruption requests a need for new policy related to intellectual property and "part piracy", perhaps through the development of new digital rights management solutions. Without the legal system and business model for 3D printing, the market will be badly disrupted and the development will be interrupted. The social innovation nowadays seems to expand its range to ethnics, project management, risk evaluation and so on which are all derivatives of social cognition.

There are still a number of problems for us to solve, in which how to deal with the guns 3D-printed, and could someone take these kind of guns aboard? It came into reality in US, but there is no systematic punishment because of even no intimate knowledge for the various problems initiated by 3D printing.

It is not enough to deal with one specific problem, instead what we should do is to reconstruct the social framework by reviewing the social innovation caused by the additive manufacturing macroscopically. Only then we could find the right way to utilise and get benefit from it.

6.0 Ecosystem of 3D printing

6.1 Human Ecology and Ecosystem

The additive manufacturing, 3D printing is to serve the users, customers, i.e. human beings. This echoes the core and ultimate aims of society. Amos H. Hawley proposed that the environment, population, and the ecosystem tend to move toward equilibrium (Human Ecology, p10). In his theory, Human Ecology, Hawley wrote that humans will modify their behaviour patterns to fit with changes in their biophysical environment. Through this adaption human groups can either evolve or expand into complex societies. For systemic change to occur, such as expansion of a population, disequilibrium is required along with multiple challenges to the environment.

This kind of environment of 3D printing involving design of software, green issues, standard setting, cost control, legal system and business model profoundly change our way to adapt to the contemporary society. The multidimensional system is gradually evolving into a social organism with manifold contradictions. These conflicts are the essential elements integrating in the process of crashing and collision, in which we could find the conflicts between additive production and subtractive production, production en mass and small scale production, ownership of means of production and lending, technical innovation and social innovation, etc. After reorganising and reconstructing the framework, human ecology merges with the human environment, which embeds and alters in the circumstance of 3D printing, and it finally makes the formation of ecosystem.

6.2 Checks and Balances

The ecosystems of planet Earth are coupled to human environments. Ecosystems regulate the global geophysical cycles of energy, climate, soil nutrients, and water that in turn support and grow natural capital. Ultimately, every manufactured product in human environments comes from natural systems.

Likewise, the environment of 3D printing nourishes the growth of new technology, and the practice of additive manufacturing in turn develops the social framework. Even though the conflicts mentioned above will interact with each other to be real barriers or restraints for 3D printing, the system of checks and balances like the leverage eventually narrows all the gaps and differences. However, what we should do is not to wait for the changes, but only try to change and compromise all the essential elements actively by ourselves.

7.0 3D printing and research-based Marketing Teaching

3D printing is reshaping the world. The development of 3D printing technology and its application into different fields are actually challenging many so called mature and solid marketing concepts. For example when delivering the unit of Marketing Principles, it is preferable to apply research-oriented teaching approaches during marketing teaching delivery and link relevant 3D printing-related case studies with related marketing topics which are always followed by group discussions. What surprises and fascinates students is the power of 3D printing. Its existence has begun to push researchers, academics and even students to scrutinise the validity and reliability of many marketing concepts and framework.

Take the understanding of marketing mix, the most important marketing concept as an example. In order to achieve success, all businesses must get the marketing mix right.

This involves having the right product at the right price in the right place using the right promotional methods. These are known as the 4 P's - product, price, promotion and place. The marketing mix elements have to be 'blended' by marketers in an attempt to satisfy customer needs and wants. 3D printing technology is currently changing people's understanding to 'Product' and making replacement available, which also arouse lots of changes in the other 3 Ps, i.e. price, place and promotion. Below are the examples which indicate how to integrate 3D printing technology application into marketing teaching. Below are the examples which indicate how to integrate 3D printing technology application into marketing teaching.

• Pricing topic and 3D printing impact: For instance, 3D printers are being used to create low cost prosthetics where they are most needed, especially to those who lost their limbs during the war and cannot afford a replacement. The idea to create cheap, customisable prosthetics that anyone can afford will become main stream and help transform the lives of the affected [13].

• Place topic and 3D printing impact: It is incredibly expensive if you plan to transport items to space. However, with 3D printing available, they can print out parts, tools or other items they need in the event of an emergency. NASA announced that they will ship a 3D printer for trial purposes to the International Space Station in August 2014.

• Sustainable marketing and green consumerism: Environmental sustainability aims at getting profits while helping to save the planet. Today's greening activities focus on improving what companies already do to protect the environment and look to the future. The majority of plastics used today is non-biodegradable and poses a threat to the environment. However, these plastics can actually be recycled into filaments used in 3D printing. It is found that turning your recycled plastics into spools uses less energy than conventional plastic recycling. That is to say, 3D printing can help save the environment.

New products are important—to both customers and the marketers who serve them. For companies, new products are a key source of growth. For customers, they bring new solutions and variety to their lives.

In summary, to create successful new products, a company must understand its consumers, markets, and competitors and develop new products that deliver superior value to customers. New products underpinned by the 3D printing technology innovation are doomed to reflect development of cutting-edge marketing knowledge in the short and long run.

8.0 Conclusion

Throughout the whole paper relevant to the emerging additive manufacturing, 3D printing is reshaping the world. The development of 3D printing technology and its application into different fields are actually challenging many so called mature and solid social science, legal and marketing concepts.

When delivering such as a unit of Marketing Principles, it is preferable to apply research-oriented teaching approaches during my marketing teaching delivery and link relevant 3D printing-related case studies with related marketing topics which are always followed by group discussions. What surprises and fascinates students is the power of 3D printing. Its existence has begun to push researchers, academics and even students to scrutinise the validity and reliability of many marketing concepts and framework.

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