EXPLORING 3D PRINTING

Reflections on Four Futures for an Emerging Technology

Master´s Thesis
in Futures Studies

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1 INTRODUCTION

The evolution of disruptive technologies has always been a major source of transformational change in the modern society (Campbell, Williams, Ivanova, & Garrett, 2011). Ever since the inception of the agricultural revolution around the 16th century, humans have continuously invented technologies which have disrupted the ways with which different aspects of society function. Some of these disruptive technologies such as the steam engine, atomic energy, the light bulb, the digital computer, the internet, and the microchip to mention but a few have undoubtedly changed our world in very dramatic ways. These technologies developed with varied levels of uncertainties regarding their socio-technological impacts on society and they took decades of conceptual and structural reformations before attaining advanced levels of development capable of altering the ways humans live. With the aid of early anticipatory strategies and technology foresight, some societies were able to manage and better prepare for the surprises and long-term social changes which arose from the advancement of these disruptive technologies. Others were engulfed in a number of negative consequences which resulted from their inefficient anticipation of the socio-technological changes impacted by the technologies.

Presently, there exists a number of emerging technologies which deserve such long-term anticipatory efforts.With them, humankind can better prepare for the disruptive social changes and shocks which they might impact on society as they evolve into major disruptive technologies. One of such socially as well as technologically disruptive technologies existing today is 3D printing. Despite the fact that the technology's level of disruption in multiple spheres of society has been elaborated concisely in the literature,some academic scholars assume that its disruptive potential could largely contribute to the techno-structural and political revolutions of the approaching post-industrial society. The idea of the post-industrial society coined by sociologist Daniel Bell in his book *The Coming of Post-Industrial Society* (Basic Books, 1973) described the transition of the American society from its largely agrarian economy towards an industrial version in the nineteetnth century. During the period,a huge portion of the American population abandoned farming for better paying jobs in the industrial and manufacturing sectors of the economy.In the twentieth century however, increased efficiencies in the industrial economy resulted in a rapid decline in employment within the manufacturing sector. It thus became difficult to continuously assert that the American society was still an industrial society (Cornish, 2001). In this light, Kumar (1976) lauds the idea of the post-industrial society for the simple reason that it forces us to re-assess the idea of the industrial society and to ask if society is indeed undergoing a new state in its evolution.

Kumar notes that the convergence of a number of diverse theoretical perspectives provoked by a social reflection on the structural framework of the present-day industrial society resulted in the idea of an approaching post-industrial society. One of such notable perspectives is Galbraith's (2007) theme of a new industrial state characterized by the transition of power to the techno-structural class coupled with the unavoidable merge of socio-technological systems necessitated by rapid advancements in technology and planning. Viewing from the direction of this master's thesis, the 3D printing technology can be perceived as one of those disruptive technologies which Galbraith's techno-structural class will likely utilize in attaining major transformations in the future society. Similar to disruptive digital innovations on the world-wide-web, Anderson(2012) argues that the 3D printing technology could bring about an even greater level of disruption and social change to the physical world.He supports this argument using connotations of the real world being much larger than the digital world. Consequently, the democratization of manufacturing would bring about a larger degree of change in the real world.

Presently, the emergence of new organizational structures of innovation on the world-wide-web further uncovers the magnitude of the discontinuity existing between the past industrial society and the present or the kind of society which could emerge in the future. The world observed an increased motivation towards the art of creating through the coming of the information age along with the ubiquity offered by the internet. Most young people sought after creating diverse digital services as pathways to independence from the collapsing economic systems of the industrial era. A number of innovations created on the web has transformed the cultural perspectives, attitudes and values which many humans inculcate. These creative web enterprises have changed the ways we communicate, interact, exchange ideas, buy and sell, innovate, and organize events among a host of other social changes. They have further justified the irrefutable power of innovation that comes with democratization of technology. A similar perspective is currently being applied to the physical world with the aid of the 3D printing technology. The technology seems to be portraying the character of a democratized version of the early traditional manufacturing paradigms of the industrial era. Transferring such a level of democratization in manufacturing to the techno-structural class within the 'third sector' (Bell D. , 2008) of society such as schools, research bodies, hospitals and so on, there is no doubt that 3D printing will trigger radical dimensions of social change within various aspects of society in the future.

As a result, it becomes evident that the discussions on 3D printing’s distruptive potential from a futures perspective requires pragmatic re-assessment.The required re-assessment in question cuts across an in-depth understanding of the trends shaping the socio-technological impacts of 3D printing in the modern post-industrial society.Furthermore, the re-assessment necessitates an in-depth analysis of the possible and probable futures associated with 3D printing while inventing desirable futures for the technology as it evolves over time. With the decreasing time-span of technological change (Masini, 1993) in our world today, it is important to anticipate the possible or likely patterns of discontinuous change which might arise from the 3D printing technology in society. Successful anticipation of the uncertainty associated with the technology's future will involve effective capabilities for identification, early preparation, and response to change as the technology advances. As a result, the academic direction for this master's thesis focuses on clarifying the complex systemic inter-relationships between the megatrends, trends, weak-signals and possible wild-cards likely to shape the patterns of change by the technology within society in 2030. Future images of 3D printing's impact on society will further be presented in this master's thesis with an aim to creatively depict the relationships between diverse stakeholders in the 3D printing paradigm such as DIY enthusiasts, manufacturers, digital makers, policy makers and professionals as they all engage in this emerging technological revolution.

1.1 Aim

This master's thesis attempts to study the uncertainty related to 3D printing as an emerging disruptive technology .It further aims at simplifying the nature of the technology's uncertainty for the comprehension of the reader . Critics might ask, 'why engage in studying uncertainty for such a disruptive technology?' Schwartz (1996) simplifies the reasoning behind considering uncertainty in almost every level of technological development in society. He does this by bringing to light the unpredictability of events which appear suddenly due to the advancement of innovative technologies or the evolution of change. He further attests to the fact that an extreme lack of confidence which thwarts all levels of freedom within society could erupt as a result of the unpredictability of events. One of such unpredictable global events was the oil crisis in the 1970's. According to Schwartz, mastering the art of acting in confidence entails learning to incorporate the study of uncertainty into long-range planning. Schwartz's assertion on the hindrance to freedom due to the unpredictability of events further supports Masini's (1993) first principle of Futures Studies.

According to Masini(1993), there exists a constant perplexity in the relationship between knowledge and fear or desires. She further notes that in most cases, humans feel the need to acquire knowledge of the past and present as a precondition for action towards the future. Nonetheless, the fears and desires of humans hardly correlate the acquired knowledge of the past and present and in most cases contradicts it. Herein lies the dilemma of unpredictability which inhibits human freedom in society. With respect to the dangers associated with ignoring unpredictability, the navigation through uncertainty for 3D printing in this master's thesis will be executed with a goal to envision the technology's opportunities and threats for society in 2030.

In agreement with Ratto and Ree (2012), the existing academic literature on 3D printing still lacks extensive social and humanitarian perspectives as regards the dynamics of change which the technology might impact on society in the future. A huge number of the existing academic scholars concentrate on the engineering, industrial and intellectual property perspectives of this emerging technology. As a result, this master's thesis attempts to contribute to the understanding of the complexities associated with 3D printing from a socio-technological futures perspective. The thesis further aims at contributing to a better context for decision-making related to individual or collective desirable futures by presenting a focused futures analysis of possible and probable images which are likely to shape the future of 3D printing in 2030.

3D printing still appears to be in its nascent stage of exploitation by the global economy. However, similar to the inconceivable nature of the internet's ubiquity prior to its technological disruption in every sector of society, 3D printing is expected to impact substantial social transformation as well. The fact that slightly adjusting a manufacturing technique from a subtractive process to an additive one can have massive implications for both manufacturing and society is of invaluable importance for futures research. While not being an extensive attempt to debunk the numerous spheres of society in which transformative change might likely occur, the thesis attempts to meliorate the understanding of the reader on the interactions between 3D printing and certain dimensions which constitute the framework of society. Dimensions such as politics, economy, social, technological, environmental and culture will be analyzed within a PESTEC framework to clarify the ways in which 3D printing might impact change in society.

1.2 The Research Background

The industrial society has experienced tremendous change as a result of subtle modifications of traditional subtractive manufacturing methods. A wide variety of business opportunities and expansive economic activities have been fueled by advances in subtractive manufacturing over the past decades. Subtractive manufacturing refers to the creation of objects by paring down undesired material mass in order to achieve desired shapes or forms (Brown, 2012). Despite the bourgeoning wealth in society generated by this dominant manufacturing paradigm, the presence of numerous social and environmental problems in our world today reflects the fact that erstwhile manufacturing paradigms might require an overhaul. While some of these threats have been greatly reduced, others such as poor health-care, illiteracy, unemployment etc remain unresolved today. As emerging innovation paradigms present newer opportunities, most of these unresolved threats might transcend into the newer technological paradigms in which they could become significantly eradicated. From the perspective of manufacturing, the paradigm shift towards digitalization could likely bring about the resolution of some of these unresolved problems in society.

The information age is currently experiencing the emergence of a maker sub-culture comprising of DIY tech-savvy enthusiasts who invest a lot of time into efforts to physically materialize numerous aspects of the digitalized world. Further boosted by the internet, the depleting level of the porosity which lies between the digital and the material aspects of society seems increasingly obvious today. As a result of this porosity, 3D printing appears to be one the platforms which could increasingly empower the materialization of digitalization. 3D printing possesses huge potential in moving traditional subtractive manufacturing over to a productive desktop activity with even less financial investments (Ratto & Ree, 2012). In sharp contrast to subtractive manufacturing, 3D printing fabricates products by adding layers of a digital model one after the other in a horizontal manner until a physical product is formed. The process is usually completed with the aid of a 3D printer.

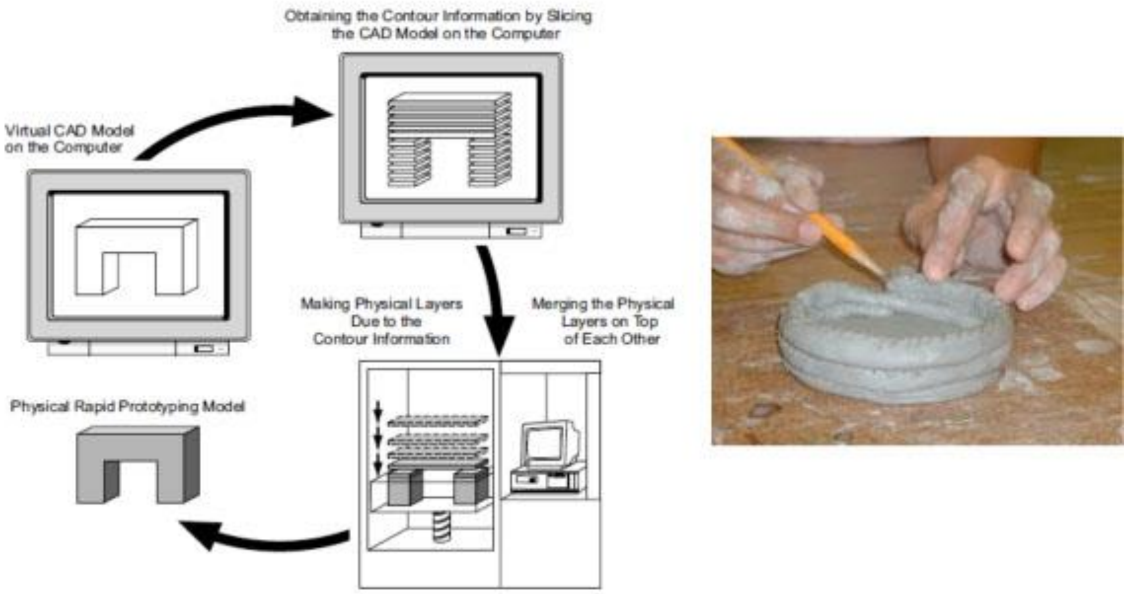

Figure 1 Concept of layered fabrication (Gebhardt, 2003)

Consequent to this fact, a prominent level of curiosity has aroused considering the fact that a mere contrast in methodology has the potential to disrupt to a large degree, the subtractive manufacturing paradigm which has served as an important building-block of society for decades. Thus, it is of paramount importance to enlighten the world on the likely opportunities and threats which 3D printing might bring forth assuming it attains global adoption. Inferring from a coherent trend analysis report by the National Intelligence Council (2012), the year 2030 has been chosen as a focus for futures analysis in this master's thesis due to the convergence of four significant megatrends namely Individual Empowerment, Diffusion of Power, Demographic Patterns and Food, Water, Energy Nexus in 2030 (National Intelligence Council , 2012). The 3D printing technology which has been reported on in a number of articles over the media has subsequently been referred to in the NIC (2012) report as a significant driving force influencing significant aspects of these megatrends. Thus, enlightenment on the future possibilities which could evolve from the inter-relationship between 3D printing and these megatrends is an important quest. Consequent to this enlightening enquiry into the uncertainty associated with 3D printing in 2030, the following strategic question is the driving futures perspective which this master's thesis aims to illuminate;

- *How will 3D printing transform society in 2030?*

Basically, the principle behind layered fabrication by 3D printing involves the creation of products by depositing raw material three-dimensionally using a layer-by-layer pattern until the desired object takes real-life shape. This production technique, formed in the mid-1980s within the manufacturing industry, was literally employed in the development of product prototypes in their early stages of development (Campbell, Bourell, & Gibson, 2012). It produced prototypes in a quick and automated manner and was widely used in the manufacturing industry for analyzing, examining and exposing defects early on as products were developed. Although current application of this technique has been observed to go a little beyond just mere prototype production, the advancement of the technology has been incremental. 3D printing has the potential to disrupt the entire design, manufacturing and production patterns which constitute the fabrics of modern industrial societies.

Presently, a number of academic scholars highlight possible sectors of society which could experience immense change from this technological revolution. Some of them include a potential reduction of assembly lines and supply chains in most manufacturing processes. As a result, the complex intricacies and advanced manufacturing processes embedded in manufactured products during the assembling stages of production might turn out to be cheaply manufactured and revitalized in the long term (LaMonica, 2013). The diminishing use of assembly lines in manufacturing and their possible eradication on the long-term possesses numerous implications for suppliers of product parts as well as for their distributors. More so, the possible eradication of assembly lines could impact massive change in inventory management for a number of companies and businesses.

Furthermore, mass customization might likely arise from this emerging technology since the time it could take to alter the physical characteristics of a product will be shortened as a result of its digital composition. Mass production might thus be replaced by mass customization in the long-term which equally has vast implications for the import and export trade around the globe as well as in the lives of citizens. In addition, 3D printing could provide some answers to humanity's numerous environmental problems due to its transformative potentials in a Neo-growth society. Neo-growth is a term referring to a system of economic growth without inducing any form of stress on the environment while maintaining or improving societal well-being (Malaska, 2010).The Neo-growth paradigm further recommends the continuous discovery of novel growth sources which combine economic growth as well as human growth and empowerment harmoniously thus coinciding with the fundamental principles of sustainability (Heinonen & Ruotsalainen, 2013). Inferring from this description of the values of a Neo-growth society, 3D printing can be perceived as one of its components because the technology represents a novel technological revolution which enforces the harmony between economic growth and human empowerment.

To an acceptable extent, 3D printing enforces economic growth in a sustainable manner due to the fact that the philosophy behind its technique incorporates a precise formulation of extremely thin particle layers which make up the object or product being manufactured. This results in little amount of manufacturing waste since the exact desired shape is being fabricated. In addition, 3D printing could also reduce humanity's carbon and environmental footprints in transportation and production for a number of products and services thus replacing cross-border trade dynamics and production activities with the transportation of digital goods and algorithms over the internet or digital devices.

Concerning human empowerment, 3D printing has the potential to create more local jobs. Countries which have relished export-led growth and innovation mercantilist policies could be threatened by this paradigm shift in manufacturing. Localization of production might likely eliminate the need to transfer or transport high-wage industries or goods to other countries in search for cheaper labor or production costs. This shift has the potential to bring back jobs to locals thus adding value to the human capital within society.

Finally, the field of Medicine is likely to experience significant impact with the proliferation and employment of a number of advanced 3D printing techniques. Diagnosis, prescription and treatment of various illnesses and maladies might evolve into totally radical paradigms which will foster the use of better health products and services while improving the well-being of individuals in society. Odontology and prosthesis are significant areas of medicine which 3D printing is currently revolutionizing in very dramatic ways. Pill-printing technologies and advances in genetics are also significantly being harnessed at present.

1.3 The Research Questions

Numerous discussions on the future of society appear to be transcending into a post-industrial era characterized by a series of technocratic and moral adjustments to the idea of growth. Manufacturing, a mechanism generated by the industrial revolution has been described as an autonomous industrial source of wealth or growth in many modern western societies (Yoshikawa, 1995). However, critics of the conventional capitalistic growth attached to the manufacturing paradigm which the first and second industrial revolutions contributed to in many modern societies seem to be on the rise. Before the discussion on these criticisms, it is imperative to understand what an industrial revolution means and what kind of revolution is expected of a future post-industrial society. The term industrial revolution "encompasses a collection of inventions or technologies which greatly expands the productive output of the people while dramatically changing multiple aspects of their lives (longevity, quality of life, wealth and so on….." (Anderson, 2012, p. 38). According to Anderson, the first and second industrial revolutions were largely influenced by the convergence of three drivers namely; a series of technological inventions, an intellectual renaissance and the discovery of cotton which impacted lives in dramatic ways. The transition to mechanized production and the technological inventions which emerged were perceived to have initiated major transformations in the organization of society.

To further gain a deeper understanding of the organization of society initiated by the industrial revolutions, applying a system-dynamics perspective to the emergence of the industrial society is of paramount importance for several reasons. One of such reasons is the imperative to comprehend the inter-relationship between the elements which constitute the entirety of both technological revolutions. To further support the need for a systemic perspective in understanding the development of the industrial revolutions, Senge(1990) postulates that there exists deeper levels of inter-relationships underlying change patterns in highly complex systems. Corroborating Senge's notion on the systemic understanding of change, Aaltonen and Sanders(2006) note that the analysis of the whole is always greater than the sum of its parts and thus the analysis and comprehension of the future development of any phenomenon cannot be predicted entirely by understanding the nature of its constituent parts. For this reason, it becomes important to understand the robustness of the systemic emergence of the industrial society through the analysis of some scholars such as Briavoinne (1839). Natalis Briavoinne simplifies the comprehension of the developments in the industrial revolution as a system in this extract from his report presented to the Royal Academy of Belgium in 1839;

In the second half of the past century, faster progress was imprinted on the human spirit; knowledge took on a focus that was both more intense and more practical. A re-

markable phenomenon! At the very time when all the classes and almost all the peoples of Europe were rushing furiously at each other, amassing enormous efforts to destroy each other, at the same time people everywhere were seized with a greater desire for improvement. This passion then took such a great hold among men, it endowed them with resources so fertile, that a twenty-five-year war accompanied by internal convulsions could not stop progress in all branches of the material organization of society. In the midst of this enormous unrest, the sphere of work enlarged; the means for performing it were multiplied and simplified more each day. As a consequence, the population grew as risks of mortality were reduced. The treasures that the earth contains were better and more abundantly exploited; man produced and consumed more; he became richer. All these changes constitute the industrial revolution (Briavoinne, 1839).

The contrast to the main focus on technological prowess in discussions surrounding the development of the industrial revolution becomes rapidly evident with such a systemic view. It is for this reason that some futurists such as Destatte(2013) criticize the idea of an approaching third industrial revolution and the philosophy of growth which might accompany such a revolution. These criticisms translate to the need for a structural reconstruction of the material organization of society as described by Briavoinne. Cornish (2005) attests to the assumption that the enormous change and massive organization in the structure and functioning of society by computers could be perceived from a systemic point of view as a third technological revolution. The transformational changes by the computer to the modern society correlates partly to Bell's (2008) theme of a post-industrial society. Bell envisions the post-industrial society as one in which a service economy proliferates thus replacing the industrial economy of goods production. He further makes an argument for the increased replacement of blue-collar jobs by white-collar jobs and the gradual disappearance of the former industrial machinery making way for the emergence of an intellectual technology. In summary, the strategic resource of the post-industrial society would be theoretical knowledge (Kumar, 1976), with its techno-structural class comprised of mathematicians,scientists,economists and engineers with new and advanced computational capabilities. In otherwords, the post-industrial era is described as one in which enormous growth will be observed through increased innovative activity influenced by the extension of technical expertise or scientific induction into various non-business sectors of society (Bell D. , 2008).

As a consequence, an extensive intellectual revolution in all sectors of society seems to be an appropriate description of the kind of revolution which is expected of a future post-industrial society. Destatte(2013) recognizes the fact that a transition from one society to another undergoes enormous change in four areas namely; materials, time, energy and living things. Translated into the intellectual revolution of the future post-industrial society, he advocates that change will likely emerge from technological advances in polymers, artificial intelligence,nuclear and solar energy and genetics. Infact, corroborating Destatte's assertion, a fourth technological revolution might be presently taking place in society due to rapid advancements in computational technology. This revolution can be observed today in society as advances are being made in biotechnology,especially in the field of genetics (Cornish, 2005) .

With reference to an earlier discussion (see chapter 1.2) above highlighting 3D printing’s influence on four significant megatrends in 2030, the technology serves as a platform upon which Destatte’s(2013) postulated change areas will likely undergo experimentation in 2030. Since our world is experiencing an era of unprecedented rapid change which necessitates a much farther look into the future (Masini, 1993) , 3D printing's advancement deserves similar increased anticipation as it is largely perceived to influence the advancements in polymer technology, artificial intelligence, solar and nuclear energy as well as genetic technology in the future. Galtung’s (2010) assertion that there is and will never be a final stage of development, but a common path which must be developed in unison correlates with the inspiration behind the direction of this master’s thesis. If humanity aims at creating the kind of desirable futures which will be livable for all and for future generations, it is of utmost importance to deliberate in unison as efforts are made to illuminate the possible and probable futures which might likely evolve from our present courses of action, planning and decision-making in society.

Correspondingly, this master's thesis will attempt to provide insight on the possible and probable futures as well as the development of alternative futures for 3D printing in 2030 with society being the main focus. Further the master’s thesis will provide answers to the following research questions.

- *What is the present state-of-the-art of 3D printing in society?*
- *What are the opportunities and threats for society in 2030 from 3D printing?*

Efforts to scan for the present state of the art of 3D printing in this master's thesis correlate with the assumption of “Globality as being a major characteristic of Futures Studies" (Masini, 1993, p. 20). Masini asserts that as a result of the increasingly shrinking rate of our world by advances in communication and transportation, developing a forward view into the future requires understanding and analyzing a problem in its complex totality. This also includes possessing consideration for the peoples and cultures of the world whenever decisions are required to be made on global issues.

In this vein, a number of potentials for 3D printing which are currently being exploited globally are discussed in subsequent chapters in this thesis. Some of them include the assumption that manufacturers of high-end, low volume automobiles exploit the cost-effective advantages of using the 3D printing technology in the production of some parts of their products. Furthermore, 3D printing allows for the integration of complex internal and mechanical functionalities in the creation of light-weight products in the aerospace industry. More interestingly, a number of museums and schools are already harnessing the advantages of replicating anatomical structures of extinct species for both educational and research purposes to name a few.

While opportunities are often lauded as attributes of almost all emerging innovations, a number of threats and weaknesses for society usually unfold as these technologies evolve over time. The widespread use of the technology will require a certain level of working knowledge for operating the modeling software required to complete manufacturing processes. More so, printing of certain large complex objects with 3D printing might be particularly slower than with traditional tooling and machining operations. There is also the troubling issue of the potential products which could be fabricated by non law-abiding citizens and terrorists in society. An analogy is the interesting case of the first ever 3D-printed gun. According to a 2012 publication from extremetech.com (www.extremetech.com), a news website focused on latest technologies, the gun is a fully functional 3D-printed .22-caliber pistol formed from the assembly of plastic and metal parts.

Figure 2 3D Printed Gun

Source:http://www.extremetech.com/extreme/133514-the-worlds-first-3d-printed-gun

In contrast to these threats, 3D printing's opportunities centered around the environmental impact of a manufactured part, waste generation, energy consumption and water usage to name a few might end up being positive paths for the threats of climate change. The current consumption patterns of modern economies appear to be based on a remotely conducted means of production and the values of comparative advantage. At the end of the production cycle ,the shipment of products and services to several global locations is carried out. Considering the energy and water consumption levels utilized per product, the environmental deficiencies of such production systems are perceived to be enormous in emerging Neo-growth societies.

Additionally, Mendoza's (2013) assertion on the disappearance of the blue-collar job corroborates with Bell's (2008) argument on the replacement of blue-collar jobs by white-collar jobs in the post-industrial society. Despite the fact that manufacturing efforts have been boosted by technological advances in engineering, programming and robotics, the influence of these technological advances has emerged with far less dependence on human workers. Automation is fast becoming a dominant production trend in the modern society. It is therefore evident that the less-educated or unskilled portion of society might be negatively impacted by this trend. Job creation through 3D printing will likely require intensive skill-acquisition training in order for a huge number of people to fit into the additive manufacturing paradigm.

Further, the rise of professionals such as designers and lawyers might be observed since 3D printing mostly deals with the design and manipulation of computer-aided-design files. More individuals might develop great affinity for the various design professions which might arise and thus trigger job increases in that sector. As 3D printing becomes progressively cheaper, lawyers could also infiltrate the 3D printing industry by delivering copyright infringement protection services thus sparking a rise in job opportunities for legal experts. More so, numerous talks on the issue of intellectual property and policy reformulation in a world where virtually anyone can manufacture anything they so desire has been raised. Averting calamities associated to cyber-hacking or cyber-wars might require proper policy design and implementation by policy makers in order to avoid national security threats.

1.4 Scope of the Research

The scope of this master’s thesis lies within the identification of possible applications, potentials and threats by 3D printing to society in 2030. The study will attempt to investigate potentials for a number of industries, businesses, markets and personal lives where significant change might be imparted. However, it must be noted that the opportunities and challenges for 3D printing as identified in this thesis will be limited to the available data sources used in the futures research methodology employed.

Futures studies represent a non-static evolutionary discipline which continuously evolves as its assumptions and practices are challenged and reformulated (Slaughter R. , 2005). Scognamiglio (2010) further complements the argument on the evolutionary nature of Futures studies. He notes that Futures studies have no ontological consistency. Rather, discussions on the future refer simply to the present anticipation of the future, represented by an image or an idea and perceived as a scenario, foresight, hope or forecast. Lombardo (2006) further reinforces the arguments on the ontological inconsistence of Futures studies by asserting that people tend to become highly inspired by aspiring images and visions in their efforts to conceptualize and create futures. He further notes that people usually imbibe a certain balance of emphatic, emotional and intuitive notions while maintaining rational conceptions of the future as they attempt to visualize and create it. As a result of these perspectives on the manner with which futures are constructed among humans, this master's thesis aims at contributing to the evolution of the discipline by creating inspiring future images of 3D printing in 2030 while allowing for the emphatic yet rational nature of readers in their attempts to conceptualize the future of the technology.

Moreover, the originality of this thesis lies in the creation of alternative future images in order to inspire forward-thinking alternative futures for 3D printing. These future images will be developed and presented in efforts to further ameliorate the complexity attached to the future possibilities and probabilities of this nascent manufacturing trend. With the aid of the data collected in this thesis, the developed images of the future will highlight the interaction between different driving forces and trends and their likely future consequences on certain identified sectors of society.

As explorers of unknown regions (Cornish, 2005) , humans have proven to possess the potential to transform the unknown future into that which they so desire. Human potential for futures transformation is further reinforced by the assumption that "the future is the only territory upon which humans can exert impact" (Masini, 1993, p. 7) . This is because much work cannot be done to the past other than carrying out a deep analysis on it. As regards the present, Masini notes that as soon as it is lived, it becomes attached to what has happened in the past because it is already past. Thus, the only territory upon which humans have to potential to influence change is that which is yet to evolve - the future. Cornish's (2005) seven lessons of the great explorers highlight a number of events which depict the human capability to alter the future into desirable futures. However, in a fast changing world where the pace of change thumps at geometric progressions, anticipating for future challenges might prove to be quite challenging as important signals get lost amidst a magnitude of environmental noise.

Consequently, a critical study of the interaction of trends and driving forces between past, present and possible futures is of rudimentary importance as attempts are being made to navigate the uncertainty attached to the future of 3D printing. Nonetheless, it must be noted that this master’s thesis is not a highly comprehensive analysis of the state of 3D printing in its entirety. More so, the technical aspects of 3D printing processes will not be analyzed deeply. However, a number of the state-of-the-art applications of 3D printing will be discussed for illustrative reasons.

2 TRENDS IN THE DEVELOPMENT OF 3D PRINTING

By employing a literature study of academic papers, blogs, reports, articles and interviews related to 3D printing, some trends which appear to be shaping the current roles which 3D printing plays in the modern human society have been observed in a literature survey for this master's thesis. In a world where rapid change is a dominant paradigm shaping the organizational structure of society, a concise understanding of trends, which can be referred to as drivers of change, in our modern societies today is fast becoming a vital activity. Trends, which serve the purpose of connecting the past to the future, enables the understanding of likely future changes while facilitating the conversion of past knowledge into possible future outcomes (Cornish, 2005). Cornish (2005) further notes that the longer a trend lasts, the more likely its extension into the future will be observed. However, with appropriate anticipation systems, understanding the existence of these trends and changes in them seems to be an important pre-requisite for detecting discontinuities in change.

As a result, the literature survey was carried out in order to identify both trends in their development stages as well as the dominant 3D printing trends in society. It consisted of a futurist blog which highlighted instances of the transformations in entrepreneurship through individual empowerment by open-source technologies which the abrupt ubiquity of 3D printers have generated (Frey, 2013). Corroborating his argument, Ratto and Ree(2012) note the emergence of a number of fabrication spaces like Materialize, Thingverse and Studioludens in which budding entrepreneurs can experiment and test their product ideas as well as their market potentials before bringing them fully into their niche markets. These fabrication spaces encompass different innovations in 3D printing which appear to be intensifying the growth of this new kind of entrepreneurs as well. Further, a significant trend from the literature survey illuminated the fact that dissatisfaction in mass produced goods which contrast the high level of heterogeneity in the needs of market products was on the rise among consumers. The rise of a new kind of consumer namely 'the prosumer' was identified (Hippel, 2005).

Conclusively, the term 'craft' seems to be revolutionized by 3D printing in society. Horton (2013) corroborates this argument by affirming that the emergence of open-source technologies for 3D printing such as Makerbot and RepRap projects constitutes major drivers for the massive reductions in costs of many unique personalized products. Such products when viewed from the lens of the old paradigms of craft-making accrue higher prices because of their level of uniqueness and intimacy with their owners.

Prior to a more detailed discussion of these briefly described trends is a discussion which attempts to clarify the definitive differences between 3D printing and Additive Manufacturing below.

2.1 Distinction between 3D Printing and Additive Manufacturing

The definition for 3D printing seems to contradict that of Additive Manufacturing frequently in academic literatures but in fact, they could be perceived as two poles of a technological spectrum. Nonetheless, most of the definitions for both terms are related to the idea of layered fabrication by the addition of small units of material in contrast to subtractive manufacturing. For the purpose of this master's thesis, the definition by the American Society for Testing and Materials (ASTM) seems to be most appropriate. Additive Manufacturing refers to a collection of emerging technologies which utilize a bottom-up approach in the creation of an object by the addition of material one cross-sectional layer at a time (ASTM International, 2010). These emerging technologies differ in the manner with which they fabricate objects.

In an attempt to clarify the definitive disarray existing between Additive Manufacturing and 3D printing, a satisfactory description involves viewing 3D printing as one of the technologies under Additive Manufacturing in which products are manufactured in a layer-by-layer process. 3D printing involves the use of “art to part’’ techniques in the fabrication of complex objects from a computer-generated digital model without human intervention or machining operations (Beaman, 2012) . On one hand, Additive Manufacturing is more of “an industrial process which usually involves higher capital investments associated with an instituted supply chain or offered as a service” (Hague & Reeves, 2013, p. 39).

According to LaMonica (2013), Additive Manufacturing is the industrial version of 3D printing. Additive Manufacturing is not entirely nascent as a manufacturing technique. It is a technology with a broad historical background as an early manufacturing process for over 150 years with its roots derived from typography and photo-sculpture. Manual “cut and stack” methods might be a suitable way to describe the early manufacturing modes used to create free-form objects in a layer-wise process (Bourell, Beaman, Leu, & Rosen, 2009) . It is quite interesting to note that patents seem to have played a significant role in the development of layered manufacturing in the 19th and 20th centuries. In contrast, the 21st century has observed the expiration of a few of these patents which has consequently sparked the proliferation of disruptive innovations using the 3D printing technology (Wohlers & Wohlers Associates, 2011). The figure below depicts some of the major time events in the development of patents for additive manufacturing and modern day 3D printing. Despite not being entirely complete, it represents a comprehensive compilation of the periods in time related to the chronological development of 3D printing.

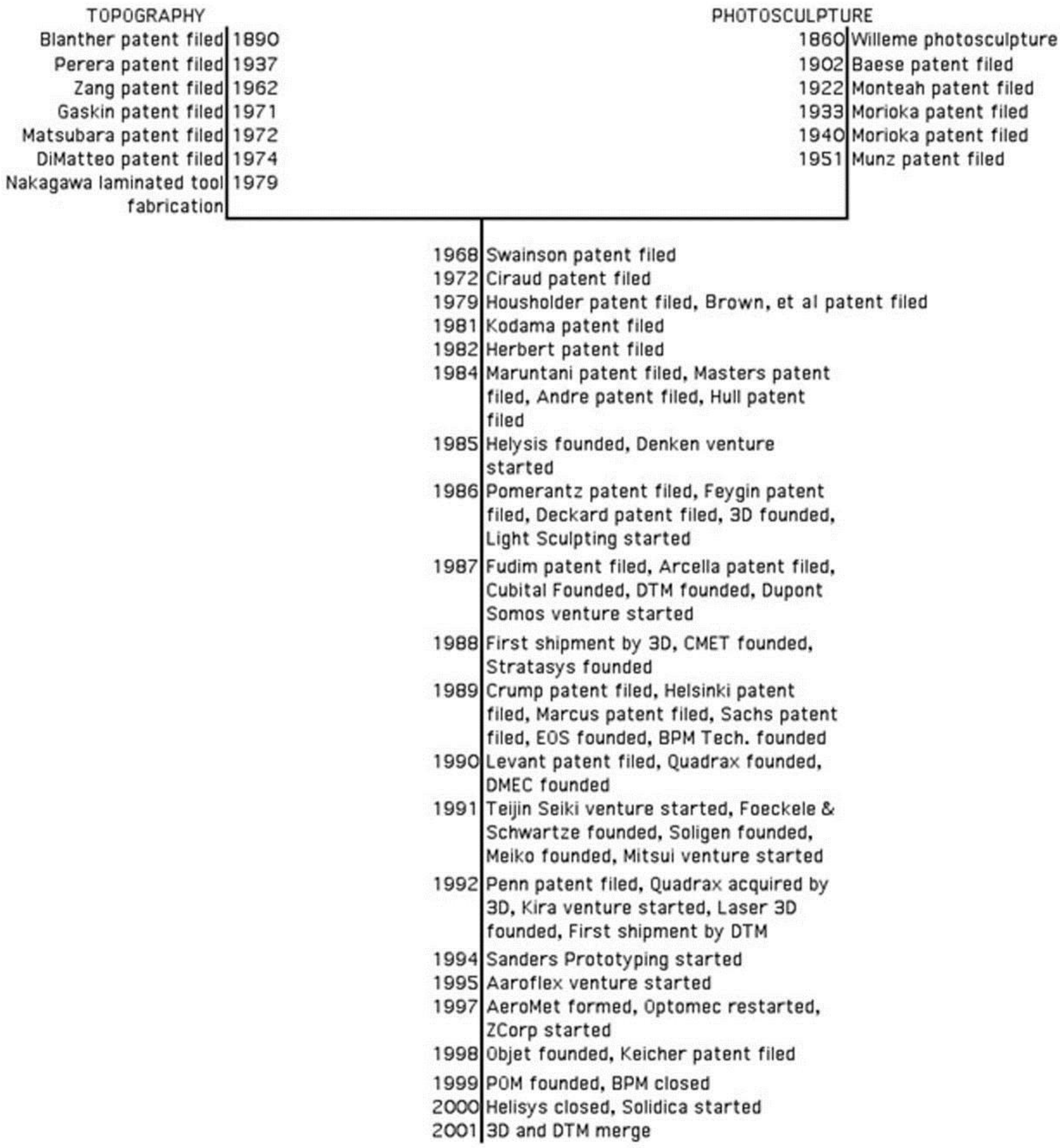

Figure 3 Timeline showing patents forAdditive Manufacturing

Source:http://www.lia.org/blog/2012/04/the-history-of-laser-additive-manufacturing/

On the other hand, 3D printing can be perceived as one of the numerous techniques under Additive Manufacturing with attributes suitable for new entrants, hobbyists, makers or enthusiasts as these groups attempt to get involved in Additive Manufacturing. 3D printing techniques derive roots from the inkjet printing technology with the utilization of a printer-head as their common feature (Dimitrov, Schreve, & de Beer, 2006). The process basically begins with the creation of a computer- aided- design (CAD) file which is then sliced up into numerous two-dimensional bitmaps using rapid-prototyping software. These slices are then transferred to the 3D printers for final printing and live transformation into a digital model (Mendoza, 2013).

Spanning through 25 years, layered manufacturing served as a practice used to verify design prototypes by rapid prototyping before strategies for mass production were put in place in the manufacturing industry (Hague & Reeves, 2013). Rapid prototyping, an early perspective for viewing additive manufacturing, was introduced in the mid-1980s for quick, automated fabrication of product prototypes in early product development stages. However continuous alterations and modifications of some of the early additive manufacturing processes have shaped the manner in which modern additive manufacturing technologies have evolved today. Hull (1986) affirms that additive layer manufacturing was firstly commercialized in California USA in the 1980's. Since then, the rate of maturity and technological advancement of the process has increased exponentially. Today, additive manufacturing has rapidly evolved from a process for rapid prototyping into a novel manufacturing paradigm - 3D printing. As nascent as the technology is presently, it is attaining public and institutional adoption in society.

One of the reasons for its heightened rate of adoption is the fact that a number of critical 3D printing patents will be expiring soon. A significant analogy of the level of impact caused by these patent hindrances to the proliferation of the technology is exhibited in the advancement of the RepRap technology. The commercial success of the RepRap open-source project was fueled by the expiration of the fused deposition modeling patent in 2009 (McKinsey Global Institute, 2013). In the near future, society could expect another wave of innovation in both technicality and commercialization with 3D printing due to the approaching expiration of the last selective layer sintering process filed by its inventors (Carl Deckard and Joe Beaman) in 2014 (Wohlers & Wohlers Associates, 2011). Currently, a variety of 3D printing techniques exist with each having a slight modification of two broad methods of fabrication. The first method involves a gradual layered structural formulation of an object by depositing materials from a nozzle. The second method, however, exploits the tendency of fusing powdered materials with the aid of ultraviolet light or lasers into a solid object in a layered fashion. These 3D printing techniques include selective layer sintering, stereo-lithography, inkjet bio-printing, fused deposition modeling and direct metal laser sintering[1].

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[1]See Box 9., p 107; 'Additive manufacturing techniques'; McKinsey Global Institute. (2013). *Disruptive technologies: Advances that will transform lives, businesses and the global economy.* McKinsey&Company.

2.2 Present Trends Shaping the Role of 3D Printing in Society

Futures thinking is an inherent need of humans (Masini, 1993). It embodies the principle of continuity and "it is the continuity from the past to the future that improves human capability to anticipate and forecast future occurrences" (Cornish, 2005, p. 48). Change has always been a part of human lives . Nonetheless, Cornish (2005) attests to the assumption that if every phenomenon in life constantly changed, it would be impossible to generate any knowledge about the future. Thus ,the continuity of change enables humans to anticipate future changes and detect discontinuities. Discontinuities which often send early warning signals reinforce the need to include the study of trends into futures thinking (Groddeck & Schwarz, 2013). Trends could be defined as continuing but significant societal changes over an extended period of time (Buck, Herrmann, & Lubkowitz, 1998). The importance of understanding trends as a means for detecting discontinuous change becomes even more evident in our fast-changing world today where important signals of discontinuous change are lost in an enormous magnitude of noise resulting in the emergence of suprises and shocks.

As a consequence, the following discussion on the trends shaping the role of 3D printing in society will be carried out. Following the discussion on each trend is a brief discussion on some of the industrial applications of 3D printing as a result of the emergence of the trends. The aim is to understand the magnitude and variation of change which the technology impacts on some of the identified sectors of society presently. The discussion further attempts to encourage the reader to envision possible future changes or discontinuities in the identified trends and the application areas of 3D printing which could transcend into more dramatic socio-technological changes for society in the future.

2.2.1 Emerging New Set of Entrepreneurs

According to a futurist blog, 3D printing is setting the stage for the creation of a new kind of entrepreneur. Frey (2013) notes that a dramatic cultural shift caused by 3D printing is changing the face of entrepreneurship for business-minded individuals. Even further, the cultural shift characterized by the heightened desire to transfer digital information into materialized real-life goods using 3D printing is slowly accruing the values of an economic shift (Anderson, 2012) .Nurtured by the explosive emancipation of the internet's ubiquity, the manner with which people can now transform ideas into real-life business ventures seems to be meliorated in society presently.

This disruption to entrepreneurship is partly as a result of the convergence of an increasing number of DIY enthusiasts and affordable open-source 3D printers. A notable example is RepRap, a UK-based open-source project launched in 2007. Ratto and Ree (2012) also note that most DIY hackers or enthusiasts have adapted these RepRap projects into the construction of custom-made robots specialized in fabricating products. One of such affordable open-source desktop fabrication robots is the MakerBot 3D printer.

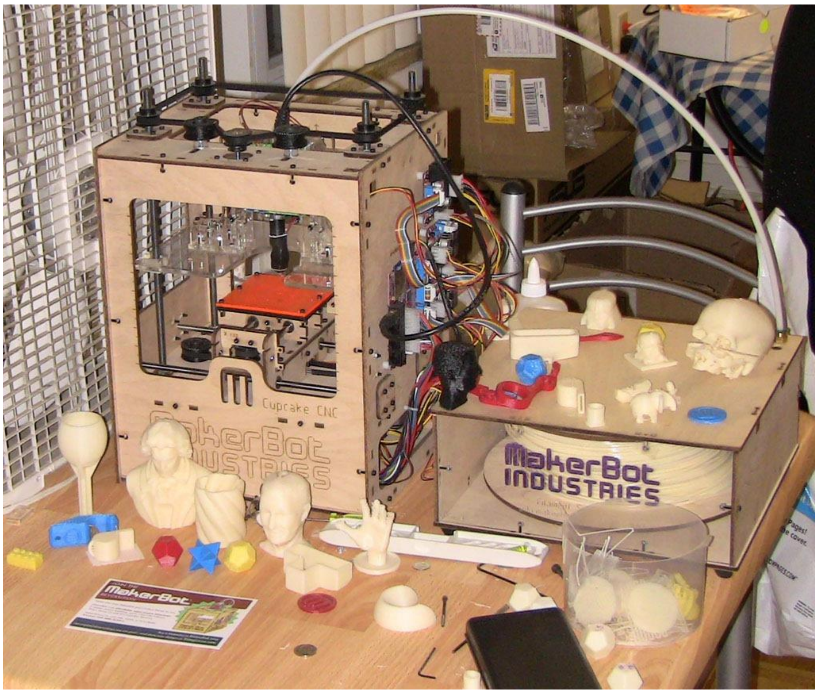

Figure 4 MakerBot CNC Cupcake

Source:http://www.techknight.com/blog/2010/10/8/makerbot-roundup.html

In the figure 17 above, the Makerbot CNC cupcake allows manufacturers or makers to print objects using melted plastics as a raw material. Most models are usually created or freely downloaded from online websites like Thingiverse.

Some application areas reinforcing this trend are design and customer presentation. Design in this case encompasses concept modeling, digital design visualization, manipulation and repetition. As a result of the relatively high speed and reduced cost of operations of the modern 3D printers, large numbers of physical prototype reiterations can be evaluated and verified at an instance by designers and entrepreneurs in the early product development stages of manufacturing. With the aid of such affordable innovative printers made with open-source hardware, most innovators and aspiring entrepreneurs can find greater ease creating products and testing for their market potentials in the intended niche markets. Even further, product prototypes in their exact shapes, sizes, look and feel as the final products can be presented easily to customers or clients for assessment in terms of functionality and efficiency before producing for markets. This dramatically eradicates the uncertainties associated with mass-producing a high number of products without testing for their viability and performance in the niche markets. On the long term, the reduction of risks of entry to business through 3D printing could have dramatic effects for the future of business and entrepreneurship in society.

2.2.2 Emerging Consumer Behavior

The term 'prosumption' is a term attributed to a unique type of consumption, a trend that is being observed in the modern society at present. Borrowing insight from his book titled 'The Third Wave', Toffler (1984) describes the prosumer as a type of consumer whose consumption patterns nullify the distinction between a consumer and a producer. In other words, performing production tasks normally carried out by industries represents negligible fundamental change to this group of consumers. They can both produce and consume with ease. As a result of the nature of complexities these consumers face in their everyday life patterns, they definitively embrace emerging technologies at their early stages of development (Gerhardt, 2008).

Viewing prosumption in the 3D printing paradigm, there seems to be an increasing interest in the individualization of products by consumers. This individualization is characterized by a desire for customized products which have the ability to accommodate the diverse idiosyncrasies of consumers' tastes and preferences. Hippel (2005) confirms that when the dominant producer strategy of mass production contrasts the high level of heterogeneity in consumers' needs, many users will be ultimately left dissatisfied with the products available in the markets. Frank and Reisinger (2003) further assert that consumers' needs for products in society have been observed to have high heterogeneity levels in many fields. This contrast in consumption patterns establishes the gap which 3D printing is likely to fill in the future of consumption in society.

2.2.3 Unique Fabrication Spaces

One very significant trend which is currently shaping the roles of 3D printing in the modern society is the emergence of distinctive virtual and physical fabrication spaces for public use. 3D printing as an emerging technology is fast permeating into more common places in society such as homes, schools, hospitals, offices and several public locations through the adoption and use of virtual platforms. In other words, these virtual spaces can be viewed as potential mini-factories where different kinds of products can be conveniently fabricated (Ratto & Ree, 2012).

From a virtual perspective, a number of digital communities and forums focusing on the dissemination of 3D printing information, outsourcing services, entrepreneurial opportunities and collaborative platforms are on the rise in society today. 3ders (www.3ders.org) and the Belgium-based company, Materialize, are highly notable examples of virtual spaces encouraging fabrication with 3D printing. These digital services represent virtual factories for 3D enthusiasts, designers and aspiring manufacturers who collaborate to share unique design ideas and create resplendent art pieces for commercial purposes. A highly notable application of this fabrication factory type disruption within society presently is observed in the area of medicine. Hospitals and medical institutions are fast-becoming mini-factories for the fabrication of replacement parts for patients although many of the current applications still seem to be in their research stages.

Currently, over 40,000 acetabular hip-cups which are the sockets for replacing hip-joints have been fabricated with the aid of 3D printing (Wohlers & Wohlers Associates, 2011). On a similar note, Invasalign, a dental appliance manufacturing company employs the services of stereo-lithographic printers in the manufacture of 50,000 to 60,000 appliances per day (McKinsey Global Institute, 2013). Even further, 3D printers which can print as much as 20,000 tablets per hour have been observed to undergo commercialization as drug-delivery systems (PressTV, 2011). Moreover, 3D printing technologies are widely used in printing models used as surgical aids in cases of complex anatomy. These models provide platforms for surgeons to ameliorate their understanding of the anatomical intricacies usually difficult to visualize two-dimensionally. Some of the medical processes which have benefitted from the use of these printed models are maxillo-facial and cranio-facial reconstructions (Gibson, et al., 2006) and tissue engineering. One implication for the emergence of these mini-factory paradigms in medicine is the fact that medical practitioners can practice efficient and accurate drug-dosage control for their patients. This trend further highlights the emergence of a future society in which other members of the third sector (Bell D. , 2008) of society will be able to fabricate a variety of resources needed to carry out functional processes with ease in an efficient manner.

2.2.4 Redefinition of Craftsmanship

3D printing seems to be intensifying the redefinition of craftsmanship in the modern society. The unique nature of 3D printing appears to be bringing about a disruption to the dominant cultural conceptions associated to craft-making. Despite the fact that both the terms craft and 3D printing are associated with making, crafts have historically been known to possess an inherent value characterized with 'paying more for individualized products' (Jacoby, 2012). However, as costs of personal fabrication using 3D printing become greatly reduced through the emergence of open-source technologies, the notions associated with high prices of these personalized crafts seems to be changing.

Figure 5 3D printing as a craft creating intimacy between products and users

Source:http://www.3ders.org/articles/20130115-joshua-demonte-create-architectural-jewelry-with-3d-printing.html

In the figure above, the designer has chosen to make his jewelries out of architectural geometries. With the aid of 3D printing, he has been empowered to make his craft come to life. This trend raises questions on the future of personalized lifestyles in society in the future. It highlights also the possibility of a future when people will be empowered to define their personalities through the choices of clothes, shoes or ornaments they wear. Such a change in individual choices could likely bring about dramatic social change to businesses and markets within society as dominant business models get disrupted to suit the personalized needs and choices of individuals.

2.2.5 The Emergence of 4D Printing

Ongoing research reveals the extension of 3D printing into a fourth dimension. At a TED conference in 2011, architect and computer scientist Tyler Tibbits revealed the manner in which the ingenious 4D printing works[2]. He exploited the concept of self-

[2]http://www.youtube.com/watch?feature=player_embedded&v=emW1TQ290ec

assembly by attempting to translate efficient complex mechanisms which constitute some natural systems (DNA replication, protein-folding and so on) into the physical environment. His philosophy towards the marriage between self-assembly and 3D printing revealed the fact that 3D printing only represents a journey into the innovative world of self-assemblage and not a final process of manufacturing. 4D printing involves embedding smartness into 3D-printed objects.

The basic idea behind four-dimensional printing lies in exploiting the energy of water molecules as catalysts for strands of 3D-printed materials that assemble themselves into pre-programmed self-adaptive shapes. In other words, it fuses a smart material, known for its efficiency in absorbing water with a regular plastic piece. Once printed, the plastic object is placed in water where it uses up energy in water molecules to form the shapes corresponding to its pre-programmed sequence of codes (Nigel, 2013) . With respect to future applications of this emerging innovation, Tibbits further inspired the TED audience to imagine ordering a piece of furniture (like a kitchen cabinet) which pops out from its pack and assembles itself into the originally advertised product. This could bring even more disruption to the packaging industry which will also require new business models to satisfy consumption patterns in the future.

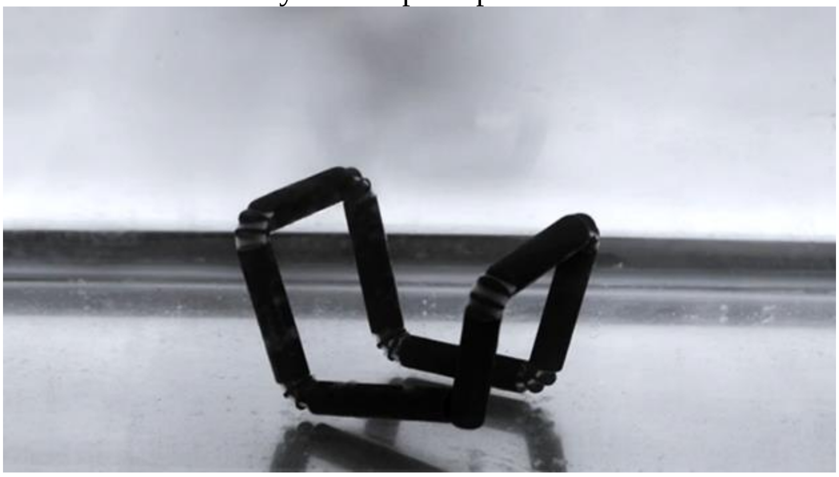

Figure 6 Self-Assembly with 4D printing

Source:http://solidsmack.com/cad-design-news/4d-printing-stratasys-and-mits-new-self-assembly-lab-push-development-of-smart-3d-prints-video/

3 METHODOLOGY

This chapter discusses the research methodology which was employed in answering the research questions for this master's thesis. The chapter further attempts to improve the understanding of the methodological perspective used in carrying out this research. First of all, the chapter briefly discusses the epistemological dimension of the research methodology called Interpretivism. More so, it argues on the reason why this methodology was most appropriate in efforts to simplify the understanding of the uncertainty surrounding the future of 3D printing in this master's thesis. Furthermore, the chapter presents arguments for the choice of employing Environmental Scanning as the chosen futures research method used in collecting data from which the results for the future of 3D printing was aggregated.

3.1 Arguments for Interpretive Research

The methodological approach employed extensively in this master's thesis was Interpretivism. An interpretive research advocates that “the relationship between understanding and meaning is an indirect one” (Fisher, 2010, p. 58). The methodology suggests that improving understanding on a complex phenomenon is insufficient in unveiling the direction for the most efficient action. Presently, society is surrounded by rapid unprecedented and unrelated change which makes options for action in terms of decision-making highly unclear.

Consequent to the emerging nature of 3D printing as a disruptive technology, this master's thesis adopts the use of interpretivism in efforts to aggregate diverse probable or possible futures, cognitively envisioned by a number of interviewed experts, in an attempt to discern the dichotomy between understanding and meaning of these images of the future. The methodology attempts to further reinforce the robust nature of the strategy required for solving the complex issues in society today. These cognitively envisioned future images are dependent on different structures of meaning and how change is interpreted from the interviewed experts' individual perspectives for this master's thesis regarding 3D printing.

According to Choo(1998), groups, organizations or individuals mainly explore for and synthesize information either to create meaning from its environment or produce new knowledge which in turn helps facilitate the development of efficient decision-making strategies. The exploration of information within the human environments by individuals is highly influenced by the notion that existing objects or spatial forms within environments are usually perceived by humans as being stable (Lombardo, 2006).Lombardo further notes that without the sense of stability in their environments, it would be impossible for humans to adopt adaptive, coordinated behavioral mechanisms within them.

As a result of environmental changes which erupt into discontinuities, people tend to perceive and experience events in different ways thus influencing their decisions. The influence on their decisions is driven by the structures or patterns of understanding which they develop cognitively. Weick(1995) further notes that change in an environment induces active reconstructions of the features within the environment as people engage with newer experiences over time. Usually, these reconstructions could be inspired by beliefs which people initially conceived about their environments while living within it. These beliefs serve as connectors to newer information being communicated by the environment in order to generate more prominent structures of meaning. Without these beliefs which Lombardo refers to as a continual "perception of persistence and change", futures consciousness would seem challenging since human consciousness would be composed to a great extent by a series of "disconnected events and momentary experiences" (Lombardo, 2006, p. 9).This is in part due to the fact that the continuity from the past to the future greatly influences human capability to anticipate and forecast future occurrences (Cornish, 2005).

Further, the structures of meaning which humans accrue in understanding change in their environments could be modified by actions which thus create newer significant structures of meaning surrounding those actions. In simpler terms, meaning could be induced by people when they make actions which justify earlier actions made as they try to make reconstructions in their changing environments. Interpretive research suggests that structures which link the understanding of a phenomenon and its meaning are determined by an interplay the peoples personal opinions, values, relationships with each other and their different interpretations of change. These interpretations are usually linked as a result of the series of arguments and disputations which people undergo in the process of generating ideas either mentally within themselves or with other people.

Moreover, on justifying the choice to use an interpretive approach for this thesis, the interplay of conversations and argumentations in the process of conceptualizing interpretations seem to place an impulsive role on human understanding and will. Fisher (2010) argues that this role encompasses the capability to construe the patterns of understanding of different phenomena into appropriate actions. As a result, the single quest of improving knowledge of the phenomena in question might not generate absolutely decipherable routes to action. Nonetheless, an improved knowledge or understanding of a problem should assist the human mind in utilizing its power of judgment at arriving at more efficient courses of action. Therefore, interpretive research seeks to explore an array of views which people have on particular phenomena.

In logical terms based on Fishers’ argument, understanding the technicalities or socio-technological change which 3D printing will likely impact on society is highly insufficient in deciphering steps to action for managing the opportunities and threats which might erupt from the technology. More diverse patterns of meaning from different cultural perceptions and professions are required to design more efficient steps for planning for the future of 3D printing. Thus, with the aid of these diverse alternative futures for the technology, the concept of strategic robustness can be achieved. With the generation of diverse perceptions, opinions and values related to the future from different groups or individuals, a wider perspective towards strategy planning will be achieved as policy makers, businesses, corporations or individuals adapt to the disruptions which the technology could likely impact on society.

From this perspective, it is imperative to reiterate the fact that this master's thesis attempts to exploit the range of interpretations based on individual opinions and values as they generate meaning from the patterns of change likely to be impacted on society by 3D printing. The thesis further attempts to promote a better platform for understanding the possible and probable futures related to 3D printing with respect to the development of efficient actions and decision-making required to stay ahead of possible future shocks by the technology.

3.2 Arguments for Environmental Scanning

Environmental Scanning is an important family of methods in futures research. It is an instrumental foresight exercise employed for the early detection of weak-signals, societal trends and significant technological drivers which could impact change in the future (Tonn, 2008). It encompasses an array of activities all involved in acquiring and efficiently using information about events, trends, driving forces and relationships in both the internal environments and the periphery around a particular topic of enquiry. To a great extent, Futures studies have been extensively regarded across the literature as a fundamental constituent of every strategic planning process (Hamel & Prahalad, 1994).

Therefore, as an element of Futures studies, Environmental Scanning is essential in strategy planning efforts to get ahead of change since plans are usually dependent on assumed forecasts about future possibilities or probabilities (Gordon & Glenn, 2009). It is a necessary activity for businesses, governments or foresight institutions which desire to enhance their competitive edge ahead of future changes in order to avert catastrophic surprises and improve their long-term or short-term planning strategies (Sutton, 1988). However, most organizations or institutions are "hard-nosed in dominant strategic efforts and do not attempt to criticize mainstream ideologies or paradigms shaping the external environments in their industries" (Slaughter R. A., 1999, p. 442). Thus such organizations or groups find it extremely difficult to adapt to massive changes in their industries. Attaining successful adaptation to external change using environmental scanning as a foresight tool depends on the capacity for efficient interpretation of these external changes occurring in the external environment by any organization, government or individual (Choo C. W., 2001).

Futures studies constitute a continuous learning process which evolves into newer perspectives as change continuously adopts different patterns in its evolution. Environmental Scanning modes usually depend on the ways different groups perceive the extent to which an external environment can be analyzed (Daft & Weick, 1984). Since the future represents lucid consequences of past events (Veenman, 2013), groups or institutions which perceive their environments as unascertainable tend to create plausible interpretations with which they could be able to create continuities linking the past events to the present in other to forecast possibilities for the future. However, other groups which perceive events and the dynamic processes in an environment as analyzable and ascertainable might be inspired to generate precise interpretations of events through systematic scanning exercises. It should be noted that the level of scanning and nature of forecasts which could be achieved from scanning often times relates to the amount of uncertainty in the environment being scanned as well. Some environments could be highly dynamic and complex, thus decision-making becomes highly unmanageable. These kinds of hostile environments thus increase scanning as a result of the need to discover new niches or detect discontinuities in order to avoid harsh surprises thus better preparing for strategic shocks and developing enhanced platforms for the identification of opportunities (Wilensky, 1967).

Relating the idea of environmental hostility to the emerging nature of 3D printing, the environment in which 3D printing is currently situated could be said to be in its infancy where all kinds of probable, possible or preferable futures could be made pertaining to the extent of disruption it could impact on society. The dynamic inter-relationship of the forces shaping the technology's development at its current emerging stage could be perceived to be reinforcing a form of environmental hostility surrounding the uncertainty for the future of 3D printing. Several industries seem to be assessing its impacts already by monitoring the emergence of diverse new trends in 3D printing which make it more complex to envision the different patterns in which the future of the technology could evolve over time.

However, monitoring such a rapid emergence of trends as developments in 3D printing advances is quite insufficient in fashioning out the required strategic steps towards action. In this vein, 'futurists' are required to serve the critical duty of proving that current approaches to foresight lack the capabilities to constantly attain a position ahead of change while fashioning out more robust strategies for the achievement of better results (Hines & Gold, 2013) . For this reason, environmental scanning has been sought out to be an efficient first step in efforts to design more robust anticipatory insights pertaining to the future of 3D printing in 2030.Environmental scanning entails the identification of not just the trends shaping the future of any phenomena, but also driving forces, wild-cards and black-swans which usually end up being highly critical components of disruptive future changes.

Environmental Scanning often times concentrates on changes that occur over time otherwise called trends. Trends also include megatrends and weak-signals depending on the strength of their potential to drive future changes. Megatrends could also be described as strong developmental forces in the society which have high possibilities to influence the unfolding patterns of the future within a 10-15 year time-frame. Although megatrends represent our current knowledge of the future, there is not a certainty about the way governments, economy, businesses or individuals will react to the changes in the future. Similarly, wild-cards which are usually referred to as low-probability events tend to have significantly high impacts when they eventually occur in the future. They tend to be difficult to control because they evolve so rapidly thus diminishing the capacity of existent social systems and frameworks to generate adequate responses to them (Petersen, 1999).Despite this characteristic of wild-cards, it is of paramount importance to create alternative futures for them in order to be better prepared to respond to the varied patterns of change which might erupt as they unfold in the future.

3.3 Research Plan

The research plan for this master's thesis constituted a careful exploration of the ways in which a number of experts from the fields of Futures Studies and 3D printing visualize the future of the technology in 2030 . The exploration was done with the use of face to face interviews, scanning of media sources such as newspapers and journals, internet blogs, and websites. Further, an environmental scan of both the internal and external environments was used to scan for recent, possible, probable and preferable future images for 3D printing.

Regarding the results analysis chapter of this thesis, the research also employed the combination of a futures table and narrative future images as methods to clearly communicate the findings from the horizon scan. Heinonen and Ruotsalainen (2013)note that the futures table could be described as a matrix used to analyze a specific problem or case study from a number of chosen dimensions which serve as multiple variants. As a result, the PESTEC table was chosen to be used for the analysis of the trends and driving forces shaping the future of 3D printing in 2030. It served as a means to access the external factors affecting the evolution of 3D printing from the political (P), economic (E), social (S), ecological (E) and cultural, citizen and customer(C) dimensions (Heinonen & Ruotsalainen, 2013).In addition, the utilization of the table served as an attempt to desegregate possible weak-signals from the noise which exists in the literature and media sources related to the 3D printing technology.

4 DATA COLLECTION, ANALYSIS AND RESULTS

The horizon scan employed for data collection in this master's thesis included seven face to face interviews of experts representing the fields of Futures studies and 3D printing. The interviews were conducted in the form of informal discussions utilizing a set of questions. The interviewees included Olli Hietanen, a permanent expert at the committee for the future in the Parliament of Finland and the vice director of the Finland Futures Research Centre.The next interviewee was Thomas Frey, an American senior futurist and the executive director of the DaVinci Institute, a non-profit futurist think-tank in Colorado, USA. Following was an interview with David Lefutso, a South-African futurist, foresight specialist and an academic contributor in the field of foresight and scenario development. Next in the interview sessions was Professor James Allen Dator, the director of the Hawaii Research Center for Futures Studies at the Department of Political Science, University of Hawaii,Manoa. Following was an interview with Ken Vartanian,the Director of Marketing at Optomec, a manufacturing company focused on the development of additive manufacturing systems with its headquarters at Albuquerque, New Mexico. The next interviewee was Tony Ahlqvist, a senior scientist at VTT Technical Research Centre of Finland and a foresight researcher. Lastly, Risto Linturi, the Programme Director of Radical Innovations at the Aalto University School of Science and Technology, Finland and a renowned expert with 3D printing concluded the interviews sessions with experts for this thesis.

All seven interviewees were chosen for the data collection phase of this master's thesis on the basis of their repeated efforts in contributing to the limited futures literature on 3D printing. While most of the interviewees were futurists ,the master's thesis gained extensive insight from the interview with the director of marketing for the Optomec Corporation as regards the technological development of the modern-day 3D printing technology and trends in the development of its modern technological paradigms. The interviewee (Ken Vartanian) was specifically chosen to give a comprehensive description of the evolution of present 3D printing technologies with an aim to envision the likely development roadmaps of the technology in 2030. In support with the assumption that 'globality' is a major characteristic of Futures studies (Masini, 1993) , a futurist from Africa was interviewed . This interview was carried out in order to generate disruptive possible,probable or preferable future images for 3D printing in the sub-saharan region.

Furthermore, this master's thesis could have attained an rather extensive array of insights for the future of 3D printing by incorporating more interviewees from the developing world on other continents. However, due to the constraints on time dedicated for the completion of this master's thesis,planning for and conducting the interviews from the interviewees living in these distant locations proved challenging.Nonetheless, the relatively small number of interviews conducted for this thesis were optimally and efficiently analyzed for plausible future images for 3D printing in 2030. While some of the face to face interviewees were conducted in Finland ,others interviewees located outside out of Finland were interviewed with the aid of the Skype application software.

Questions which were most familiar to the respondents were answered in the most detailed manner while others generated depictive future ideas. A pre-questionnaire and a power-point presentation of the research topic were initially sent to the interviewees in order to get them familiar with the topic under study. Dates for the interviews were then fixed and carried out at locations suitable for those located in Finland. The questions in the pre-questionnaire were grouped under two broad themes. The questions representing the first theme requested discussions on the potential disruptions, opportunities and threats by 3D printing for society in 2030 .On the other hand, the second theme was represented by questions about views on the possible future images for 3D printing in 2030. Furthermore, a number of video interviews of experts from diverse backgrounds located on internet media sources were consulted in order to enrich the diverse future images for 3D printing in 2030. Even further, some journals and articles scrutinizing the future of 3D printing from different dimensions were also referred to as well. However, for the benefit of the reader, the answers to the questions discussed in the interviews will be presented in an aggregated form in the data analysis section of this master's thesis in order to enhance the understanding on the positive and negative aspects of this technology as its development advances in the future.

The results of this thesis will be presented in a chronological order with the PESTEC table highlighting the significant trends, weak-signals, possible wild-cards followed by narratives depicting images of the future for 3D printing in 2030. These results will be drawn solely from the research data gathered from the horizon scan used for this thesis. Different approaches to categorizing future images have been extensively used in the futures literature in numerous journals. For the purpose of this Master's thesis, however, the future images will be categorized according to the generic futures archetypes developed by Professor Jim Dator of the Hawaii Research Centre for Futures Studies, USA. The professor's approach to futures thinking stems from a broader understanding that futures “develop according to past archetypes or a reoccurrence of deeply rooted patterns through time as trends and events evolve” (Bezold, 2009, p. 123). The names of the four narrative archetypes of the future which are presented in this thesis are Continuous Growth, Collapse, Discipline Society and Transformation Society (Dator J. , 1981a). The constituent elements in each of these future images will be discussed and narrated following a PESTEC table showing the inter-relationships between the identified trends, weak-signals and possible wild-cards which constitute the narrative for the specific future image under analysis.

4.1 PESTEC Analysis

The Futures table used for this research is the PESTEC table. The table was used to study the inter-relationships between the various PESTEC (political, economic, social, technological, environmental and cultural/customer/citizen) dimensions. However, before presenting the individual tables representing the four archetypes of futures images, the lists below provide a summary of all the significant trends, weak-signals, wild-cards, future opportunities and threats gathered from the data collected for this thesis. This list will serve as a reference list from which the identified future images which constitute each generic futures archetype will be selected from. More so, following the list is a general PESTEC table showing the inter-relationships between the different dimensions of the constituent forces shaping the future of 3D printing in 2030.

4.1.1 Identified Trends and Weak-Signals

Presented below is a list of the trends likely to shape the future of 3D printing in 2030. The trends highlighted were generated from the interviews carried out for this thesis. These trends affect all the four futures presented but with slightly varying impacts.

- Robotization
- Automation
- Wireless electricity and wireless powered products
- Artificial intelligence and artificially intelligent products
- Smart products
- Internet of things
- Personalization and Hyper-individualization

A quick glance over these trends reveals how much they already impact various aspects of society presently. Robotization and automation are trends already observed to be shaping lives of people with significant application in health-care. Similarly, wireless electricity and the emergence of products which utilize wireless power to function seem to be transforming the ways industrial equipments and even medical devices function with less use of replacement batteries or cable wires. Furthermore, as artificial intelligence threatens to dramatically influence the dominant educational systems and jobs in our societies to near archaic states (Parameswaran, 2011), the emergence of artificially intelligent 3D printed products might exert social change in very unprecedented ways thus making artificial intelligence a significant trend indeed.

Similarly, the integration of smart products and the internet of things appear to be trends which could shape the ways humans interact with products and everyday appliances in society. The emergence of a democratized way of manufacturing such products coupled with the possible ubiquity of the internet of things could significantly drive dramatic transformational change in the way people live. It could also generate a number of threats for governments as well as difficulties for security initiatives to monitor the manufacture of certain dangerous smart products within society. Moreover, Hyper-individualization which is a term associated with the individualization trend, was coined by one of the interviewees for this thesis. It refers to an extreme form of individualized lifestyle with extensive disregard to societal norms or values. This form of lifestyle seems prevalent in our societies today. Empowered by the open source nature of 3D printing, these hyper-individualized lifestyles could evolve with a lot more ease as people increasingly desire to define themselves in various unique ways thus giving them an avenue to depict their inner-selves through the kind of products they associate themselves with.

Further, weak-signals which refer to information or events in the present which have the ability to presage future changes (Hiltunen, 2008) play significant roles in the conceptualization of future potentials of any phenomenon under study. According to Dator (2005), weak- signals can also be seen as emerging events or issues in their early developmental stages which might probably become trends in the future. For this reason, the following were identified as possible weak-signals from the interview sessions with the respondents for this thesis.

- Why-not instincts: This refers to the emerging inquisitive nature of DIY enthusiasts, makers and hobbyists of the 3D printing technology. A constant series of questioning as to why certain products cannot be printed or certain feats cannot be achieved with 3D printing is likely to spark the rise of advanced innovations using the 3D printing technologies. This inquisitive nature could be observed to drive the manufacture of certain artificially intelligent or smart products which could dramatically transform society in numerous ways as well.
- Race for 'Firsts' : The race for firsts was also identified as a weak-signal which refers to the massive interest generated through the use of media. It includes compensations through competitions for the generation of remarkable innovations using 3D printing. They could be a surge in the number of interested participants willing to make history or become notable innovators among most 3D printing hobbyists or enthusiasts .This surge could likely increase innovation activity in the 3D printing paradigm.

4.1.2 PESTEC Classification

In addition to the identified trends and weak-signals discussed above, a number of opportunities, threats and future images for 3D printing in 2030 were mentioned in the interviews conducted for this master's thesis as well as in the other scanned sources used in gathering data for this thesis. Through a PESTEC analysis of the views mentioned in the interviews, it was observed that some views which were perceived as opportunities also had the potential to develop into threats in other future images presented. This anomaly reinstates the need for more robust strategies as regards planning for the future of 3D printing. Following is a condensed list of these identified views classified according to the PESTEC dimensions.

Political

- Large 3D printers on seas increase territorial disputes among nations.
- Emergence of galactic politics and wars as countries struggle to set up 3D printers for layered mining on other planetary bodies.
- Government control on size of businesses, industries and export led growth. Increased personal 3D printing leads to decrease in businesses and vice versa.
- Difficulty for government to respond through laws to some 3D printed products.
- Increased violation of 3D printing laws creates complex challenges for policy makers.

Economic

- 3D printers as large as sea ships; sea factories in the oceans.
- An end of storage of parts or other home or organizational utilities.
- The emergence of natural-resource economics (businesses buy and sell purified oxygen for daily breathing).
- Increased materialism through home printing.
- 3D printing to support agriculture in temperate regions.
- Wireless electricity transfer and storage in 3D printers; eradication of electricity wires.
- Lower prices of goods (even free if individually printed).
- Insufficient availability of purified oxygen for common citizens as a result of natural-resource economics.
- Lower wages, contracted economies.
- 3D printing brings back many jobs lost to foreign factories.
- Less need to transport goods.
- The emergence of Additive Mining.

- Increased advertising with more 3D printed surfaces on transport facilities, objects and personal gadgets.
- 3D printers as leverage resources or workers in factories.
- Reduced economy of scale; increased economy of closeness.
- 3D printing of anything from anything.

Social

- People want to become the 'first' to print things e.g. first 3D printed gas station.
- 3D models flood the internet for free; anything can be printed.
- More non-tested 3D printed products which hurt or kill people e.g. collapse of 3D printed buildings.
- Increased hunger as rich people pay more for 3D printed products from biomass.
- Wide scale application of 3D printers and robots in education systems.
- Industries organize massive 3D printing competitions which help disrupt their business models (e.g. replacement roof competitions in the insurance industry).
- Increase in the number 3D printing universities or institutions.
- More availability of production resources; reduced inequality in terms of resource availability for the poor.
- Difficulty for governments to respond to some 3D printed products (undetectable plastic guns and bullets).
- Increased cases of suffocation and oxygen-related diseases due to insufficient supply of purified oxygen for common citizens.
- 3D printing of dangerous products like bombs, guns etc from anything.
- 3D printing generates more value for labor.

Technological

- 3D printers for advanced home construction.
- 3D printed sensors and gadgets for smart packaging.
- Advanced rocket and aviation-fuel printing using 3D printers.
- Heightened pressure on available bio-materials as raw material for 3D printing.
- Free-form structures in Architecture replacing flat walls using 3D printers.
- Material innovation; finished products made from liquefied wood, insects and so on.
- Advanced 3D Organ printing(Kidneys, Livers and so on).
- Robots as 3D printers coordinate the mining of rare-earth minerals in the galaxies.
- 3D printing under the arctic ice, using gulf streams as source of energy.
- Increased use of 3D printing for repair work in aerospace industries.

- 3D printers as large as sea ships.
- Teleportation of objects using 3D printers as a new transportation mode.
- Oxygen, hydrogen and other atoms in water or air as raw materials for 3D printed products like concrete.
- 3D food printers in space to provide food for astronauts.

Environmental

- 3D printing to support agriculture in temperate regions.
- 3D printers as drones to aid early detection of wild-fires in forests areas.
- 3D printed constructions to provide quick shelter for victims of natural disasters.
- Synthetic 3D printed stems and branches in agriculture which pests feed on to reduce use of pesticides.
- Fabrication using wastes from other global regions with 3D printers.
- Creation of artificial bio-mass to balance 3D printing demands leads to a bio-catastrophe.
- More pressure on natural resources and bio-diversity as 3D printed food from bio-mass becomes very cheap.

Cultural/Customer/Citizen

- 3D printers common as microwaves in present day homes.
- Household printers for domestic printing; products as algorithms.
- Not every citizen will abide to government restrictions on 3D printing.
- Increased trade between algorithm societies, trading in algorithms instead of real products.
- 3D thinking in the real world such as 3D writing, 3D drawing and 3D painting inspired by 3D printing.
- Ethical issues concerning 3D printed food.
- Advanced 3D Organ printing(kidneys, livers etc).
- Large 3D printers replace grocery stores and shops; on-demand printing anytime inspires efficient use of land space.
- 3D pill-printers replace pharmacies or drug stores; end of transportation of medicine or drugs for patients.
- Reduced drive to purchase market products.
- Revival of old and extinct brands or products using 3D printers.
- Hyper-individuality inspires unique 3D printed personal products.
- Grind and Re-use culture with 3D printing.
- New materials for 3D printed clothes e.g. materials which do not need ironing, materials from oxygen atoms etc.

A thorough analysis of this categorical classification under the PESTEC dimensions reveals certain recurring trends,opportunities or threats in a number of dimensions.An opportunity in one dimension could be seen as a threat in another dimension. From the political dimension, it is obvious that control of 3D printing policies by leaders of nations might be challenged in a myriad of ways. Despite these identified political challenges, the technology holds some unique opportunities for economic progress. One example is the assumption that the government control on the size of 3D printing businesses can either increase economic growth or decrease it. This highlights a dynamic relationship between both dimensions. Further analysis on the economic dimension highlights another assumption that materialism and unsustainable consumption might be encouraged through home-printing with 3D printers. Since everyone might be able to afford 3D printers, printing of anything from any kind of raw material is likely to spark a growth of materialist consumption patterns among consumers in society.Nonetheless,the economic dimension buttresses some opportunities in the social dimension such as reduced inequality. Since commodity prices might likely be reduced as more people own 3D printers,then the poorer portion of societies might be empowered to carry out local production with the emergence of increased resource affordability. More so,the social dimension reveals another dynamic trend inter-relatiosnhip between the economic and the political dimensions.This resonates in the fact that governments might not be able to control what products or commodities people print from their homes. While one might argue that home-printing could have some economic and social impacts in society,it poses a challenge in the political dimension in terms of security and control.

Furthermore, the inter-relationship between the technological and environmental dimensions seem to be direct at first glance. With advances in sensors and the developments of gadjets using 3D printing, environmental opportunities can be observed such as the early detection of wild-fires using drones and so on. However, some sort of negative relationship can be observed. The assumption that these technological breakthroughs could instigate the emergence of catastrophic events is a threat which should be considered critically as with all emerging technologies nonetheless. Finally, it can be observed that government control might once again become a challenge in the cultural/customer/citizen dimension. People might not adhere to governmental policies concerning 3D printing which poses more challenges to security and control of the kind of commodities which can and cannot be printed personally. Since a repetition of the difficulty in governmental control of 3D printed products appears to cut across almost all dimensions of the PESTEC, it serves as an important indicator which should be considered and integrated into policy and government strategy planning in order to avoid future surprises when events unfold in unprecedented ways.

4.1.3 General PESTEC Table

In an attempt to simplify the understanding of the inter-relationships between the PESTEC dimensions and how they might influence the future of 3D printing in 2030,a general PESTEC table is presented below showing all the identified opportunities, threats and future images in one holistic view. This table was created personally by the author of this master's thesis based on the findings from the interviews and the horizon scanning done as regards the future of 3D printing. The views represented in the table reflect the same views in the PESTEC classification above (see chapter 4.1.2). However, in the following chapters, different PESTEC tables representing Dator's generic alternative future image archetypes are presented along with their future image narratives.

Table 1 General PESTEC table showing driving forces and trends shaping the Future of 3D printing in 2030

PESTEC	FUTURE OF 3D PRINTING 2030			
POLITICAL	Large 3D printers on seas increase territorial issues among nations. Emergence of galactic politics and wars as countries struggle to set up 3D printers for layered mining on other planetary bodies.	Government control on size of businesses, industries and export led growth; increased personal 3D printing leads to decrease in businesses and vice versa.	Difficulty for government to respond through laws to some 3D printed products.	Increased violation of 3D printing laws creates complex challenges for policy makers.
ECONOMIC	3D printers as large as sea ships; sea factories in the oceans An end of storage of parts or other home or organizational utilities The emergence of natural-resource economics (businesses buy and sell purified oxygen for	3D printing to support agriculture in temperate regions Wireless electricity transfer and storage in 3D printers; eradication of electricity wires Lower prices of goods (even free if individually printed) Insufficient availability of purified oxygen for com-	Lower wages, contracted economies. 3D printing brings back many jobs lost to foreign factories Less need to transport goods The emergence of Additive Mining Increased advertis-	3D printers as leverage resources or workers in factories. Reduced economy of scale; increased economy of closeness 3D printing of anything from anything.

	daily breathing) Increased materialism through home-printing.	mon citizens as a result of natural resource economics	ing with more 3D printed surfaces on transport facilities, objects and personal gadgets	
SOCIAL	People want to become the 'first' to print things e.g. first 3D printed gas station 3D models flood the internet for free; anything can be printed More non-tested 3D printed products which hurt or kill people e.g. collapse of 3D printed buildings.	Industries organize massive 3D printing competitions which help disrupt their business models (e.g. replacement roof competitions in the insurance industry). Wide scale application of 3D printers and robots in education systems. Increased hunger as rich people pay more for 3D printed products from biomass	Increase in the number 3D printing universities or institutions. More availability of production resources; reduced inequality in terms of resource availability for the poor. Difficulty for government to respond to some 3D printed products (undetectable plastic guns and bullets)	3D printing generates more value for labor. 3D printing of dangerous products like bombs, guns etc. from anything Increased cases of suffocation and oxygen related diseases due to insufficient supply of purified oxygen for common citizens.
TECHNOLOGICAL	3D printers for advanced home construction 3D printed sensors and gadgets for smart packaging. Advanced rocket and aviation fuel printing using 3D printers. Heightened pressure on available bio-materials as raw material for 3D printing	Advanced 3D Organ printing(Kidneys, Livers and so on) Material innovation; finished products made from liquefied wood, insects and so on Free-form structures in Architecture replacing flat walls using 3D printers.	Robots as 3D printers coordinate the mining of rare earth minerals in the galaxies 3D printing under the arctic ice, using gulf streams as source of energy. Increased use of 3D printing for repair work in aerospace industries. 3D printers as large as sea ships;	3D food printers in space to provide food for astronauts. Oxygen, hydrogen and other atoms in water or air as raw materials for 3D printed products like concrete. Teleportation of objects using 3D printers as a new transportation mode
ENVIRONMENTAL	3D printing to support agriculture in temperate regions 3D printers as drones to aid early detection of wild-fires in forests areas.	Fabrication using wastes from other global regions with 3D printers. Synthetic 3D printed stems and branches in agriculture which pests feed on to reduce use of pesticides	Creation of artificial bio-mass to balance 3D printing demands leads to a bio-catastrophe 3D printed constructions to provide quick shelter for victims of natural disasters.	More pressure on natural resources and bio-diversity as 3D printed food from bio-mass becomes very cheap
CULTURAL/ CUSTOMER/ CITIZEN	3D printers common as microwaves in present day homes Household printers for domestic printing; products as algorithms. Not every citizen will abide to government restrictions on 3D printing Increased trade	Large 3D printers replace grocery stores and shops; on demand printing anytime inspires efficient use of land space. Advanced 3D Organ printing(Kidneys, Livers etc.) Ethical issues concerning 3D printed food 3D thinking in the real world such as 3D writing,	3D pill-printers replace pharmacies or drug stores; end of transportation of medicine or drugs for patients. Hyper-individuality inspires unique 3D printed personal products. Reduced drive to purchase of market	New materials for 3D printed clothes e.g. materials which do not need ironing, materials from oxygen atoms etc. Grind and Re-use culture with 3D printing Revival of old and extinct brands or products using 3D printers.

	between algorithm societies, trading in algorithms instead of real products	3D drawing and 3D painting inspired by 3D printing.	products	

4.2 Future Images for 3D Printing 2030

Bell (2008) argued that the post-industrial society would require the arduous harmony of three distinct and contrary domains namely, the techno-economic structure, the political system and the cultural domain. He further noted that these domains would be governed by three principles namely efficiency, equality and self-gratification (Cornish, 2001). Analyzing the numerous images of the future collated from the interviews and horizon scan conducted for this master's thesis, a synthesis of the likely trends and weak-signals which correlate with Bell's envisioned distinct domains and principles in the post-industrial society becomes rapidly evident. They can be observed from the documented instances of future positive and negative events related to the principles of efficiency such as the use of sustainable materials, equality as can be observed with a fair distribution of resources for production among individuals and self-gratification (Hyper-individualization) in society.

This variety of plausible future images which all have likely possibilities to impact profound change in society in the future readily corroborate Dator's argument that "there is not one future to be predicted, however there are numerous alternative futures which will need to be anticipated for and pre-experienced to some extent" (Dator J. , 2009, p. 2) . Dator notes that as much as most people believe there is one future that can be predicted correctly, people most times assume that the correct future is a continuation of present processes or patterns of events. It is usually a challenge to get peoples' minds to think of a discontinuity in the dominant practices which they currently live by in society. Whenever the dominant practices seem negative, people usually believe it will continually remain negative without developing the capacity to imagine the possibility of a positive event and devising the most effective path to action when such possibilities evolve. In other words, Dator notes that the future is perceived as unknowable by many people in society. In attempts to collate and grasp the 'correct future' among the variety of future images which exists in the world ranging among cultural issues, gender and inequality, food security, hunger and other problems affecting different societies around the world, Dator asserts that his approach to Futures studies is to encourage people to think in a deeper way about the dominant nature of their beliefs and preferences and the consequences of such beliefs on the long-term in relation to the beliefs and preferences of others around the globe.

This reinforces a key assumption in his notion and definition of Futures Studies. He notes that Futures Studies is not a study discipline designed to predict the future but rather one with the goal of studying and analyzing to a reasonable depth, a variety of different images of the future (Dator J. , 2009). As an emerging intellectual discipline entangled in strong debates on the elucidation of its epistemological and ontological underpinnings, significant work has been done to counter these debates asserting a position for Futures studies between positivist and post-positivist post-modernist constructs (Aligica, 2011). Bell’s (2003) efforts to counter positivist debates seems to have played a huge role in strengthening the fields' resilience in academic or intellectual domains. These efforts include an emphasis on ‘images of the future’ and the subsequent delineation of Futures Studies utilizing the values inherent in critical realism against post-positivist post-modernist frameworks.

Contrary to notions on the impossibility to study such an abstraction as the ‘future’, Slaughter (1998) further strengthens its ontological foundations by describing the future as an important constituent of present. Buttressing the argument that the future cannot be predetermined as a result of humans’ possession of the freedom of action, he advocates that the future can however be “understood, explored, mapped and created” (Slaughter R. A., 1998, p. 372). Slaughter (1998) further asserts that Futures Studies plays the role of systematically actuating a renewed gestation for socio-cultural and political assumptions ,thus accruing to its disciplinary strengths, a capacity to invoke the culmination of less viable but dominant paradigms in the production and use of knowledge. The emphasis on culminating less dominant paradigms in peoples' understanding of uncertainty through the use of analysis of future images became a strong focus in Dator's approach to Futures Studies.

Regarding the best possible structure to categorize the variety of future images generated for every given phenomenon under study, Dator came to a conclusion that all future images were constituent elements of four generic archetypes namely Continuous growth, Collapse, Discipline society and Transformational society. Similarly, the four generic alternative futures framework derived by Professor Jim Dator of the Hawaii Research Centre for Futures Studies, USA was used. 'Generic' in the sense that each future image archetype for 3D printing constituted a variety of positive and negative images which reflects a common base for futures thinking. Dator's framework aided the categorization of the numerous future images for 3D printing generated in this master's thesis according to a relational and common theoretical and methodological futures structure (Dator J. , 2009). A useful attribute of Dator's generic alternative futures framework is that it forces governments, businesses, individuals and other aspects of society to equally consider all the depicted future images since they all have equal probabilities to evolve over time (Dator J. , 2009) .

Consequently, this master's thesis attempts to categorize the identified trends and numerous future images into these four generic future image narratives for 3D printing in society in the year 2030 using a chronological order each following a PESTEC table. Each individual PESTEC table was also developed by the author of this master's thesis according to Dator's generic alternative futures structure in order to highlight the opportunities and threats which constitute that specific future image. The plot and character in the future image narratives is consistent depicting different life events of Henry, a British architect in the four alternative future images.

4.2.1 Continuous Growth Future for 3D Printing

The Continuous Growth future image narrated in this master’s thesis coincides with Professor Jim Dator’s generic alternative futures archetype for a continuous growth society. This is represented by the “most accurate information about potential directions which current trends seem to be headed” (Bezold, 2009, p. 132) . Dator further describes this future as a continuation of the conventional features and frameworks which constitute society. As regards the future of 3D printing in 2030, the following PESTEC table has been generated highlighting the identified constituent opportunities and threats which constitute a continuous growth future image.

Table 2 PESTEC showing driving forces and trends shaping a Continuous Growth future image for 3D printing in 2030

PESTEC	FUTURE OF 3D PRINTING 2030 Continuous Growth Future Image			
POLITICAL	Replacement of grocery shops and stores with 3D printers free up land spaces which increase policies favoring international investments in 3D printing industries and businesses.	Government policies encourage 3D printing, more industrial 3D printing in society	Government reforms of educational systems and health frameworks for 3D printing technologies to further attract international intellectual talents	Government policies in advanced countries authorize and promote the use of 3D printers and 3D printer robots in military bases in other countries.
ECONOMIC	Increased Additive Mining, products are manufactured directly at mine sites from processed raw materials in sophisticated 3D printers.	Increased materialism through home printing. Increased advertising with more 3D printed surfaces on transport facilities, objects and	The emergence of natural resource economics (businesses buy and sell purified oxygen for daily breathing)	Manufacture of anything from anything. 3D printers as large as sea ships; sea factories in the oceans

		personal gadgets		
SOCIAL	People want to become the "first" to print things e.g. first 3D printed gas station	Industries organize massive 3D printing competitions which help disrupt their business models (e.g. replace-ment roof competitions in the insurance indus-try).	3D models flood the internet for free; anything can be printed	Increased interest in education at 3D printing colleges or institutions.
TECHNOLOGICAL	3D printers for advanced home construction 3D printed sensors and gadgets for smart packaging. Heightened pressure on available bio-materials as raw material for 3D printing	Liquid printing emerges such as printing of rocket fuels in space or printing of liquids that conduct electricity into products. Advanced rocket and aviation fuel printing using 3D printers	Robots as 3D printers coordinate the mining of rare earth minerals in the galaxies 3D printing under the arctic ice, using gulf streams as source of energy .	Oxygen, hydrogen and other atoms in water or air as raw materials for 3D printed products like concrete. 3D printers as large as sea ships
ENVIRONMENTAL	Fabrication using wastes from other global regions with 3D printers.	3D printers as drones to aid early detection of wildfires in forests areas.	More pressure on natural resources and biodiversity as 3D printed food from biomass becomes very cheap	3D printing to support agriculture in temperate regions
CUSTOMER	Household printers for domestic printing; products as algo-rithms.	3D printers common as microwaves in present day homes	3D printers equipped with 3D software paired with custom scissors or hair clippers to give customized haircuts	Families 3D print replacement pros-thesis or body parts within homes in cases of accidents on other family members or friends

Narrative for Continuous Growth Future for 3D Printing

It is a warm summer afternoon on the 16th of July, 2030. Henry has just sold his 3D printed home which he designed and printed himself two years ago. He has just been recruited for a new architectural job in India and will be relocating in 3 weeks time. His new employer, an architectural company in Mumbai requires his expertise on 3D print-ed houses.

Over the years, Henry, a 48 year old British architect, has mastered the art of printing houses using 3D printing techniques. His breakthrough research has incorporated the patented works of some intelligent Russian scientists who have found a way to make concrete using oxygen and hydrogen atoms from water or air as raw materials. At the moment, Henry owns a few factories in China which manufactures parts of his designed houses from this innovative new kind of concrete material. He then ships these materials to the locations where his clients need them for printing. He has been in this business for about 3 years now. His business model involves either selling the designed houses as CAD files to his clients or he designs and prints the houses with his unique concrete material at the specified global location. His house was the first fully functional printed house which he designed and erected himself about 6 years ago.

However, these innovations in 3D printing have taken a different turn in China now that air and water have become raw materials. Beijing is beginning to experience the emergence of investors who have shown high interest in buying polluted air, refining it and selling the purified air to the masses. There has been a lot of production and manufacturing in China and Beijing has been a hub for 3D printing for some years now. With these new set of investors, the cost of living in Beijing has increased as people are made to incorporate the increased bills for having purified air and water along with their costs of living. Nonetheless, the situation is a bit different in the USA. Henry had just attended a 3D printing symposium in New-York city where he learned that there have been lots of cases of households having 3D printers which print anything out of any kind of raw material fed into the printers. As a result of an explosion of 3D models all over the internet for free, anything that can be dreamed of can be downloaded and printed by individuals in their homes.3D printers have become extremely common in houses and a lot of useless products have been printed all over the country. Landfills have begun running over and garbage lay carelessly across some streets. Professionals have been called upon to gather and brainstorm on designing the most efficient policies in order to manage the excessive 3D printing done in many cities around the USA.

However, there have been a lot of innovative efforts in the USA through the 3D printing technology. Allianz inc, which is one of the biggest insurance companies in the USA set up a competition last month for the first person or group to print a fully functional housing roof. This roof printing has disrupted the business models of a lot of insurance companies in the USA because a lot of insurance complaints from clients are associated with the roofs of their houses. Nowadays, there are competitions all over the country for the first to print a number of products such as the first printed gas station in California, and the first printed rocket fuels for some complex space exploration jet engines in New Jersey and so on. Henry also met some scientists at the conference who were discussing on the benefits they have achieved from their 3D printer robots sent to Mars. These robots have been made to control the mining of certain rare-earth metals which are transported to the USA and used for the manufacture of a wide range of products. In that same year, they also set up similar robots to handle the 3D printing of some other products under the arctic using the gulf-streams as their sources of energy. These robots communicate with the large 3D printing factories, the size of cruise ships which move around the seas, coordinating different kinds of production activities using diverse 3D printing techniques.

Now with his new job in India, Henry hopes to help in the development of these 3D printing ideas for use in Architecture. He is primarily interested in the use of 3D printers as robot-workers which handle a number of operations in the manufacturing processes which will be involved in his architectural constructions. He also intends to produce some parts of his designs from bio-materials as he has acquired information about the high level of bio-mass generated around villages in India.

4.2.2 Collapse Future for 3D Printing

The Collapse future image highlights a number of probable or possible economic or environmental difficulties which might be encountered as certain driving forces shape the future of 3D printing in 2030. In the face to face interview with Professor Jim Dator (2013) conducted for this master's thesis, he argues that even though the collapse future image might be viewed as popular due to the numerous events depicting different challenges in society presently, a better way to visualize the collapse scenario is through the conception of newer beginnings. He further notes that the collapse scenario highlights a situation whereby older ways of doing things do not produce reasonable results anymore and thus, newer ways should be devised and implemented. The collapse future image does not necessarily highlight the worst-case scenario or image for society, however it portrays a degradation from the current state of a phenomenon or cause to a lower stage in its development (Dator J. , 2009).The following PESTEC table highlights some of those identified future images which portray possible collapses in the future of 3D printing in 2030.

Table 3 PESTEC showing driving forces and trends shaping a Collapse future image for 3D printing in 2030

	FUTURE OF 3D Printing 2030 **Collapse Future Image**

PESTEC				
POLITICAL	Large 3D printers on seas increase territorial issues among nations	Emergence of galactic politics and wars as countries struggle to set up 3D printers for layered mining on other planetary bodies	Difficulty for government to respond through laws to some 3D printed products	Increased violation of 3D printing laws creates complex challenges for policy makers.
ECONOMIC	Economic turmoil as more people lose their jobs to increased use of 3D printers in production.	The emergence of natural-resource economics (businesses buy or collect polluted air in large quantities and sell purified oxygen for daily use by citizens)	Increased additive mining increases the amount of earthquakes in certain regions.	Large 3D printers on seas emit nano-particles and other harmful particulate matter into the seas which destroy and threaten aquatic life over time.
SOCIAL	More non-tested 3D printed products which hurt or kill people e.g. collapse of 3D printed buildings.	Increased hunger as rich people pay more for 3D printed products from biomass.	Increased cases of suffocation and oxygen related diseases due to insufficient supply of purified oxygen for common citizens.	3D printing of dangerous products like bombs, guns etc from anything
TECHNOLOGICAL	More open source technologies result in cheaper prices of sophisticated 3D printers which print full metal guns, bullets and weaponry.	Heightened pressure on available bio-materials as raw material for 3D printing	Advanced identity thefts or classified information breaching increase as sophisticated 3D printers combine codes and pins or passwords into bank cards or security cards in governmental domains	3D printing used to scan and to replicate finger prints which jeopardize security at airports or security check points
ENVIRONMENTAL	Creation of artificial biomass to balance 3D printing demands leads to a bio-catastrophe	Increased pollution levels as 3D printers used industrially emit numerous nano-sized particles in the air thus increasing health problems in many societies.	Numerous particles or molecules emitted from 3D printers react in the atmosphere to cause unprecedented heat flames or wild fires in many societies.	More pressure on natural resources and biodiversity as 3D printed food from biomass becomes very cheap
CITIZEN	Not every citizen will abide to government restrictions on 3D printing	Ethical issues concerning 3D printed food	Burglary and car thefts increase as 3D printers help scan and print keys with ease in society	3D printing used in the replication of prison cell or handcuffs keys increase efficiencies in organized crime as more and more criminals evade authorities and threaten security levels in the society

Narrative for Collapse Future for 3D Printing

Three months after Henry leaves the United Kingdom for his new job at an architectural firm in Mumbai, India, he receives a telephone call from the district police command in Liverpool. His 3D printed house which he sold before he left the United Kingdom has just collapsed killing three pet-dogs which were at home while the owners left for work. He was quite shocked the victims were the pet-dogs but those could have been humans killed as well. He is advised to return to the UK for the stipulated legal proceedings and payment for damages to the victims. In the same month of November, 2030, Henry had been informed about the infringement caused by 3D printing to some aspects of the

British government policies and a reform is being planned. A lot of British citizens have found a way to rise up against some of the government policies through a revolution inspired by the printing of various kinds of ammunitions using 3D printers. Some hand grenades, guns, knives and other dangerous weapons have been created from all kinds of bio-mass materials which are cheap and readily available for the individuals. Explosives have also been made so easily with any kind of material found since the 3D models are readily available on the internet.

With the open-source nature of modern 3D printing technologies and the 3D models for free on the internet, the government of the UK has found it very difficult to control the kind of printing that goes on around the city. Some laws have been put in place controlling who has the right to own a 3D printer and what products must require scrutiny by security forces before being printed but a lot of citizens have failed to abide by these laws. Henry is scared to go back home at this moment to avoid being trapped in the uprising. However he must be present at the legal proceedings for his collapsed house soon to avoid being fined. He is even more worried as the natural resource economics in China has escalated beyond reasonable levels and his factories are among a few which have been threatened to be shut down by the Chinese government. Citizens in Beijing will be staging a revolution soon with dangerous 3D printed weapons and ammunitions.

They will be revolting against the government and businesses alike because the level of hunger has increased tremendously while they struggle to buy basic purified atmospheric oxygen to live. Earlier in January, some Chinese economists devised a way to introduce charges for purified atmospheric oxygen coming into the houses just as regular electricity gets supplied. This is as a result of the increased production activities using special 3D printers which consume massive amounts of electricity and cause tremendous air pollution all over the cities. The pollution and smog levels in the cities have more than quadrupled since the 2014 levels in many Chinese cities. For some time now, the citizens have paid these high taxes attributed to the safe and efficient delivery of clean air into their homes. The purification of the air, being controlled by private businesses even causes more hikes in the tax rates required to be paid for this natural resource. Many hospitals are trolling with cases of suffocation and lung-related illnesses as a result of the inability of patients and their families to afford these high costs for clean air to breathe.

Furthermore, there has been a lot of innovation around the manufacture of products from bio-mass which has further created a huge market and now the elite class and a huge portion of the middle class in China is beginning to pay exorbitant prices for products produced from bio-mass. This practice has placed a lot of pressure on the available agricultural resources which the citizens feed on. Instead of feeding the hungry, a large share of the agricultural produce is therefore directed towards the generation of biomass as a raw material for the production of a number of goods and products which the average citizen cannot afford. This has also increased the amount of urbanization and migration to urban areas by locals of the suburbs and under-developed parts of China. The increased use of 3D printing further makes it challenging to provide jobs for these uneducated migrants and thus massive congestion has been witnessed all over the urban Chinese cities.

The citizens in China are furious and lots of guns, bombs and other ammunitions have been printed as a revolution is being called for among the people. In the efforts to create a balance for the hunger levels by increasing the amount of bio-mass required for production, some Chinese scientists have embarked on the creation on an artificial bio-mass material which could be used solely for the production of the products which these elite consumers require. However, it has just been reported that a bio-catastrophe has been observed along the seas bordering China as this artificial bio-mass material possesses a unique but deadly attribute. The bio-mass material grows speedily in sea water while utilizing the salt for its metabolism. Thus its rate of growth is increasing unusually in the seas and reducing the surface area occupied by the seas swiftly. The scientists are astonished as they never anticipated for such an event and have thus halted all innovation activity to balance the demand on bio-mass manufactured products.

Even worse, Henry has just been informed by the Russian scientists controlling the production of materials in his factory in Beijing on the need for their presence in Russia as requested by the Russian government. Russia, USA, Canada, Germany and Britain through the United Nations resolutions are having a number of disputes as regards whose 3D-printer robots should have specified allocations for the mining of metals and other resources from Mars and some other galactic bodies. The expertise of these scientists is required as the Russian government needs to deeply understand the consequences of certain policies and actions with its 3D-printer robots and factories both on the seas and in space. Just as the galactic politics inspired by 3D printing have increased the disputes among nations, climate change and 3D printing have also formed an alliance of issues which are also heightening disputes among the nations of the Arctic Council.

These disputes have emancipated due to the fact that climate change has caused the melting of a large area of the Arctic ice thus opening up areas for the establishment of massive 3D printers which coordinate all forms of production activities. The distance it takes to transport products from China to Europe and some other parts of Asia has been extremely reduced due to the opening of these areas caused by the melting of the arctic-ice. As a result, China has set up a number of massive 3D printers to coordinate its production and trade activities along with the other Arctic council nations. These nations include Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and the United States.

With the intrusion of another global power such as China, disputes over the arctic territories have heightened which might result into an Arctic war in the near future if these disputes persist. Nonetheless, while the emergence of a revolution caused by the manufacture of products from bio-mass is being observed in China, in some other parts of Asia, 3D printed food from bio-mass is being largely accepted by the population. The level of hunger in these countries have increased over the years and thus bio-mass manufactured food using 3D printers is seen as hope for food security within the region because of its affordable nature by the poor residents. However the manufacture of these foods have come with a price as a lot of pressure have been placed on the forest and agricultural resources in these countries increasing the already high deforestation levels and bio-diversity losses within the region.

4.2.3 Discipline Society Future for 3D printing

The Discipline Society future image portrays a future in which most societal frameworks and processes tend towards the evolution of sustainable societies and a decline of unsustainable growth. Dator notes that the discipline society future images represents a counter reaction to the continuous growth future image in the sense that, people eventually become weary of the continuous evolution of new paradigms of growth on a finite planet and tend to cultivate cognitive patterns of sustainability (Dator J. , 2009). These cognitive conservative patterns within people eventually become the norm thus resulting in the proliferation of more sustainable consumption patterns and the emergence of conservative societal frameworks replacing a continually growing society. In the face to face interview with Professor Jim Dator (2013) conducted for this master's thesis, he noted that these societies could build upon a set of accepted values, principles and norms which people within the societies abide by in order to attain the greatest fulfillment there could be. The following PESTEC table highlights the identified future images which shape the future of 3D printing in 2030 into a Discipline society.

Table 4 PESTEC showing driving forces and trends shaping a Discipline Society future image for 3D printing in 2030

PESTEC	**FUTURE OF 3D PRINTING 2030** **Discipline Society Future Image**			
POLITICAL	Government control promoting 3D printing results in increased job creation	Government control promoting increased personal 3D printing leads to decrease in unsustainable export businesses and production.	Government control of home based and industrial printing enforces reduced material use and thus increases sustainability levels of manufacturing 3D printed products.	Improved urban environmental sustainability strategies as more land gets freed up through the replacement of grocery stores and shops by 3D printers.
ECONOMIC	An end of storage of parts or other home or organizational utilities Wireless electricity transfer and storage in 3D printers; eradication of electricity wires	3D printing to support agriculture in temperate regions 3D printing brings back many jobs lost to foreign factories	Lower prices of goods (even free if individually printed) Lower wages, contracted economies.	Reduced economy of scale; increased economy of closeness Less need to transport goods ad goods can be printed using digital files, more transportation of raw materials.
SOCIAL	Democratized renewable electricity generation within homes as 3D printers are equipped with options to generate solar or wind power for home use.	Increased use of renewable raw materials like insect proteins and algae for food production.	Reduced inequality in terms of resource availability for the poor.	. 3D printing generates more value for labor.
TECHNOLOGICAL	3D printers specialized for the manufacture and customized programming of drones for specialized tasks in the home or for industrial uses for use by consumers or manufacturers, such as aides for random chores or grocery purchases in the home or for industrial uses; they can be grinded, remanufactured and customized for various tasks	Material innovation; finished products made from liquid, wood, insects and so on.	Increased use of 3D printing for repair work in aerospace industries.	Increased production of multipurpose 3D printers for the generation of renewable energy in industries and homes.
ENVIRONMENTAL	3D printers as drones to aid early detection of wildfires in forests areas.	Fabrication using wastes from other global regions with 3D printers.	3D printed constructions to provide quick shelter for victims of natural disasters.	Synthetic 3D printed stems and branches in agriculture which pests feed on to reduce use of pesticides
CUSTOMER	Grind and Reuse culture with 3D printing, more people grind up waste commodities to serve as raw materials for the manufacture of newer products using 3D printers.	Large 3D printers replace grocery stores and shops On demand printing anytime inspires efficient use of land space.	3D pill-printers replace pharmacies or drug stores; end of transportation of medicine or drugs for patients.	Reduced drive to purchase of market products

Narrative for Discipline Society Future for 3D Printing

Henry, the 48 year old British architect currently working in Mumbai is amazed by the ripple effects caused by 3D printing all around the world. In the evening news today, a complex relationship between 3D printing and economic growth and development which varies in different countries is being reported. Nonetheless, he is hopeful that the outcomes of 3D printing in India will become a model for the world to adopt. India has become a much greener country in 2030, thanks to 3D printing. Even with its increased population of 1.6 billion today, the government of India has been proficient in creating anticipatory systems for the potential effects of 3D printing. It has become efficient in controlling the size of its economy through the enforcement of policies that increase or decrease both industrial and private 3D printing when needed.

Economy of scale has been frowned at by the government of India and now in Mumbai, a lot of jobs and manufacturing processes lost to factories abroad in China and other parts of the globe have been brought back to be operated by the people. The government feels there is a need to slow down the rate of unsustainable economic growth and thus export-led growth has been diminished. Now, the citizens in Mumbai produce the resources the city needs whenever needed with the available raw materials ranging from bio-mass to other metals. As a result, market products have become cheap in Mumbai and the wages and salaries of workers have been reduced tremendously. Certain raw materials however need to be purchased depending on the needs of the buyer and the printed product. Some innovations in materials have made it cheaper for people to buy and produce products locally such as materials from insects, liquids, woods and so on. If any product or gadget is needed by the citizens, they can be printed modestly in their homes using any material they can afford and the products usually have considerable strengths for safety in use and durability. The people have also learned to control their individual materialistic lives since they can tailor their product needs according to their priorities and get them printed in their homes cheaply and effectively.

The city of Mumbai now buys waste materials from its neighboring countries and fabricates the waste into raw materials for 3D printing which individuals and small businesses can purchase at affordable costs for their domestic and industrial uses. As a result, there has been a decreased inequality ratio as the availability of resources which was made available only to wealthy businessmen and the elite can now be affordable by creative individuals and locals interested in manufacturing. The people now have more value for their work as they produce unique products and sell them to other prospective buyers at their own determined prices. Each home-use printer also has a system with which the government regulates the amount of electricity used by each household.

Normally people pay higher for more electricity consumption through printing but using the newly designed system, the government has devised a way to monitor those houses where illegal printing of certain dangerous objects or products are being printed around Mumbai. Henry has just learned from his Indian colleagues that numerous gangs have been abducted in Mumbai for excessive use of electricity in the manufacture of guns, bombs, explosives and other illegal weapons in many discrete locations on the outskirts of Mumbai.

Here in Mumbai, interestingly, the industries and corporations have stopped every form of storage of parts or products which have been a significant cause of congestion within the city. As a result, a lot of space has been made available for housing or other production needs. One of such efficiencies in the use of land-spaces has been the replacement of hundreds of pharmacies and shops with large modern 3D printers which print various kinds of pills, products and groceries fast as consumers and patients demand for them. However, residents in Mumbai have raised certain ethical issues concerning 3D-printed foods and what materials they are being printed from. As a result, the government has enforced strict adherence by producers of 3D printed food to have labels on the surfaces of their products detailing the kind of materials and environmental impacts of the materials of these printed food products. More so, the urban city design in Mumbai incorporates the use of modern 3D-printers in homes which serve as electricity storage devices as well as manufacturing and recycling accessories for consumers. This has brought about the eradication of over-head electricity cables all over Mumbai while conserving household income for many families. In addition, there have been free workshops all over the city aiming to instill a grind and re-use culture among residents living in Mumbai. People can grind up their furniture or accessories which are no longer in use into materials which can be employed for printing and producing newer products for use in their homes. In this manner, the amount of waste that goes into the landfills in Mumbai has decreased tremendously.

Also significant in the innovative activities of Mumbai is its method of protecting the environment from agricultural pesticides. A new synthetic material made by 3D printing has been used to coat the stems and branches of the agricultural produce being grown on the farms in Mumbai. This has reduced the need to use harmful environmentally degrading pesticides in efforts to control pests since the pests can feed on this outer coated membrane while the agricultural products grow in a healthy fashion internally. Mumbai Airlines has also become a leader in the airline industry thanks to its frugal business model which employs the repair of aeronautic parts using 3D printing. The airline service generates massive revenue in savings by digitally scanning damages, acquiring a digital model and fixing the exact location of the damages using the required materials needed for the purpose instead of overhauling the entire damaged parts as has been done over the years.

Henry is beginning to observe a variety of business opportunities for 3D printing in India. One of such businesses which inspire him comes from the city’s use of 3D-printer drones in detecting wildfires early before they become fully blown-out forest fires. As a result of the space generated from the different applications of 3D printing in the city, Mumbai has seen the flourishing of certain forest areas. However, forest fires have been a challenge for some time now. The last forest fires five months ago resulted in the destruction of many homes within those forest regions and many citizens were displaced from their homes as a result. 3D printing played a huge role in quickly printing temporary homes using different cheap raw materials from the wreckage for these displaced citizens while the government focused on ways to curb the further outbreak of fires.

However an efficient control system for the forest fires inspired by liquid 3D printing and artificial intelligence has been put in place. Two sets of 3D-printer drones have been used significantly which communicate to each other in the event of emerging forest fires. Using the atmospheric oxygen and hydrogen molecules in the air, these 3D printer drones can print basic water molecules which can extinguish little pockets of fire. The first set of drones serve as detectors which transmit signals to the other set of drones called extinguishers. The extinguishers print as much needed water for extinguishing these forest fires while they are still developing. In the event of a larger fire size, the drones send signals to the fire service for professional forest fire extinguishing. With the aid of this automation, the government has prepared an efficient system to control these escalating forest fires while still in their developmental stages.

4.2.4 Transformation Society Future for 3D printing

The Transformation Society future image reflects a rebirth process of the fundamental frameworks of societies totally different from what individuals have once witnessed. In addition to this perspective of the transformation society, this future image focuses on those paradigm shifts characterized by individualized effects of imminent technologies and the fragmentation which could arise from them (Dator J. , 1981a). Dator (2009) further asserts that the transformational future highlights the transformative power of technological advancement resulting into a society with newer notions for humanity such as a likely transformational post-human and trans-human nature on an artificial earth. The following PESTEC table represents the identified future images in this master's thesis which are likely to plunge the future of 3D printing in 2030 into the Transformational Society.

Table 5 PESTEC showing driving forces and trends shaping a Transformation Society future image for 3D printing in 2030

PESTEC	FUTURE OF 3D PRINTING 2030 Transformation Society Future Image			
POLITICAL	Large 3D printers on seas also equipped with war machinery and weaponry increase territorial issues among nations	Wars in space and on other planets such as mars using 3D printer robots.	Difficulty for government to respond through laws to some 3D printed products.	Increased violation of 3D printing laws creates complex challenges for policy makers.
ECONOMIC	The emergence of Additive Mining, using 3D printers to mine, and manufacture products directly with raw materials at mine sites.	3D printers as leverage resources or workers in factories, companies combine the services of 3D printer robots and human staff as major sources of manpower	Advertising with foods or liquid products, 3D printers print foods and other liquid products in the shape of company logos, and other brand identities.	Shipment of cheap powdered foods made from algae or insect protein to nations affected by natural disasters which can be printed into different combination of food products
SOCIAL	Combined use of artificial intelligence and 3D printer robotization to take entire lectures for practical courses in schools and colleges,3D printers teach autonomously while students print on the same printers	Wide scale application of 3D printers and robots in educational systems	3D printer robots as laboratory assistants for students in schools and colleges.	Children download, customize and print their own toys at home from any kind of material at their disposal.
TECHNOLOGICAL	3D printers which use lasers to heat food or other food products.	Teleportation of objects using 3D printers as a new transportation mode	Oxygen, hydrogen and other atoms in water or air as raw materials for 3D printed products like concrete.	3D food printers in space to provide food for astronauts.
ENVIRONMENTAL	An end to the use of water for producing food in some societies suffering from extreme water shortages when food products are printed into varieties of combinations, shapes and tastes using powdery form of foods made from cheap organic sources.	3D printers as drones to aid early detection of wildfires in forests areas.	Lightweight fully 3D printed airplanes	3D printers grind up and print newer 3D printers thus managing resources for production or manufacture of products, foods and so on.

CITIZEN	Household printers for domestic printing; products as algorithms. Increased trade between algorithm societies, trading in algorithms instead of real products	3D thinking in the real world such as 3D writing, 3D drawing and 3D painting inspired by 3D printing.	Revival of old and extinct brands or products using 3D printers. Hyper-individuality[3] inspires unique 3D printed jewelry such as necklaces shaped like maps of nations or other memorable artifacts	New materials for 3D printed clothes e.g. materials which do not need ironing, materials from oxygen atoms etc

Narrative for Transformation Society Future for 3D Printing

It is a few days to the Christmas holidays in 2030 and most schools all over the globe are getting prepared for final examinations in order to wrap up their academic sessions. Henry, a British architect who has just recently started working in Mumbai India, receives a call to visit Thailand for another 3D printing conference in a week's time. On arriving Bangkok on the 29th of December, 2030, at the school where the conference is to be held, he realizes that some researchers are working with all kinds of 3D-printed robots in the industrial design studio as they prepare for a presentation. The studio is equipped with massive 3D printers which print prototypes fast for the researchers to study. They also have numerous models of robots which they print and assemble.

These robots assist them in automating their tasks while they study the intricacies of their designs. Even further, he observes that the medical researchers in the bio-medical imaging lab have been printing different kinds of bones and tissues for their presentation. These researchers do not only print these models, but they also fix the mechanical faults while the printers are in use. Henry observes the shift from the passion of tasks related to information technology towards mechanical engineering as most of the researchers now perform basic mechanical engineering tasks in their varied fields of expertise. As the conference begins with its first keynote speaker who is a Kenyan entrepreneur, the Kenyan gives his account on his use of 3D printers as workers in his groundnut factory. Seventy percent of his workforce comprises of 3D-printer robots while the rest are humans. He claims his production output is much more efficient with these machines handling complex processing of the groundnut production while the humans control the management of these 3D printer robots and their software.

Henry realizes further that 3D printing still has some great transformative attributes in other countries in the world when a Singaporean scientist comes up for his presentation. The Asian continent has been transformed significantly in 2030. In Singapore, scientists have been able to build entire cities using 3D-printed concrete made from a combination of carbon-dioxide in the atmosphere and nitrogen atoms as well. Not only con-

[3]Hyperindividuality refers to an extreme form of an individualized lifestyle with total disregard to societal norms or values.

crete has been produced but these raw materials have been used to create unique fabrics in Singapore for basic clothing. Some of these fabrics do not need washing or ironing and the ways people associate with dressing in Singapore has changed dramatically.

Due to the availability of these raw gaseous materials for purchase by the Singaporean citizens, hyper-individuality sets in as people have been observed to print a wide variety of unique objects and products all over the country for use in their everyday life. Nowadays, every Singaporean defines their lifestyle in whichever way they want very easily. They do not need to buy already produced goods but create their own products which has become a norm. They recreate extinct brands or products or even combine these brands with modern products and print them out using this combination of gaseous raw materials to create very unique everyday products for use in their homes or places of work. Even further, he notes that his nation has been able to transfer a fully functional food printer to the Singaporean space station in mars which provides food readily for its astronauts. The scientist notes that ongoing work is in process which can help teleport instruments, objects and certain products from earth to Mars for its astronauts as well using advanced quantum teleportation network connections of 3D printers.

5 DISCUSSION AND CONCLUSION

Analyzing the trends, weak-signals and the future images identified and narrated in this master's thesis as future elements likely to shape the future of 3D printing in 2030, it becomes evident that structural changes to present processes in society require early anticipatory efforts. Some significant future images which call for such early anticipatory efforts as documented in the PESTEC tables are related to the extreme uses of 3D printing for local wars and violence in society. 3D printing might develop into an arming technology exploited for its convenience in creating dangerous weaponry thus threatening the peace in society which could further degenerate into terrorism and radicalism.

Furthermore, an end to storage which is a conservative discourse needed in many materialist societies today can be encouraged by 3D printing most especially the idea of imbibing a grind and re-use culture among citizens. Citizens can be encouraged to reduce their materialist consumption patterns by re-using or customizing commodities as they desire. It further poses an opportunity as well as a threat in the sense that consumers might develop an attitude of printing virtually anything from anything. Thus by so doing, more innovations in material use by citizens could further decrease their materialist consumption patterns since they will be empowered to print commodities with whichever materials can be afforded such as waste materials. This opportunity can also be seen from the transformative future in which concrete could be produced from oxygen and hydrogen molecules in the air. However, suffocation in some societies due to the emergence of natural-resource economics was the resulting threat from such innovative activities.

In addition, the idea of 3D-printed food and 3D printing's support to agriculture is indeed a significant opportunity. If such an initiative is effectively achieved, it could help facilitate food security strategies in society. However, ethical arguments as regards 3D-printed foods are likely to arise. It might be logical to think that consumers might feel uncomfortable consuming foods such as 3D-printed meat from bio-materials. However, it might be perceived as a disruptive innovation for space explorers to have food printers in space while on missions in the galaxies. Similarly, the fact that tools and mechanical parts can be replaced in space by astronauts, manufacturers and individuals using 3D printing is also significant. This reduces the need to continuously buy new parts or store back-up parts in cases of break-down of machinery, tools or parts of mechanical systems.

With a more nuanced view to conservatism as regards the end of storage, the replacement of grocery stores or shops or even pharmacies in many urban cities with 3D printers might provide solutions to congestion and urban sprawls in urban cities within society as more space for construction of homes might be made available. However, there might an emergence of arguments on the increased energy usage by these massive printers. The combination of wireless electricity storage and transfer among 3D printers is such a radical opportunity for 3D printing. The technology could evolve into a paradigm which facilitates the eradication of wires from urban settlements and cities .In other words, 3D printers could be perceived to serve a dual function of electricity storage for homes and a recycling or manufacturing device in many homes.

Based essentially on the assumption that negligible investment efforts into 3D printing have generated significant economic impacts, the nature of the technology’s disruption seems overwhelming from a futures perspective. Some innovations “hardly attain the reputation of inventions even with heavy financing efforts” (Albright, 2002, p. 445). However, as regards 3D printing, such an assumption could be regarded as inapplicable. Thus, it is highly essential for governmental agencies, organizations, businesses and individuals to develop long-term foresight systems which will ease the identification of critical weak-signals and discontinuities in present trends which might likely shape the future of 3D printing as it evolves over time. Despite the fact that numerous futures for 3D printing seem plausible in 2030, it is important to be conscious of a number of present impediments which might decelerate the rate of progress in the advancement of the technology’s global adoption. Furthermore, ongoing research also reveals possible avenues for possible economic impact. The following sub-chapters discuss these observed impediments and likely avenues for economic impact by 3D printing in 2030.

5.1 Outdated CAD Software

One constraint to the global adoption of 3D printing today is associated with the existing CAD (Computer Aided Design) software used in designing 3D printable products. Hague and Reeves (2013) note that current brands of software employed in the design of these products were originally intended for creating 3D geometries and developing conventional manufacturing operations. The traditional CAD software had design limitations of their own which included the inability to render complex geometric forms which numerous additive manufacturing processes can generate. More so, these CAD systems were incapable of generating complex shapes. The shapes they could produce were particularly notable for their incoherence with precise mathematical geometries. Thus, it seems that the current advances in 3D printing processes possess unique abilities to create more complex geometries than those which the traditional CAD software is capable of (Hague & Reeves, 2013). This discrepancy creates a disparity since 3D printing largely depends on CAD renditions of objects and products before fabrication can be executed.

Nonetheless, innovative activity aimed at creating a solution to this issue is currently ongoing. A unique set of CAD software is currently under development and could be strictly employed for 3D scanning and other additive manufacturing purposes. With the development of smart-phone applications and innovative efforts such as with the Xbox Kinect produced by Microsoft presently, generating 3D scans of products or objects can be achieved with minimal efforts today (McKinsey Global Institute, 2013). In 2030, similar but much more efficient innovative efforts might emerge from advances in artificial intelligence, nano-technology and the combination of smart products with the internet of things.

5.2 Incomplete Panacea for Sustainability Issues

Another significant impediment to the global adoption of 3D printing stems from the perspective that the technology does not present a highly efficient panacea for sustainability issues in business and manufacturing as a whole. This impediment relates largely to inefficiencies exhibited by the different metals and polymers used as raw materials for 3D printing presently. One of the hypes on the technology in the media is its revolutionary capability to shorten the supply chain of products thus allowing for more local manufacture in different regions of the world. If completely true, 3D printing is likely to generate massive benefits for society and businesses.

Currently, the materials required to carry out 3D printing of products are limited to powdered or liquefied polymers of metals through laser or jetting methods. Therefore, an enormous amount of energy is required to melt or liquefy these materials . Even further, most of the polymer powder-based materials still lack potential for recycling. As a result, it might be difficult to assume that 3D printing will guarantee the high environmental sustainability and corporate responsibility standards required by most businesses and manufacturing processes today. One significant example has been observed by researchers at the EADS, the European Aerospace Consortium. According to the researchers, about 90% of raw material (powdered or liquefied aluminium or titanium) cut away is usually regarded as unacceptable for the manufacture of similar aeronautic parts. Instead of recycling the unused aluminium material, these so-called waste materials are employed in the fabrication of other low value products. In a similar fashion, titanium powder requires just a fraction of the raw chunk of material to fabricate aeronautic parts with desired rigidity standards (Hague & Reeves, 2013).

In 2030, material innovations could reduce the waste generated from present raw materials for 3D printing in society. With a combination of increased afforestation initiatives and the emergence of innovative materials such as gaseous raw materials employed in the production of building materials such as concrete, combined with nano-technology in such a way that wastes are continuously used as raw materials, a more conservative approach to counter the amount of waste involved in this kind of production can be carried out. Threats are likely to emerge from such innovative approaches however, it can be considered as a plausible future image for a conservative approach to the waste generated in present 3D printing processes in society today.

5.3 Possible Intellectual Property Disputes

Issues concerning the management and control of intellectual property play a huge role in shaping the kind of futures that will likely evolve in the 3D printing paradigm as the technology advances. Intellectual property issues have been observed to hinder the level of involvement in 3D printing by major players in economy and businesses. Since 3D printing seems to be shifting towards a more open-source platform, poor management of intellectual property will most likely lead to heightened complexities in the technology's legal debates. In simplified terms, the future images narrated above deem it apparent that an explosion of CAD files of numerous products all over the digital world would likely result in easier ways to copy, duplicate and forge designs and brands of businesses or individuals. This excessive availability of CAD files could likely result in difficulties in deciphering cases of irresponsibility associated with the level of safety for 3D printed products since the barriers between the designer, printer and additive manufacturer becomes completely obscured.

In 2030, it is likely that the barrier between the stakeholders involved in 3D printing will be increasingly obscured due to advances in technology. The rise of a different kind of lawyer is thus highly essential to control the level of disputes which could arise from copyrights and intellectual property infringements due to 3D printing.

5.4 Potential Future Economic Impact

It is assumed that accuracies in forecasts improve their significance in our complex globalized world. However, the utilization of "long range technological forecasts is particularly instrumental in efforts to maintain resilience to disruptive social change or economic development by policy makers and governments" (Albright, 2002, p. 443). Despite the fact that this research focuses on the future of 3D printing in 2030, it is crucial to avoid neglecting disruptive activity five years earlier from the target year since it corresponds to the path along the technology's roadmap. The McKinsey global institute's forecast for this emerging technology provides crucial estimates on the kind of futures which might evolve for 3D printing as it advances over time. The technology is forecasted to have an enormous potential to generate economic impact of up to $230 billion to $550 billion annually in a number of sized application areas by 2025 (McKinsey Global Institute, 2013). The application areas in which economic impact is most likely to occur are in consumer printing, direct manufacturing, tool and mold manufacturing.

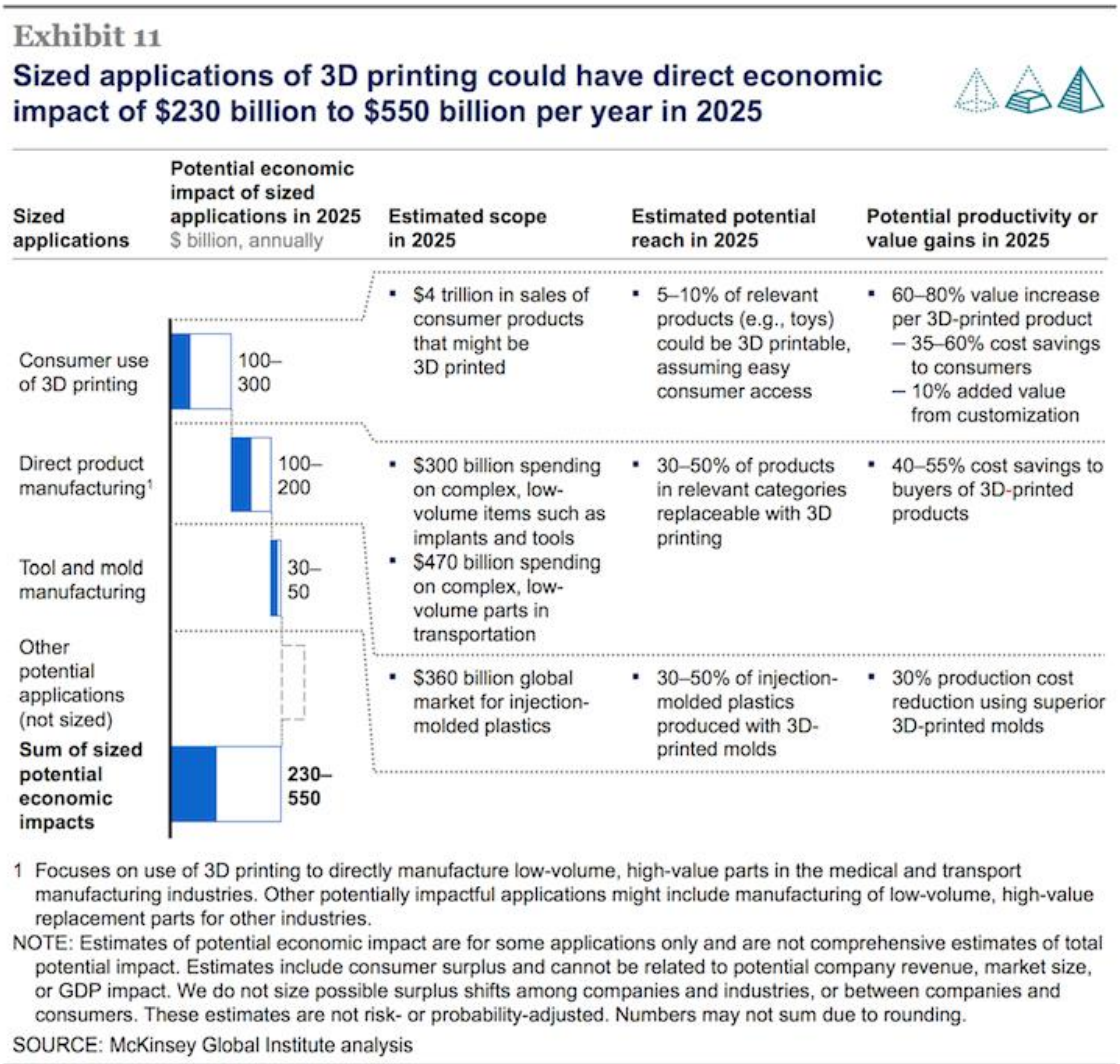

Figure 7 3D printing potential economic impact 2025

(McKinsey Global Institute, 2013)

Consumer printing is expected to accrue an annual economic impact of $100 billion to $300 billion dollars by 2025 (McKinsey Global Institute, 2013). This is partly due to the fact that the proliferation of open-source 3D printing projects and the expiration of the technology's patents seem to be paving the way for heightened use of 3D printing by consumers. Savings attributed to home 3D printing from the retail perspective do not only stem from the elimination of wholesale and retail distribution, but also from reduced cost of designs and advertisement efforts embedded in the products' original prices. It is plausible that most consumers will have access to 3D printing in 2030. Access to 3D printing could be in the form of printer ownerships, printing products at a local store, post office, library or the ability to buy 3D printed products from online platforms. In 2030, 3D printing could have substantial impact on certain consumer goods such as footwear, toys, fashion accessories, jewelry and basic plastic or ceramic furniture. Despite current high material costs for 3D printing, the value of mass customization could likely generate significant economic and environmental impacts as well. This could further encourage more lifecycle-thinking among consumers in a likely approaching neo-growth society.

As regards direct, tool and mold manufacturing, 3D printing will stand out with its unique capability of producing highly complex and customizable products by 2025 (McKinsey Global Institute, 2013) even though the cost advantage of traditional subtractive manufacturing over additive manufacturing will remain as high as it is presently. The McKinsey report further forecasts the likelihood for 3D printing to accrue an annual economic impact of $100 billion to $200 billion in the direct manufacture of products. Direct manufacturing entails the complete production of finished goods with the aid of 3D printing. According to the analysis in the PESTEC tables for this thesis, some potential products which could generate economic impact from direct manufacturing in 2030 include highly complex, low volume products such as medical implants and complex mechanical or aeronautic engine components. In health-care, the ability to directly print kidneys, ears, livers, dental implants, prosthesis and other parts of the human body could provide solutions to shortages of these parts in surgical operations.

5.5 Conclusion

The seven interviews and horizon scan conducted for the development of the four generic future images narrated in this master's thesis highlight important areas of society which could likely be transformed through 3D printing. However, a number of challenges were encountered in efforts to develop robust foresight as regards the future of 3D printing with such a small number of interviewees and the four generic future images structure. One challenge was the inability for the respondents to reply to requests for updated versions of their interviews.

While the generic futures were being developed, it was observed that certain clarifications on the ideas of some interviewees were needed. However, most of the interviewees had difficulties in trying to stretch their thinking further after disbursing their initial future ideas for 3D printing. Some of the interviewees regarded the idea of filling in more ideas into the PESTEC tables as inappropriate as they believed it would mean conducting the research for the master's thesis themselves instead of being the sole task of the thesis author. The fact that the number of interviews was limited increased the challenges in developing a more robust variety of ideas since a higher number of interviewees would have resulted in an increased probability of getting more valuable updates to interviews or more interviewees willing to add more future ideas to the PESTEC tables.

Another challenge which was encountered while employing the four generic futures structure correlates with Dator's assumption that "some future images are usually observed to be overlapping among two or more of the futures archetypes, while others fit perfectly to one of the four generic future archetypes" (Dator J. , 2009, p. 6) . A number of future images generated for 3D printing in this thesis could be perceived as very important elements in two or more generic future archetypes. There was the challenge of being original, consistent but unique in each of the future narratives while avoiding repetition or overlapping of ideas from other narratives. This challenge also stemmed from the fact that similar ideas for 3D printing existed both among the insights given by the interviewees and the horizon scan. As a result of the emerging nature of the 3D printing technology, most ideas regarding plausible disruptions to society seemed to be related in numerous ways. Thus, categorizing the generated futures images accordingly in a clear manner within each of the four generic future archetypes presented a slight challenge.

Nonetheless, while analyzing the aggregated futures images according the individual futures archetypes in the PESTEC tables, it can be observed that the continuous growth future image highlights certain consumption and growth patterns which might not be sustainable on the long-term. The collapse future on the other hand highlights important areas of society in which the values promoting an end of the old ways of doing things should be encouraged. If current trends persist, 3D printing could cause massive collapses in many sectors of society and thus the collapse future should be put into careful consideration. On the other hand, the discipline and transformational society future images seem to reflect the outcomes of conservative and transformed paradigms of society respectively. In other words, if a collapse future image is avoided, society could likely observe the emergence of a conservative discipline society based essentially on defined values, norms and beliefs in varied societal contexts. The case is similar for the transformative society although a bit more extreme. It highlights a complete transformation through 3D printing of the techno-economic structure of society infused with the emergence of post-human and trans-human discourses. 3D printing can influence such radical transformations to society and humanity which could either present more threats or increased opportunities.

While 3D printing appears to be presently influencing the proliferation of a prosumer sub-culture in the contemporary society, it might not be surprising to observe the emergence of more maker community crowd-sourcing activities and collaborative digital ecosystems in 2030. Similar to the present complex software and web-development ecosystems, it is likely that 3D printing will achieve a similar feat through advances in open-source projects which will dramatically increase the number of people interested in the maker sub-culture. In order for businesses to thrive in this maker paradigm, anticipatory efforts on the part of entrepreneurs will therefore be necessary in fashioning out suitable business models which will create more added values to products than those printed at home by consumers. In addition, it would be beneficial for manufacturers to deeply exploit the intricate values in employing the use of 3D printing for rapid prototyping in order to maintain their competitive edges when 3D printing becomes globally viable for direct manufacturing.

Other industries such as the logistics industries will also need to devise creative business ventures which will retain their competitive advantages as 3D printing might likely disrupt the shipping of goods and services in very dramatic ways. An insight from the future images in the transformational future PESTEC tables suggests the transportation of algorithms instead of goods and services in 2030. This would require a disruption in the present business models of the logistics industry in order to stay ahead of such a transformative change. Furthermore, a major challenge for policy makers will encompass the reformulation and design of more effective regulatory policies for 3D-printed goods. These regulatory policies will be required to instigate accurate processes for the approval of materials for 3D printing. More so, there is the greater challenge of designing these regulatory policies in such a way that expected economic impacts will be achieved in economies which desire to encourage innovation and growth. In other words, policy makers will be required to develop robust long-term strategies which will guarantee the achievement of efficient intellectual property control systems while considering implications for security and legal concerns in society as well as sustainable growth and development.

3D printing is already a reality and is currently inducing dramatic changes in various sectors of society presently. However, in order for society to thrive most effectively in the event of global adoption of the technology, efficient foresight systems and policy reformulations as well as attitudes towards continuous adaptive anticipation of discontinuous change will constitute some of the most essential efforts required to keep the advancement of the technology from evolving into undesirable dystopic images of the future for society in 2030.

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8 APPENDICES

8.1 Questionnaire Document

Kwazema Martins.
Masters degree programme Futures Studies,
Turku School of Economics,
University of Turku.
PREQUESTIONNAIRE FOR MASTER'S THESIS
TITLE: EXPLORING 3D PRINTING 2030

Dear Respondent,
This pre-questionnaire has been prepared in an unstructured exploratory manner. It is a constituent element of my masters thesis research process. This research is a futures research which aims to navigate uncertainty through the next 17 years. It aims at creating future images for a world influenced extensively by 3D printing. Along with this pre-questionnaire is a presentation I have created on additive manufacturing which aims to create a clearer picture of additive manufacturing to inspire the minds and thoughts of the respondents for the interview process and data collection stages of this master's thesis.
All answers given to the questions will be recorded with a voice recorder or a skype interview depending on the platform of convenience for the respondents .The level of anonymity will be absolutely discrete. The data acquired from the interview sessions will be analyzed and reported without the identities of the respondents. However, in situations where the research process needs to reference back to the respondents for a number of responses , permission will be taken from the respondents to verify the need for any level of anonymity required. These set of questions have been prepared as a guide for the direction of the questions I aim to answer in my master's thesis. Respondents are encouraged to answer all questions however more emphasis can be given to more inspiring or knowledgeable questions. The questions are provided below:
1. Where do you see 3D printing going in the next 17 years?
2. What strengths do you think 3D printing might have in society in 2030?
3. What weaknesses do you think 3D printing might have in society in 2030?
4. What are your opinions on the opportunities from 3D printing for society in 2030?
5. What are your opinions on the threats from 3D printing for society in 2030?
6. In terms of 3D printing, what views do you have for a Continuous growth future image in 2030 ?

7. In terms of 3D printing, what views do you have for a Collapse world future image in 2030?
8. In terms of 3D printing, what views do you have for a Discipline Society future image in 2030?
9. In terms of 3D printing, what views do you have for a Transformation Society future image in 2030?

Please, I will be highly appreciative if you take some time to think ahead of those questions and contact me to let me know when it will be suitable for you to have skype interview. The interview has been structured to be about 90 minutes long at the maximum. However, more insights are welcome which could possible extend the intended time-frame. Further, please if you have any questions, don't hesitate to contact me.
My contact details are as follows:
Email: bigkwazz@yahoo.com
Phone: +358417079684
Thanks for your co-operation and if interested, I will be most delighted to hand over a copy of the results of this research to you. I hope to have a positive response from you soon.
Yours faithfully
Kwazema Martins.

8.2 Interview Transcript by Olli Hietanen

Some future trends which will shape the future of 3D printing are robotization, automation, industrial ecology, closed connection, wireless electricity, artificial intelligence and artificially intelligent products, product smartness, internet of things, personalization, wireless products and an emergence of diverse bio-materials. A significant weak-signal also includes the "why-not'' instinct. With advances in 3D printing in the future, a lot of enthusiasts, scientists and practitioners will keep asking why a number of items or innovations cannot be implemented. This will thus spark a heightened pace in the technological advancement of the technology.

- There will a lot of 3D printing in 2030.3D printers will be as common as microwaves in present day homes.3D printers will have advanced for use in home construction . There will be an end of storage for everything from parts to utilities in organizations as massive printing will be done in business organizations.

- The Marine industry will experience a huge impact. There will be the need to not only produce boats and ships but also factories, towns, cities, bridges. Factories will be built on the seas from bio-materials and the energy drawn from the seas. The emergence of printers the size of cruise ships will be observed in the marine industries and the industry will benefit a lot from these large-sized printers.

- More so, home printers for domestic printing such as medicines, breads foods etc will be prevalent. Most products will be algorithms. When making diagnosis or appointments with the medical practitioners, treatment and medicines will be sent as algorithms which can then be printed by users. There will be more transfer of algorithms instead of actual products such as bread algorithms, chocolate algorithms….all algorithms. This will spark the rise of the Algorithm society. The challenge for the algorithm society will not be the printer itself but for raw materials. There will be tougher race for raw materials among different algorithm societies.

- By 2030, it will be more expensive to grow food in the cold and less densely populated countries like Finland while it will be a lot cheaper in many other countries. There isn't a big critical mass in Finland and short summer time. Therefore, 3D printing will benefit these countries if they have a high technological level or expertise. Knowledge societies will not need agriculture. Agriculture will be redefined by 3D printing in advanced technological countries. There will be more robotization and automation in the future. There will also be more industrial ecology on a global level. This industrial ecology could be seen as a closed circle of enterprises. All enterprises use the wastes coming from all other enterprises in a closed system. In other words, different countries will be trading different kinds of wastes and 3d printers will be used to quickly and efficiently fabricate all kinds of products to be used in this global industrial ecology paradigm. Different devices will be creating and storing energy as well in a connected closed enterprise like this and 3D printing has the prospect of being a major player in the manufacturing and printing of sensors and objects to be exploited in industrial ecology.

- 3D printing will aid ubiquitous computing as packages and sensors will easily recognize people more and more. Electricity will be sent like radio waves through 3D printed objects. Printers could manufacture machines that act as a source of storage and collection of wireless electricity. A home 3D printer could collect and store some electricity from the central grid bringing about the eradication of electricity wires. Printers will also replace present day shops. There will be no more shops for shoes, clothes and all; a large empty printing room will represent a shop which prints what the people need on demand any-time.

- The present day understanding of 3D printing will be transformed dramatically. The algorithms could be viewed as seeds. There will be machines which have these seeds for different products using bio-materials and bio-printers. 3D printing will adopt the agricultural principle like an apple tree. A stick in the earth in the mud manufactures apples from mud and sand and seeds. If it is possible, why can't we adopt 3D printers as trees and create the environment for the maturation of the algorithmic seeds and transform the seeds to products in a totally new system of innovation as well.

- Materials might be a challenge in the medical industry but skin-printing in health-care will be prevalent. New hearts, kidneys, livers, eyes and so on will also be printed fast and efficiently when needed. The medical industry will spearhead a lot of innovative activity using 3D printing.

- A bio-age could arise whereby there will be the emergence of an abundance of bio-materials. Wood could be explored to be liquefied or brought to a gaseous state. So from liquid wood, lots of products will be made that look like our modern products today. Also a lot of products will be made from insects and other smaller species, so a lot of plastics and glass will be made but the raw materials could be from wood. More so, there could be new metals from asteroids and mars. 3D printers as mines will be erected in the moons and asteroids for the extracting of rare earth metals. Teleportation could reduce resource costs of transporting certain materials to and fro earth from the galaxies.

- Also, under the Arctic is another region of possibility for factories which could be set up for 3D printing. Energy stations could be made from gulf streams under the ice, translating wind power technology into water-wave power technology under the arctic ice. Instead of wind, we have water-waves which produce energy needed for manufacturing purposes.

- There will be ethical considerations of products especially edible 3D printed products made from organic sources. There will also be the threat of using biomass materials as raw material for manufacturing. Biomass is created from biomaterials such as insects, grasses, animal waste etc. In a bio-age era, there will be too much pressure on the available bio-materials if all or most printers manufacture meaningful products from bio-mass, where will the world get the bio-materials which will replenish the bio-mass as raw material for manufacturing?

- Secondly, what shall the world feed on when massive quantities of bio-materials are being used up to create bio-mass for manufacturing? There could also be the threat of diverting bio-mass towards the manufacturing of non-food items. Rich people in their luxurious lifestyles will be willing to pay very high prices for shoes instead of food, leaving the poor without food. There might be more hungry people in the world as a result of using these natural resources for the manufacture of products.

- The other side of the coin is that bio-mass could be so cheap and if food can be produced from any kind of bio-mass, a minor portion of people will refuse to eat such produced foods. However a larger portion of the people will not care anymore overtime and could thus lead to a path towards the elimination of global hunger. But in this way, we will be using too much of the forests and natural resources. Bio-diversity will be lost heavily if everything can be printed from bio-materials and bio-mass.

- In the scramble to create bio-mass for printing food or edible materials, a higher need for artificial bio-mass might arise causing the emergence of some bio-catastrophe.

- Also it could result in a different form of natural resource economics. When a lot of our natural resources is used for 3D printing, a rise of natural resource business ventures which would own rights to trade different natural resources might arise. Atmospheric oxygen and so on might be owned and traded as commodities for private businesses and investors. Due to the over-productive nature of some cities in manufacturing, a highly polluted and densely populated city might be victim to harsh natural resource economics. One analogy is that people might have to buy oxygen to survive and live in the world.

8.3 Interview Transcript by Thomas Frey

- A race for "firsts" might be a weak-signal which will influence the emergence of more radical 3D printing techniques. The names of the innovators of these first-time achievers will be in the history books and people will want to get such glorified achievements or prices. Typical examples are the first printed gas station, the first printed store and so on. With enough publicity such as through magazine headlines and innovation competitions, this race for firsts could spike up the race for innovation on a global level. Insurance companies over the years have had a majority of clients' house insurance claims on the roofs of their houses. If some big insurance company orchestrates and sponsors an innovation competition for the first person to print the first replacement roof, then these competitions will spike up innovation in 3D printing. This could further disrupt the insurance companies' business models as well. Competitions will transform some aspects of 3D printing as there will be more prices and more attention to these competitions in a continuous cycle.

- The emergence of the 3D pill-printer technology which could replace a pharmacy or a drug-store will definitely experience strong push-back from the pharmaceutical industry because of the disruption to their business models it might generate. However, 3D printing could eliminate the transportation of medicines. Developing nations will benefit extensively from this innovation as pills for a number of ailments will be printed readily on site no matter the number of patients in need of these pills. The next step after printing pharmaceutical drugs will be conducting medical tests on patients to attain the right pill combinations for the particular person. Right now, the precision to automatically adjust to the medical dosages of patients is not available. Having a 3D pill printer which automatically adjusts and prints the specified dosages of the pills for specific patients opens a new area of research.

- Visiting a clothing store could entail an automatic registration of individuals' body measurements, sizes, choices or preferences and perfectly print out the clothes on the spot in less than five minutes. Today, 3D printing materials for clothes are bad, and the clothes come in several forms of plastic materials and so on, but it will change and type of fabrics will change for the clothes such as materials that don't need ironing, materials that do not need water for washing etc. Shoes can also be printed to fit all the idiosyncrasies of your feet, so the difficulty for finding the right sizes for shoes will be eradicated.

- Printing of replacement parts by individuals or organizations might eliminate all the tariffs, import-export fees, duty charges and so on at country borders or ports of entry. It will also eliminate the time needed to wait, so people get replacement parts instantly. 3D printing makes sense for about 150 units of products. However, for volumes exceeding 150 units, a combination of additive and subtractive manufacturing techniques will be done. As Chris Anderson notes, the physical world is 6 times the size of the digital world, so 3D printing will be much larger than the internet.

- Food printers have been manufacturing foods such as desserts, creams and some chocolates. In the future, a colony on mars will be set and the food printers can provide food on mars for the astronauts. An apple for example could be reprinted into a similar apple using the same apple materials, with stems and leaves edible because they are all made from apples. In the food printer, other kinds of flavors can be added to the apple you intend to eat. Food processing companies for example might be able to print a bottle, then print the wine that goes into the bottle or a printed can, and then printed soup which goes into the can, all 3d printed.

- 3D printing eliminates all kinds of jobs, but creates new jobs too. An example is the fact that though a high number of jobs were eliminated by the internet, it created another 2.6 million jobs approximately in startup companies. Training academies will be on the rise as well as training centers because people will need to adjust their skills rapidly. Another opportunity will be the elimination of forest fires. With the use 3D printers as drones which use infrared technology and infrared sensors, forest fires can be detected when they are still very small. These drones then send signals to another 3D printed fire extinguisher drone which shuts off the fires before they start spreading. Today we don’t have the capability to detect forest fires while they are still small. 3D printer drones will be a huge market for not just the forest fires, but for other industries. There will be a lot of small 3D printer drones either solar-powered or otherwise flying around performing different duties in societies such as mail or item deliveries.

- There has been a long war between atoms and bits. Bits composed the bulk of matter in the digital world while atoms composed the bulk in the physical world. Everything in the digital world was more appealing and inviting and lots of jobs were created in that area. Lots of talents were sucked from the physical world to the digital world. But 3D printing will likely bring this shift back thus bringing back that appeal which was taken by the digital world to the individuals in the physical world. For decades now, it has been an honorable achievement to become a computer scientist. However, in the 3D printing era, it will be equally honorable to want to become a mechanical engineer. A combination of the DIY movement with the race for firsts and competitions could be strong driving forces which could massively influence the proliferation of 3D printing.

- In the future, if you get tired of your house, you just grind it up and reprint it with the material you have got from the grinded bulk. 3D printing will promote a grind and re-use culture.

- Usually, money is made either by leveraging products or leveraging people. A lot of money can be made from the sales of manufactured products. Even more so, a lot of money can be made through higher number of hours people put into the manufacturing of these products. In the future, we will be able to leverage machines. Machines will be the ones employed although they will still need humans to operate them. As regards resources, we don't know much about what is inside of the earths' core. There are vast pools of resources in there and the future might see more resource mining from the earth. Robots and 3D printers could be set that can build a base-camp in the cold climates or other planetary bodies like the moon where robots carry out the drilling and manufacturing of products while sending of information back to humans.

- In the future, electronics will be printed and embedded into products and objects such as into bicycles, tires, wheels etc and the internet of things could be a whole new market combined with this kind of additive manufacturing. Advertising could take up a new strategy with this innovative combination, because every surface could be a video surface or a visual surface to advertise products or services. There could be an era of motion-advertising where not only static surfaces will be used to advertise but also thousands of moving cars, trains, trucks and so on. It also opens up new opportunities for the arts. Sensors could also be printed into the products. The body of a car could be embedded with sensors, so temperature; barometric pressure and so on can be read from different parts of the car.

- 3D printing will take away the rigid four cornered architectural walls in construction. There will be no need to have flat walls, every wall or surface could be very artistic and it will change the looks of urban construction in an era of free-form structures.

- People have been trained from birth to think two-dimensionally .Examples are writing or drawing two-dimensionally and so on while living in a three-dimensional world. We haven't been able to think three-dimensionally while 3d printing requires three-dimensional thinking. Thus, the technology will force us to understand the third dimension. Imagine displaying the internet three-dimensionally, surf the internet and go from one website to another three-dimensionally. For artists, 3D printing could add relief to paintings and artworks.

- Hyper-individuality is a strong term showing how everyone wants to be unique and different. For example, everyone wants chairs fitted to the dimensions of their bodies and so on. Different kinds of uniqueness will also proliferate 3D printing in 2030. 3D printing will help people make products that define themselves. People will want to surround themselves with products that reflect who they are. However certain unique products such as plastic guns and plastic bullets which are undetectable by security services will be difficult for governments to respond to. Law abiding citizens might abide to the stipulated laws but some others might not.

8.4 Interview Transcript by David Lefutso

Tissue replacement is a great opportunity for the skin and human body. Bio-technology in agriculture could be used as a measure for pest control. 3D printing of synthetic plants in bio-technology could be also another opportunity. 3D printing could in a way reduce or eradicate the use of environmentally unfriendly pesticides and act as a standard for pest-control. Along with actual agricultural products, synthetic stems and branches could be printed as protective materials which insects can feed on while the actual product grows from the inside. So in a way, food security could be achieved to some extent from this perspective while preserving the soils and the environment from harmful pesticides. It would also increase gains and profits for different agricultural businesses and especially bring small farmers back to agriculture. Plants will be able to grow pest-free with this merge. In education, additive manufacturing could be used to manufacture physical educational materials whenever they are required which will enable students from under-developed and developing countries derive more from education.

8.5 Interview Transcript by Jim Dator

3D food printers will be able to go beyond the kind of unpleasant non-customizable food in space for astronauts. Rapid prototyping could be thought or viewed as a step towards teleportation. Think of 3D printing in the future as teleportation, the transport of everything. The end of the kind of manufacturing warehousing, wholesaling, retailing and transportation systems we have now once we were to have actual teleportation. It is scratching the surface. There are still developments in teleportation very long way from actualization but it's a reasonable scenario with the relationship between teleportation and rapid prototyping. Nano-technology will also be a game-changer and its relationship with 3D printing will be profound. Once you're down dealing with production at the nano-scale, atoms and the composition of matter and you can arrange it anyway you want to, everything becomes raw materials and nothing is waste. If self-replicating machines can be produced at that level, nothing is waste. It also has opportunities for 3D printing.

As for the futures archetypes,frame each of the four archetypes with a positive view. Derive them the way people saw those futures and not your own point of view. Continued growth doesn't have much discussion in the world and might not be possible. Now collapse is popular because it seems the world is collapsing, but for older people, collapse is too terrible that they see it doomy and gloomy. But a better way to see it is "new beginnings". Old things stop working the way they used to and so newer beginnings arise. In other words, an end of one way of doing things and the introduction of another. Disciplined societies would be building upon a set of values. It accepts certain values as being essential for their survival such as religious or ideological reasons and people should live according to those values and principles to be able to attain the most fulfilled life that there can be. Transformation futures change the way humans create and evolve, for example, sexual reproduction not being the only means to create humans as well as other transformations as well.In a transformation society, the concerns for energy and environmental problems fade away but more of the infusion of nano-technology could be explored in a transformation. Relating these to 3D printing and additive manfacturing, It seems we are in the stage of additive manufacturing where we can dream of all kinds of possible things and applications but as time goes on, standards get made in place.

8.6 Interview Transcript by Ken Vartanian

- 3D printing today for plastics and metals is not fit for high volume printing yet unlike injection molding which makes millions of products on a single machine. It can take an hour to print something useful on a plastic or metal printer. This will change into a much faster process in the future. Mass customization will become a big market. Companies will want to change the way products are manufactured, rather than creating the same product in injection molds over and over again. Instead of customers buying the products they make, customers can choose the different kind of alterations they need on their original products and order to get it printed. Customers can also find a digital design of a product from the company website online, alter it a bit and either buy the design or order for it to be printed by the company. This will bring a new business model for companies. It might be a very expensive to carry out this form of business model however, no one knows if it will be a viable model for manufacturing. In another approach, companies will utilize 3D Printing along with conventional manufacturing methods. For example, a complex metal part may be partially manufactured using standard machining methods and then materials will be added using 3D Printing to complete the part. In this hybrid manufacturing process, 3D Printing and subtractive methods work side-by-side each doing what it does best.

- Printed electronics is another field. Prospective customers are not satisfied with just prototype printing but they want to know how to scale the process to high volume manufacturing. It is different from metals and plastics. Customers will want to transform the process for prototyping to high volume manufacturing, for example, in order to print antennas onto cell phones, different graphics printing methods were tried to print nano-particle liquid inks that can conduct electricity on substrates but they were not successful. However, Aerosol Jet® additive manufacturing technology is suitable for printed electronics. In the future, one machine will be able to print both the physical structure and the electronics for products on one machine and in one phase.

- Scrap reduction by manufacturing re-work and repair will be new opportunities for 3D printers . New materials are made by mixing different metals to make new alloys.3D printing also has opportunities for the repair and overhaul of old products. Also products that are no longer available for purchase can be reproduced using 3D printing and maintenance can be done this way for a number of products. An example is the fact that some people still keep some outdated brands of cars with little or no parts available since technological advancement has led to the proliferation of newer hi-tech models. Whenever these owners need repairs or replacement of the parts of these cars, 3D scans will be used to digitally scan and reproduce the specific part and then replaced as requested by the owners using 3D printers.

- 3D printing will also enhance the new business model for the air-craft industries. Today, when companies buy airplanes, they own the entire airplane and take care of the maintenance. Now, in order to stop the maintenance duties on the engines and focus on the passenger carrier business, they inform the manufacturers on their lack of interest to carry out the maintenance of the airplanes. For example, instead of buying engines , airlines will utilize a new business model called power-by-the-hour. They pay a fee for using the engine by the hour. General Electric and Rolls-Royce are companies that in the future will not sell engines anymore , but will sell power. Now the work lies on the manufacturers to find ways to repair and maintain these engines. Complicating this new system are new engine designs that are very difficult to repair because they have non-detachable blades. Damages can occur anywhere and a process is required to go in to find only the damaged part and then repair that damaged portion. With subtractive manufacturing, this will be difficult. However in the future , 3D printing for repair work from this perspective will transform the whole problem. The repair of jet engines will be a big opportunity since the parts will only need to be scanned for the point where repair needs to be done and raw material will be specifically deposited at these points.

8.7 Interview Transcript by Tony Ahlqvist

- There are radical visions for 3D printing using raw materials such as water and air. The carbon, hydrogen and oxygen molecules in water and air could be used as raw materials for the production of products such as concrete, water and so on. There could be the emergence of printers which use water or thin air to print meaningful products. The recyclability of materials is another very significant potential for home 3D printing. Anything could be produced from just anything such as furniture from plastic bags which can be recycled and re-used when there is a need to produce a different product.

- However, there is the threat that people can also produce dangerous objects such as explosives from very cheap materials as well.

8.8 Interview Transcript by Risto Linturi

- 3D printing can be viewed as a part of the third industrial revolution characterized with local manufacturing and local energy generation such as solar and wind power. Also with robotics, the manufacturing becomes more local because with a flexible robot like a 3D printer, then you can make smaller numbers of products with equal costs compared with mass manufacturing. So there is no economy of scale rather there is economy of closeness because you no longer need to transport, package the goods and take into account the delays in transferring the goods. In such localized production in the future, the traditional energy providers and people who make the automated factories and warehouses for logistics will be the ones who lose the most since manufacturing is brought closer to the users and the workers who do the manufacturing are now closer to the users.

- Thinking about the increase of wealth, it can be seen from the added value received by individuals from the products they purchase. They would get individualized products even for free if printed by themselves but if when calculated from the economists' point of view through the monetary system, less people will need to buy things. Fewer products will travel and costs will be lower and the economic growth will be lower and perhaps wages will be less. It depends on the kind of control needed in the economy. If the economy wants good and cheap things for people so that they would not need to have so much money, 3D printing is a good innovation, if an economy wishes that businesses, industries or export to grow, 3D printing is bad.

- If every one of the 9 billion people in the world uploads a 3D model on the internet for free, how can businesses make money? Manufacturing jobs are now in China so when manufacturing becomes local, a lot of countries will get back those manufacturing jobs which have been lost for decades. Most manufacturing processes are remotely carried out thus work is taken away from local people. But when the exported stuff produced in China is being produced locally, more jobs will be made available to the locals including the possibility to produce commodities individually which adds value and lots of possibility to create new jobs. Considering mass production now like in China, if you think about where the money goes, it goes to huge investments and huge marketing expenses, global media or the people at the top of the hierarchy with very high paid staff. It doesn't go so much to the Chinese workers. However with 3D printing, the workers will be able to sell their products to their own customers and get the money themselves. It will not go to the investments of top managements, but to the person who does the work. Thus workers have more value for their labor.

- Inequality is usually created by unequal availability of production resources. If you lack access to good tools, you cannot sell your work for its whole value and vice versa. With 3D printing, a lot of people will be able to produce for the full values' worth of their product. The risk of producing is low in local manufacturing and when risk is low, you don't need to calculate the risk into the cost and even poor people can invest because there is low risk. 3D printing will help reduce the income inequality from that perspective. However, there is the threat of producing items that hurt us because of the non-testable nature of these live models.