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3D Printing Method for “Global Materials Management” Process

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Abstract

Global materials management is a system to develop performance to achieve desired consumer satisfaction while increasing profitability and decreasing costs as much as possible. Thus, this research aims to study the 3D printing manufacturing and just-in-time technique for global materials management to see if it decreases transportation cost, transportation time and waiting time of customers. A noteworthy number of academic studies was examined with regards to the research and afterwards strengthened it with the case study. However, the effectiveness of 3D printing technology still remains a bit doubtful but for sure the technology is developing day by day.

The study determined to focus on a heavy medical equipment's transportation cost and time with a case, and then followed by a SWOT analysis. Thus, the main research question guiding this thesis sought to look at '**The Cost and Time Advantages of Using 3D Printing for Global Materials Management**'. Results showed that there is a possibility to decrease waiting time of customers which leads to customer satisfaction. Furthermore, 3D printing manufacturing may increase the profitability by decreasing costs.

Conclusively, this research explained an interesting method with 3D printing manufacturing, global materials management and just-in-time production technique that can be invested further for having a long-run competitive advantage. Despite of the lack of manufacturing costs due to confidentiality, the research provided useful tools for organizations to analyze on their manufacturing and transportation methods.

Keywords: Global materials management, 3D printing manufacturing, Just-in-time production

Executive Summary

In all industries, companies have been searching for innovative ways to raise or protect their position in the competitive market. These determinants led most of the companies to decrease costs by handling materials management better and investing in additive manufacturing such as 3D printing. Thus, reducing the costs is a crucial factor for manufacturing, materials management and entire supply chain area. Since its first years, materials management was considered as a extensive cost to companies due to having huge inventory of materials. It is considered as the biggest amount in total production cost of organizations. Moreover, materials management has become more important year by year because business environment has been revised, and the economies has become more global in the world. So, to have the trump card in the competition in any industry, companies realized that how affective materials management could be. Furthermore, managing materials had to include a well planning and monitoring to decrease wastage which eventually affects the efficiency of an international company.

Global materials management in an international organization must be efficiently planned in order to decrease costs but also increase customer satisfaction. That is the reason why global materials management model uses dynamic data from suppliers and customers to build a production schedule. These factors drive organizations to optimize and control the whole period of materials management which is from the purchase order till the final delivery. Demands of customers mostly change the process, thus companies started to use technological developments in global materials management to diminish costs and customers' waiting time. This study suggests that international companies can utilize from 3D printing and just-in-time manufacturing by forecasting the demand by transporting the raw materials to the right place in, right time. With these determinants, the companies would have an opportunity to have reduction in costs and lead time of products.

The main goal of the study is to examine whether the transportation cost, transportation time and waiting time of customer decrease or not when the 3D printing manufacturing and just-in-time technique for global materials management is being utilized. An outstanding number of academic researchs was examined with regards to the research and afterwards strengthened it with the case study. However, the effectiveness of 3D printing technology still remains a bit doubtful but for sure the technology is developing day by day.

3D printing as a manufacturing method has the futuristic and opportunistic advantages to ensure the potential competitive advantages in any industries. However, different aspects relating to the existence of the technology's current situation, possible printing methods, and the time of printing out

one product may still contain questions marks for the operational success, but this problematic situation is changing day by day with the new 3D printing developments.

The study especially used a heavy medical equipment's transportation cost and time with a case and afterwards supported the case with SWOT analysis. With all these aspects, the main research question of this thesis wanted to find out **'The Cost and Time Advantages of Using 3D Printing for Global Materials Management'**. In other words, the purpose of this study is to look at the importance of 3D printing manufacturing and possible decrease in storages by just-in-time production technique, and especially with a reference to case study based on a heavy medical equipment which consists of two parts. The heaviness of these two parts (634 and 250 kg) of the product is very crucial in this study since both manufacturing and transporting them is a big issue by time and cost factors for the organization.

Results display that there is a change for decreasing costs and waiting time of customers and also increase profitability and customer satisfaction by using 3D printing manufacturing and just-in-time production method. Thus, utilizing these techniques can have a tremendous effect on the performance of the companies. Therefore, it is quite clear that the increase of using 3D printing manufacturing in global materials management allows for having a strong competitive advantage and long-term benefits in the future. This positively leads to value creation which will optimize the supply chain of organizations.

The process of this study was done by means of an analysis of the possible use of 3D printing manufacturing by carrying the raw materials to the European hub and utilizing the 3D printing and just-in-time production methods. Documentary information gathered via internet resources, numerous academic researchs and obtaining information from the colleagues added to the qualitative approach of the research. The quantitative approach made it possible to understand the differences of calculations based on transportation time and cost factors of a heavy medical equipment. In order the examine the determinants of the research case through a basic framework, a SWOT analysis were adopted. The internal and external aspects based on the case study gave a vision on both the qualitative and quantitative outcomes. The analyses concluded with the scale between the traditional manufacturing and 3D printing manufacturing in long-term which is still a big question that needs to be answered. The effectiveness of 3D printing manufacturing needs more theoretical and practical studies in long-term. One sure thing is, 3D printing manufacturing will be adopted at least partially. Lesson learned from the current 3D printing investments might be perceived as an opportunity for developing this technology in terms of adopting 3D printing manufacturing in the future.

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Introduction

Materials management is an essential step in supply chain management. Since its first years, materials management was thought as a cost factor due to the idea of procurement department was wasting money on materials. Space was also another argument in these thoughts. Companies were considering materials in inventory as a huge cost (Ramakrishna, 2005).

Nevertheless, with the globalization in economy and in the world, there has been an extreme revision in the business environment, ending up that materials management is the key to stay strong in the competition among the industry. In most of the cases, cost of materials was almost half of the total cost of goods manufactured. This investment situation had to include a well planning and monitoring to diminish wastage which perpetually has effect to the efficiency of an organization (Jerutokeitany et al., 2014).

Furthermore, materials management is a section of logistics that manages the goods in the supply chain. Especially, this includes the procurement of spare parts, quality control of procurement, procedures included in ordering, shipping and storing. The global materials management is the fitting model for the businesses who are searching reliable tracking of the materials management and flow in their companies in entire supply chain management, in other words, it can be said that materials management should be trustworthy like a base of companies to increase profit.

Efficient materials management gives firms an opportunity to reach powerful savings, thus efficient materials management aids to have a diminishing in cost. In 1990's the possible saving in total cost with effective materials management was around 5% (Bell, 1987). Nowadays, utilizing the 3D printing technology in global materials management can help to decrease more than 5% of total cost. The different classes of managing materials in companies contain procured materials, work-in-progress, materials and end products (Richu et al., 2014). In some parts of the literature; basic price, cost of procurement and marketing, and wastages are also included as costs in these materials. Therefore, all the materials must be well-managed to decrease costs. As almost half of the total costs in manufacturing belongs to cost of the materials, the first concern of an organization should be successfully managing materials to increase the profit by decreasing costs.

Global materials management model uses dynamic data from suppliers and consumers before creating a manufacturing schedule to measure the supply chain's beginning and end periods, from raw materials till the end customer's demand. Demand from the consumers changed the role of Global Materials Management to decrease costs and increase customer satisfaction. Development of technology has become the key factor to diminish costs in global materials management.

Because of the increment of total costs, organizations have been sought some ways to optimize materials management by minimizing the manufacturing process and transport costs. 3D printing has a potential to be that essential key in global materials management. Improvement in the technology of 3D printing have effectively increased the potential to cover the lack of flexibility in global materials management about equipments.

Author's theory is basically around five steps:

- 1) Investment in 3D printing
- 2) Transporting the raw materials to specific manufacturing places of the company in the world
- 3) Building spare parts
- 4) Using just-in-time method and assembling the builded spare parts
- 5) Transporting the finished product to the end customer in less complex transportation model

However, 3D printing may not be completely effective about printing all the parts in all industries. Thus, in the beginning it will have less affects, but in the future this method would be successful at all.

As a result, using 3D printing in global materials management with transporting raw materials, building parts and assembling the final product will lead companies to stay strong in the competition and even leading the industry. Furthermore, companies will get rid of complicated multi-modal transportation besides decreasing costs of holding inventory, and final reward will be decreasing waiting of customers and their increasing satisfaction.

Problem Statement

The main aim of the companies is simple: maximizing the profit while forecasting the future of the company, the business and the sector with research and development activities. A small disruption in materials management, utilization and optimization may cause a problem in organizational productivity which will affect total margin output at the end that is based on how efficient the materials management is.

It is really hard to have efficient materials planning, organizing, controlling and coordinating for companies due to the complex manufacturing and transportation systems. The longer the process of transportation, the more issues may occur, and which at the end may questionize the materials management managers' effectiveness in the organizations.

Therefore, while carrying huge and heavy equipments by RoRo or in any other transportation systems, it takes a lot of time or money to carry those products to customers. Thus, customer's waiting time increases with a decreasing satisfaction rate. The manufacturing company holds those products in the inventory till the procurement by the customer happens. So, for both manufacturing company and

customer, improper global materials management provides various negative results such as, damaging the material, decreasing customer satisfaction, downgrading in the productivity of employees, materials wastage, increasing costs and postponements in the process of the work, which directly influences increasing of limited resources in a bad way. Lack of technological development usage in global materials management are generally ending up with the increased costs and leading time which results as a decreasing customer satisfaction. In small companies, generally materials are being handled by persons who does not have any knowledge about the materials management. As a result, it is crucial to have a proper global materials management with using the technological developments, otherwise it would have affected negatively in the whole supply chain. Otherwise, losing the market position in the industry is inevitable.

Purpose of the Study

The problems encountered by companies are mostly trying to be solved by decreasing the total cost of manufacturing process following by the other stages of supply chain: Procurement, manufacturing, storage, transportation, control, handling of materials and the last mile. Therefore, the purpose of this study is to have a research about an enhanced model of global materials management with the utilization of 3D printing technology.

Global materials management includes all procedures management functions from purchase order of raw materials through manufacturing progresses to the final delivery of the end products to the end customers. It takes the help of developments in technology in intra and inter-organizations then it connects all of them in only one management liability for deciding the production demand, setting up the production progress and purchasing, storing and operating materials (Ondiek, 2009). So, it puts them into the liability of materials management.

After the recent technological changes in the market, it forced companies to come up with better strategies to decrease manufacturing costs and lead time to survive in the global competition. After all, at first materials management then global materials management have been identified as an opportunistic way to decrease manufacturing costs and can be considered as a beneficial strategy.

Today, companies tried many other ways like backward vertical integration from the market to the manufacturing stage to decrease production costs and increase profitability to remain in the competition.

Being supported with the developments in technology like 3d printers, companies are strictly controlling their production costs and heading their strategies to enhanced models of global materials management (Ondiek, 2009, Barker & Finnie, 2000).

Prior studies have identified that materials cost more than half of the annual turnover of a company (Ramakrishna, 2005; Asaolu et al., 2012). This without any doubt displays that priority shall be given to global materials management by monitoring the latest technological developments in the industry to accomplish serious cost saving, enhancement in manufacturing effectiveness, and increase in profitability and have a better place in the competitive global industry.

It is visible that not much been achieved on global materials management strategy since the researcher work will provide to the current literatures on materials management, global materials management and using 3d printers for the spare parts and assembling the huge equipments to decrease transportation time, cost and complexity of the work and to show how this affects the organization.

It will help to rethink about the technology development in the usage of global materials management in the organization if it has benefits from the purchase order of raw materials till the last transportation to the end customer.

The research linked to show the relationship between 3d printing, assembling spare parts of huge equipments and decreased lead time and wastage for enhancing global materials management in the company.

Research Question

When a company becomes the industry-leader in the world, managing materials globally are becoming a hard and complex situation. Consequently, materials management has become one of the most valuable strategy for companies to decrease costs and increase customer satisfaction.

Even though basically materials management is the same for the years, it changes with the change of zeitgeist and affects of technological developments.

Thus, the research question central to this paper seeks to understand: **“The Cost and Time Advantages of Using 3D Printing for Global Materials Management”**

The research reveals the different ways in which technological developments in global materials management will affect the company’s situation in the industry.

To allow for the the thesis to precisely address all the problems raised by the research question, this paper will be structured by four sub-questions. Each sub-question will be examined by literature review to find out these supporting topics to be fully auxiliary. The aim of each questions is simply to help the main research question to have a conclusion. The sub-questions defining the scope and manner of main research question are:

- What are the characteristics changes in global materials management recently?

- What are the benefits of enhanced models of global materials management?
- How can the development in technology help to have a faster, cheaper and better global materials management?
- Is using 3D printing manufacturing and assembling the transported raw materials of huge equipments beneficial by the factors of time and cost?



Literature Review

1. Materials Management

In literatures, materials management includes five important procedures which are buying, manufacturing and control of the inventory, control of the quality, storage, warehousing and transportation (Barker, 1989). Others extended the procedures with forecast of demand and quantity of materials required, a better supplier and consumer communication in the supply chain, finding local sources for imported materials, enhancing the ability of workers in material management, increasing the effectiveness inter departments and research and development (Whybark & William, 1986). Material management department is responsible for these procedures including: Procurement, control of the inventory, management of stores and handling materials, and placing.

Materials are indispensable of all producing system and it is easy to say that companies can not perform without them. The materials must be ready for use at the right price, quantity, quality and in the right place and at the right time to plan the manufacturing activity in a combined plan for an industrial operation. A producing company will feel insecure if the materials are less or more than the predetermined or in the case of not well managing (Banjoko, 2000).

The essential supply chain responsibility in the companies is to find and organize a futuristic programme for the planning of materials, components and work-in-progress (Navon & Berkovich, 2006). To obtain a competitive advantage in the industry, from the beginning, till the end customer, management of materials has become the most valuable and developable thing for organizations since they are attempting to deliver the right product at the right place and time (Jerutokeitany et al., 2014).

The primary goal is to decrease the costs as much as possible in the producing process with the stabilized or above the satisfaction level. Materials management, in this case, as the lead times decrease, will give advantages for having a better cooperation and at the same time will increase communications while decreasing the duplication of efforts and cost of the materials, thus will help to develop a better control of the quality (Bowersox & Closs, 2002).

Materials management is explained as a management system that plans and controls the quality and quantity of the materials that bought, placed with the right price and necessary quantity (Ramakrishna, 2005). Generally, in firm's accounting results, it is the biggest cost as a percentage and that percentage bases on the scope of the activities, and the profitability of the firm.

Lately, most important factor in the industry has become delivery time. Materials control is providing ordered materials in the right time, and they should be monitored closely to achieve the predetermined delivery date. Controlling the materials allow firms to deliver the products in desired

delivery dates. Besides controlling, companies also should take care of waste, depreciation and misuse. Moreover, unneeded handling should be bypassed by guaranteeing to adjust orders and storing correctly. Storing materials in a decent way helps minimizing waste in higher costs. To sum up, the main goal is to get the materials to the predetermined level in the best and most effective ways (Ramakrishna, 2005).

The book word of meanings for materials are *"the elements, constituents, or substances of which something is composed or can be made."* Some researches achieved that materials bill for 50 to 60% of the total cost.

1.1. The Development of Materials Management

In the late 1980's, the key practical areas of Materials Managements are classified as purchasing, producing, control of the inventory, control of the quality, storage and warehousing, and finally, physical distribution (Barker, 1989). Almost a twenty years later, Linton et al. (2007) added forecast of demand and quantity of the materials, a better supplier and customer connection, finding native source of the foreign materials used, improving abilities of workers in the usage of materials management, a better connection between departments, and lately, developing research and development activities in materials management. These are the activities that are being managed by materials management department (Asaolu et al., 2012).

It is obvious that to increase the revenue of a firm, either the price should be increased, or the cost should be decreased. There are many ways that Ramakrishna (2005) recommended that Materials management can decrease material cost and raise profitability in purchasing. Gathering materials at inferior prices with the enhancement of new sources, efficient bargaining with dealers about price, decreasing the cost of packaging, optimizing the transportation cost with the help of product operations management, stability in materials' quality, and finding a substitute for importing.

In an effective materials management, assembling can also be used which can be seen in the example of automobiles and computers. Consumer's willingness to wait is low so they don't want to wait for a long time. Thus, when production unit had an order from a consumer, they assemble the spare parts from the inventory for the order. Since the spare parts are already in stocks, the company just needs a little time to assemble before delivering the final product to the end consumer. It is even possible while having small amount of inventory, thanks to 3D printers that can rapidly builds the spare parts whenever it is needed.

1.2 Goals of Materials Management

The materials management activities mostly aim to contain well-known 5 R's of materials management which are shortly: Right quantity, right quality, right time, right source and right price (Gopalakrishnan & Sundaresan, 2011). This key goals of materials management from the perspective of management are listed below in details:

- Procuring with the possible lowest price, with steady quality and service.
- Keeping up the inventory turnover high by decreasing extra storage, costs of transportation and inventory deficits appearing mostly because of depreciations and disuse.
- Retaining supply constancy, avoiding delays of the movement of materials and services to customers.
- Sustaining the indicated quality level of materials consistently to continue giving services effectively.
- Decreasing risks by having alternative sources of supply to build up a competitive environment in efficiency and estimating prices.
- Reducing the total cost of procurement by developing the effectiveness of operations and progresses.
- Employing, developing, inspiring and educating workers to keep the efficiency as steady.
- Developing and managing supplier relationships well to build a supplier approach in the workplace with new thoughts and goods with decreased prices and advanced services.
- Obtaining a high level of collaboration and strategy with user departments.
- Keeping up well records to assure healthy and effective audit trail.
- Engaging in make or buy choices with tracking the newest Technologies.

1.3. Benefits of Materials Managent

Materials management practically means optimizing performance to satisfy customers' demands while minimizing costs, using the resources effectively and thus, increasing the profitability. In materials management, it is important to have the right raw materials procured, made them available for production operations at the right time and place with the minimized costs (Banjoko, 2000). Materials management is an approach which assembles the liability for deciding the production requirement that is organizing the producing processes and buying, storing and allocating materials (Ondiek, 2009).

Another way of describing material management is goes through the planning, sourcing, procurement, transportation, storing and controlling those materials in the best way to provide the most excellent service to the customer at a minimum cost. (Ramakrishna, 2005). The scope of materials management is widening which contains MRP (Materials requirements planning), procurement decision of

materials, managing the inventory, staffing, storing and management of warehouse, manufacturing and allocation of final goods in the right time with the minimum cost (Monday, 2008). Materials management is an approach includes the whole movement of information, both materials and services from the beginning with raw materials suppliers, then over companies and warehouses till the final consumers.

Materials management has three main objectives: Satisfying customer demands while increasing the profitability with reducing costs by benefiting the available resources in the best way. Basically, Materials management is explained by Jacobs et al. (2009) to guarantee the right piece is purchased and made ready to use the production operations in the right time and at the right place with the minimized cost. The main fear is the general performance of a company might be harmed if the planning for materials resources are not sufficient.



Figure 1.1: Benefits of materials management

Source: TÜVRheinland, 2014

A company's success is related with how a firm manages materials efficiently. It is being suggested that it is important to audit inventory in every stage (Chase, 2009). To sum up, efficient materials management is necessary for companies. Thus, an efficient material management process should contain these factors:

- Decreasing total costs of materials
- Managing the materials in a better way
- Diminishment in imitated orders

- Reducing the costs of inventory
- Having the materials when needed and especially in the right amount
- Developments in work output
- Quality assurance
- Advanced field material control
- More healthy connection with suppliers
- Reaching customer satisfaction with better goods

Every association, with big scale or less, reckons materials and services from other associations to varying scopes. These materials and services are acquired over transaction of cash. The different materials utilized as inputs, like raw materials, consumables and spares, are demanded to be procured and built accessible to the stores and end users as and when desired to provide steady manufacturing. For that reason, effective control of input materials is crucial in a corporation for boosting materials output, which sooner or later directly affects to the profitability of the corporation. The primary worry of any organization is maximizing the Return on Investment (ROI).

The interaction of ROI can be shown as:

$$\text{ROI} = \frac{\text{Profit}}{\text{Sales}} \times \frac{\text{Sales}}{\text{Fixed Asset} + \text{Current Asset}}$$

Figure 1.2: Formula of return on investment

So, ROI is basically sum up of profit margin and asset turnover rate. A company's profit margin demonstrates management's capability to handle costs and total revenue. The asset turnover rate exposes management's capability to efficiently take advantage of the organization's beneficial assets. Therefore, a company can increase ROI in three approaches.:

- By diminishing costs
- Increasing the sales amongst available assets or earning from the currency rates.
- Combination of two styles above.

Therefore, it can be easily said that controlling the costs is the most important step in materials management.

In many production firms, the cost of materials sololy occurs between 40-60% of the total consumption. Apparently, a wiser management of material is proposed to provide decrease in total cost of business concern and fineness in supply of inputs. This demands adequately coordinated approach towards different problems including decision making regarding materials. It is indisputable

that materials must be gathered at the minimized cost attainable in order to supply savings to the organization. Integrated Material Management (IMM) is being described as *“including material planning & indenting, procedure, variety reduction through standardization & rationalization, reducing uncertainties in demand & supply, handling & transportation, inspection, proper storage & issues of materials to the internal customers, inventory management, vendor management & finally disposal of obsolete, surplus & scrap materials etc.”* (Stephen et al., 2017). To perform these objectives effectively, it is vital to have an exceptional supplier headquarters, ordering progress & inventory management system in addition to expert Materials Management (MM) professional version. Materials management is controlling all kinds of materials in a corporation and can be divided into three divisions: *acquisition, quality control and standards*.

1.4. Quality Assurance

Materials management, additionally, makes sure that spare parts and materials that utilized in the supply chain provides lowest requirements by operating Quality Assurance (QA). Even though nearly all the writings and analysis about materials management is about procurement and standards, plenty of the daily work managed in materials management carries out with Quality Assurance problems. Spare parts and all materials are tested, to make sure there are not any momentary or longstanding problems that would interrupt the purchase order and operation stages of supply chain. Material management is often essential for industrial perspective. Quality assurance identifies planned and organized manufacturing progresses that contributes determination in a good's fitness for its predetermined purpose. It is a set of acts aimed to provide that both goods and/or services meet the consumers' desired satisfaction in an organized and solid way. Quality assurance can not surely ensure the manufacturing of quality goods but makes this more possible.

Two crucial fundamentals describe Quality assurance are “fit for purpose” and “right first time”. Fit for purpose basically means that the good must be convenient for the predetermined purpose meanwhile right first time is there will be getting rid of possible errors. Furthermore, quality assurance involves management of the quality of raw materials, assemblies, goods and items; services linked with manufacturing and administration, manufacturing and checkup progresses. It is also crucial to understand that quality is driven by the forecasted users, buyers and consumers, not by all the people in general: it is not like the “overpriced” or “high quality”. The low ranged products can also be treated quality components if they fulfill a market need.

One of the most crucial handicaps is the qualification of 3D printed parts. So critical is this problem, literally, that many define quality assurance as the only difficulty to increase the adoption of 3D printing technology, especially for metals (Al Geddawy & El Maraghy, 2011). Many producers have

struggle that both spare parts and end products manufactured with 3D printing do not have the necessary strength, stability and quality. Without the insurance of quality assurance of 3D printing, many producers will stay away from the 3D printing manufacturing technology (United States Government Accountability Office, 2015).

Quality assurance (QA), identifies planned and organized manufacturing progresses that implement determination in a good's rightness for its expected purpose. It is a set of functions expected to assure that goods and/or services satisfy consumer needs in an organized and reliable design. Quality assurance can not definitely guarantee the manufacturing of quality goods, but still increases the likeliness of it. There are two essential fundamentals of quality assurance: "Fit for purpose" and "Right first time". "Fit for purpose" is basically being sure of the product is suitable for planned purpose meanwhile "Right first time" is getting rid of possible errors.

Quality assurance involves management of the raw materials' quality, assemblies, products and spare parts; services linked with manufacturing; management, manufacturing and supervision progresses. It is vital to understand also that quality is decided by the expected customers and not by the society at all. Furthermore, it is not just "expensive" or "high quality" anymore because even inferior products can be deliberated as expensive or high-quality goods if they satisfy a market need.

1.5. Standards

The decisive part of materials management is standards conformity. Standards are having a very important part in supply chain management. For instance, a supply chain that adopts just-in time or lean replenishment needs complete excellence in the transportation of parts and material from procurement agent to storage to final destination. Systems dependent on vendor-managed inventories have to contain timely computerized inventories and powerful ordering systems for remote vendors to store orders on. Materials management mostly covers that the storage and transportation of such parts as are required follows the standards needed to prevent issues. This part of materials management is the rapidest changing one, because of the late innovations in Supply Chain Management and in logistics overall, along with outsourced management of storing, mobile cloud computing and current logistical inventories (Gopalakrishnan & Sundaresan, 2011). Therefore, materials management can be described as a combined action of numerous material activities through a shared aim and that is to reach an integrated management system to planning, acquiring progressing and distributing manufacturing materials from the raw material form the end product form.

Materials management is responsible of planning and controlling materials flow. The main aim is optimizing a firm's material resources and supplying the predetermined level of customers' service (Ramakrishna, 2005). Materials are plainly industrial products that evolve into another part of physical

good. They are the extensive parts of business cost and profitability. Almost 50% of the sales income in a company is used on materials (Ramakrishna, 2005). Therefore, many firms considering to use 3d printers manufacturing to decrease materials costs and wastages but also increase their power in the current competitive markets.

According to Banjoko (2000), there are three kinds of materials to be handled in any company: Purchased materials, work in process materials and finished products. In a wide perspective, Ogbadu (2009) described the costs of materials as basic price, purchasing costs, inventory carrying cost, transportation cost, materials handling cost, office cost, packing cost, marketing cost, obsolescence and wastage costs. So, materials management means to decrease the costs related to those costs. Thus, this study seeks to compare costs and time factors of traditional manufacturing and 3D printing manufacturing.

On one hand, materials management was described as the strategy of planning, sourcing, purchasing, moving, storing and controlling materials in the best way to provide the most excellent service to customer while minimizing the costs in the most possible ways (Ramakrishna, 2005). On the other hand, International Federation of Purchasing and Materials Management describes material management with a little bit different approach: the planning and controlling in supply chain, the products flow from raw stages to finished products, thus, to deliver the final good to consumer with a desired minimum lead time. With an improper global material management in any industry, the companies may face delays, overcosts, waste and low productivity (Shehu et al., 2015).

Materials management is a strategy that deals with planning, organizing, controlling the movement of materials from the initial purchase of raw materials till the end destination. Materials management is the engineering and supervising of the numerous materials activities. The essential material activities are:

- Purchasing activity which includes mostly recognition of required materials, market research and managing materials' records.
- Procurement activity which contains material specifications, materials studies and inbound of materials.
- Inventory management which has planning and controlling of materials handling, warehousing and handling material supplies.
- Supply management which covers for monitoring the management of material handling in the organization and strategic planning of materials.

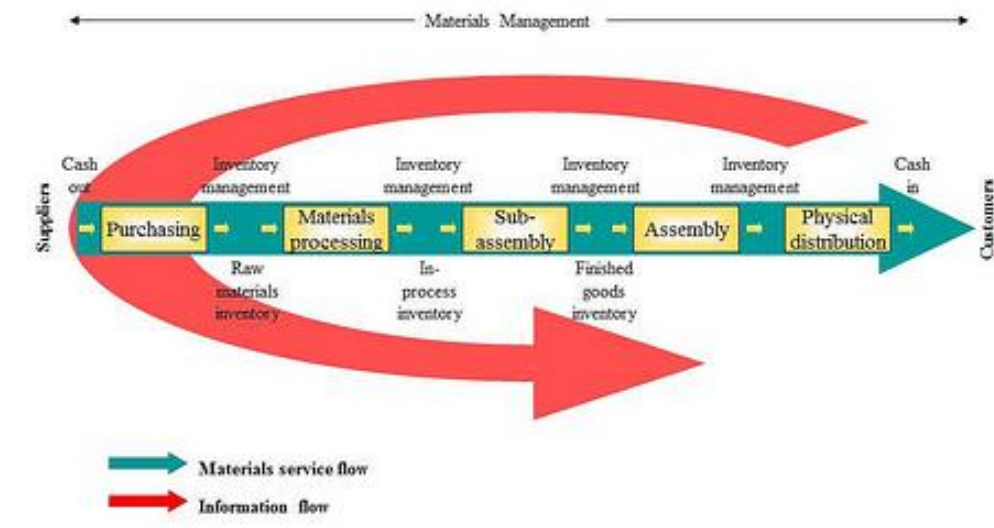


Figure 1.3: Materials management process

Source: Drawpack.com

1.6. Extent of Materials Management

The wide materials responsibilities have been described with these sub functions:

Materials planning and control: Materials needed for any process are established on the sales forecasts and manufacturing plans. Planning and control are completed for the materials considering the materials that are not ready for use to operate and those owned or in on the transportation way. This includes forecasting each needs of parts, formulating materials cost, forecasting the amounts of inventories, organizing the orders and tracking the performance regarding to manufacturing and sales.

Procurement: Essentially, the task of a materials supervisor is to maintain the right material with the help of 5 R's of materials management (at the right time, in right quantity, of right quality at right price from the right source) to the user departments. To match these goals the functions launched involve choice of sources of supply, completion of terms of purchase, organization of purchase orders, follow up, managing the relations with vendors, acceptance of fees to vendors, appraising and developing vendors.

Warehouses: After the material is transported, its physical control, protection, lowering the obsolescence and loss because of timely demolition and effective handling, maintenance of records, convenient places and stocking is performed in warehouses.

1.7. Material Planning

In all integrated materials management environments, planning for obtaining the materials is the beginning part for the entire materials management activity. Materials planning initiates the

purchasing and the following material activities continuing. Material planning is a systematic way of establishing the needs from raw materials, consumables, spare parts and all other materials that are needed to complete the given manufacturing plan for a specific date. Material planning is imitated from the whole organizational planning and for that reason, it will consistently be a sub-plan of the wide-ranging organizational plan. What it achieves is estimating and starting for acquisition of materials. There are two kinds of elements that are affecting materials planning:

Macro Elements: Universal elements like price trends, business cycles, import and export policies of each country, etc are termed as macro elements. Governments' credit policies are crucial elements as banks adopts these instructions only when continuing financial support to an organization.

Micro Elements: These are basically the elements stands within the company like corporate policy on inventory holding, manufacturing plan, investments etc. For any firms, micro elements contain: Lead time of purchasing, acceptable inventory levels, working capital, seasonality and delegation of power.

There are several methods adopted for material planning for the given time. Enterprise Resource Planning is the most frequently used one. ERP has, as its initiating spot, the annual manufacturing plan of the production responsibility. Once a company chooses its annual manufacturing plan, the entire material need, to achieve the determined manufacturing plan, is accomplished. It is a specific examination including the materials and amounts available to use, materials with amounts not available and therefore in need of purchase, the actual lead time of purchasing, etc.

Thus, it is likely to have a circumstance where some parts of an assembly are available while some parts are not, Bill of Materials is collapsed. It is measuring all the materials required for numerous assemblies, all required as per the manufacturing plan. Bill of Materials (BOM) is hence a table shows the code, classification of a material, its unit and amount, place of use and further, the estimated price of every unit. An explosion chart is a list of BOMs arranged collectively in a matrix form therefore that grouping the needs for various parts can be made. After the Bill of Material is ready, the same is provided to the procurement side which triggers the procurement functions. Enterprise Resource Planning therefore puts Lead Time into the consideration, too. Utilizing computers, arrangement of Bills of Material over explosion of lists is utterly simple and smooth.

A material planning system is designed to meet three purposes at the same time:

- Guaranteeing materials and goods are ready for use for manufacturing and transportation to consumers.
- Having the minimized and possible level of inventory.
- Plan production functions, shipment schedules and procurement functions.

The main goal of the material planning is to execute the production function in a proper way so they can accomplish the wanted results. Manufacturing companies, whatever their goods, challenge the same daily practical issue – that users want goods to have in a shorter time than it takes to produce them. This basically says that there is a need of some level of planning.

Organizations need to manage the kinds and amounts of materials they procure, plan which goods are to be manufactured and in what numbers and guarantee that they are able to meet current and future consumer demand besides having the possible minimized cost. Making a wrong selection in any of these options will make the organization lose income. Some examples are:

- If a firm procures inadequate amounts of a material used in production, or the wrong component, they may not be able to meet contracts to provide goods by the agreed time.
- If a firm procures materials more than the needs, it means basically money is being misused. The surplus quantity locks up money while it stands as stock and may never even be used at any moment. Still, some procured materials will have the lowest amount that must be met, then, purchasing excess is required.
- Initial manufacturing of an order at the incorrect time may lead to consumer deadlines to be missed.

Enterprise Resource Planning is the answer for the questions of: 'What materials are needed?', 'How many are needed?', and 'When are they needed?'. Enterprise Resource Planning can be used in both sides – the procured from outside suppliers and to subassemblies and the manufactured internally which are materials of more complex items.

1.8. Commercial Evaluation of Materials Management

'Manufacturing Location' must be considered while the evaluation process before measuring transportation costs and regional problems which may be thought. For example, it is generally known that in Europe, plants are closing on August for a summer vacation.

'Manufacturing Lead-Time' is the time between the receipt of the order and readiness of the product delivery. Lead-times can differ by product and can vary from a few days to even years.

'Transportation Time' is calculated while measuring the delivery of goods to the buyers' wanted time. In the case of shipment from a remote port especially with rare vessel transportation, the transportation time could surpass the schedule regulations would require to be built.

As a result, with all these three evaluation factors (Manufacturing location, manufacturing lead-time and transportation time) of materials management, manufacturers sought less expensive and easier

ways to produce and transport the product, that ended up with research and development activities which in this case is 3D printing manufacturing.

1.9. Materials Management and R & D

Research and Development has a crucial role in the materials management. Depending on the characteristics of materials management, working with an R & D set up is vital and necessary for the material requirement. Generally, the need of materials and the way of purchases are in a conflict situation. For instance, a material is needed critically but the accurate specification is lacking, quantity is too low for the vendors to display attraction, material is new, and the sources are not familiar, etc. These kinds of circumstances sooner or later become the limiting determinants for the purchase manager who desires to decrease the lead time in procurement. It is a truth for the procurement manager that the transportation gets delayed, sometimes awfully even though the agreed delivery schedule the vendor could not finalize the task alone because the material was of developmental nature and the time it lasted for finalization could not be estimated correctly in the initial process. Thus, R & D is having a significant impact in the materials management especially when the 3D printing is included in the system to adapt the new developments.

1.10. Objectives of Materials Management Department

There are two types of objectives of Materials Management department: Primary objectives and secondary objectives. The primary objectives contain: Low purchasing price, high inventory turnover, low cost of procurement and control, stability of supply, steady quality, low payroll costs, supportive supplier relations and maintenance of good records. The secondary objectives contain: New components, processes and goods, make or buy strategies decision, standardization and improvement of products (Khana, 2012).

1.11. Risks in the Procurement Stage of Materials Management

These risks below should be prevented by the purchase and materials managers:

- Gathering materials before they are needed, thus increasing the inventory cost and leading to deterioration in quality.
- Not being able to have the materials at the right time which leads to failure of productivity
- Getting the wrong materials
- Consecutive design changes
- Damage or loss of materials
- Errors or issues on installation
- Choice of form of contract for particular material procurement

- Seller evaluation principles
- Handling the surplus materials (Dey, 2001).



2. Global Materials Management

Transforming materials management into global materials management is important because currently supply chain management is standing on former periods' information methods. To revolutionize it to enhanced global materials management, companies need to impose dynamic information in industry which is possible because of improvements in ICT (Information and communication technology) and KM (Knowledge management). Therefore, the gap between the actual and potential of what can be done in supply chain must be fulfilled to reach better efficiencies. To achieve the potential difference, companies must invest in futuristic dynamic information such as 3d printing will help better coordination of materials and resources in the supply chain. Thus, it is global materials management which is the modernized version of supply chain management.

Supply chains can be complicated and inconsistent in size. Organizations must be able to respond to dynamic information linked with any developments in circumstances that they must be ready to respond rapidly and most importantly, flexibly to the changes in the supply chain management (McClellan, 2003). Presently, many of the organizations in the supply chain started to invest and use 3d printers to decrease supplying, manufacturing and transporting lead times till the final customer has the product in predetermined time (Lim, 2000). In the previous materials management, the lead times were not stable, so it was affecting all the procedure including the cost increase.

Most of the manufacturing companies in the supply chain still using the system designed for static information. Among those systems, most knowns are Manufacturing Resource Planning (MRPII), Just in time (JIT), Lean Manufacturing, Flow Manufacturing, and Advanced Planning Systems (APS). It was demonstrated these systems are unreliable and inflexible because they still use traditional static information (Barker, 1994). When these systems were being used in supply chain management, due to unpredictable quantities and lead times, many times inventories were having some of the materials over or lack. The companies who wants to still have a good place in the competition should stop using static information and start using dynamic information in their supply chain including global materials management (Barker, 2000).



Figure 2.1: Traditional view of a supply chain in a company

Modern supply chains will find new ways and use the recent technology to supply customer demand quicker. (Silisque, 2003). One of the ways to achieve this can be realized by using 3d printers in materials management and manufacturing. Global materials management aims logistics and production datas. Even though there is appreciable studies interested in using 3d printers in global materials management and supply chain, only limited amount of process have been made among the companies and in the industry.

There are two important concepts in global materials management. First one is intra-organisational flow, which helps companies to have a better intra-enterprise communication and increasing the efficiency between the stages in the supply chain. The second one is called inter-enterprise that binds a balanced connection between organisations by using intelligent agent technology and the theory of constraints to make information and materials flow into the both directions which is the main goal of global materials management. Through the flow, if any confusion happens, by progressing this data might end with other changes through the all network (Barker & Finnie, 2000).

2.1. Dynamic Information

The description of information has also been changed with the recent technological developments. Now information has better in quantity, changing the local into global, has easier access, decreased in delivery times, more dynamic than static (Barker & Finnie, 2000).

In the supply chain, let's consider that the lead time of raw materials to the company are being late for 3 days. If there are no extra resources in the production chain, this will affect the end customer with a suspension also for 3 days. In many situations it is possible to be more than 3 days. One fail in the supply chain will affect all the chain one by one like a butterfly effect. As the lead time increases, cost will also increase. In this case, to make customers happy, either the organization will have extra stocks for urgent cases or will use more expensive calls like air Cargo. In both cases, the cost will increase, if not, the customer won't be satisfied. Nevertheless, it is possible to take supply chains out of the chaos theory and make them more predictable with the usage of 3d printers and assembling raw materials.

On the other hand, by using static information in materials management with the present versions of supply chain management will be challenging to keep a good place in the competition in the industry because:

1. The lead times and numbers are not stable and much predictable and generally not correct in old materials management system which use static information
2. When trying to change a method, it is already too late
3. Many times, there will be need of manual intervention

4. Each stage in supply chain needs to wait to be informed by the earlier stages in the chain (Barker & Finnie, 2000).

2.2. Intelligent Agents

In the research of Ahn and Lee (2004), it was shown that supply chain management in the form of agent-based can be divided into three sections. The first one is the most important one for the global materials management which is utilizing the technology to develop the operational effectiveness of supply chains. Second one is using dynamic information to enhance network flexibility and effectiveness. Final one is the efficient agent-based architectures for supply chain management.

In the beginning section, utilizing a global view intelligent agent who assembles datas from other agents if there is a possibility of interruption to supply chain (Beck and Fox, 1994). In JIT networks, the use of multi-agent systems was also examined that would help to increase the efficiency of materials management.

2.3. Benefits of Global Materials Management

Global materials management is a modernized version of supply chain management which uses the benefits of the recent developments in information and communications technology where dynamic information is transferred between organizations, agent negotiations decide both suppliers and consumers, and PIPs carry out the required actions (Barker & Finnie, 2000).

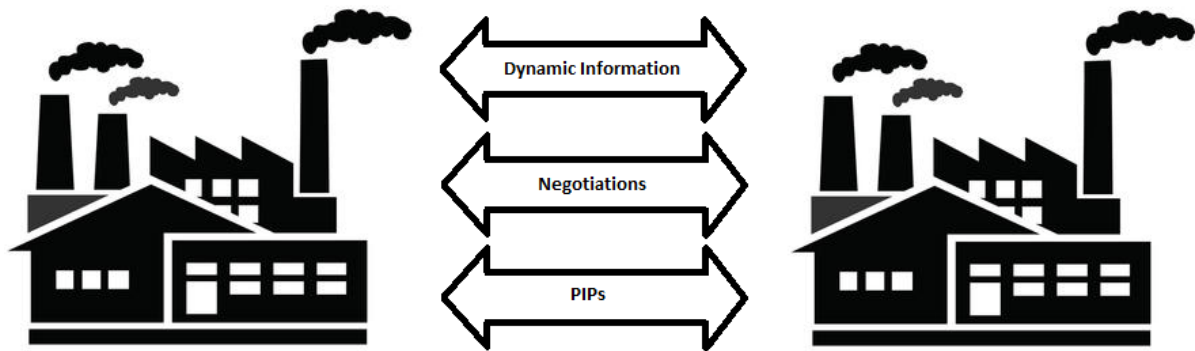


Figure 2.2: Exchanges between companies in global materials management

Global materials management model uses dynamic data from suppliers and consumers before creating a manufacturing schedule to measure the supply chain's beginning and end periods, from raw materials till the end customer's demand. Agents transmit data that they estimated for both expected delivery times from the schedules of suppliers and consumers.

The final schedules are feasible, with the help of push and pull techniques involving agents, to the company's suppliers and consumers with the on-demand based. Required material data will pass

between companies very quickly and will help to have an improved manufacturing schedules for all enterprises in the network, thus the information will be used to have a better schedule, decrease the waste and unnecessary processes.

Afterwards, manufacturing and lead time in the supply chain will be known between enterprises thus it will aid for allowing both sides to have an optimization in a synchronised way. It will not affect the supply chain a lot since the flow information is rapid. To sum up, outcomes will be:

1. A better flexibility with time and quantity
2. Decreased delivery times
3. Immediate flow of information if there is a supply problem in the network
4. There will be other possible supply options
5. The inventory amount will be lessened
6. Ordering will be feasible and decreased

3. Just-in-Time

Just-in-time was found by Taiichi Ohno of Toyota Motor Company in Japan a little after World War II. It is a supervision ideology which contains supplying the right components of the right quality and quantity at the right place at the right time. Just-in-time is not only an inventory diminishment tool but is much extensive in result thus that the company performs more effectively and with lowest resources (Mukhopadhyay, 1995). Just in time is an inventory approach in which organizations boosts effectiveness and lessens waste by obtaining materials only as they are required in the manufacturing progress, by that decreasing inventory costs. Just in time is an all-including ideology found on wiping out waste. Anything that does not add benefit to progress is labeled as waste.

According to the JIT in Toyota, there are seven significant sources of waste in production: Process, methods, movement, product defects, waiting time, over production and inventory. With the benefits of 3D printing all the sections are being achieved in global materials management. To acquire the process section the best way is having a capacity to regularly make the product with minimized wastage, in predetermined quantities, and with the minimum costs. Product defects is also a wastage that can be reduced with the help of 3D printing. Waiting time decreases with 3D printing manufacturing and JIT systems which minimized transportation movements after assembling. Overproduction is also totally out of the system. Inventory costs are especially too high when there is an excess inventory, which at the end will be costed to the end products additionally.

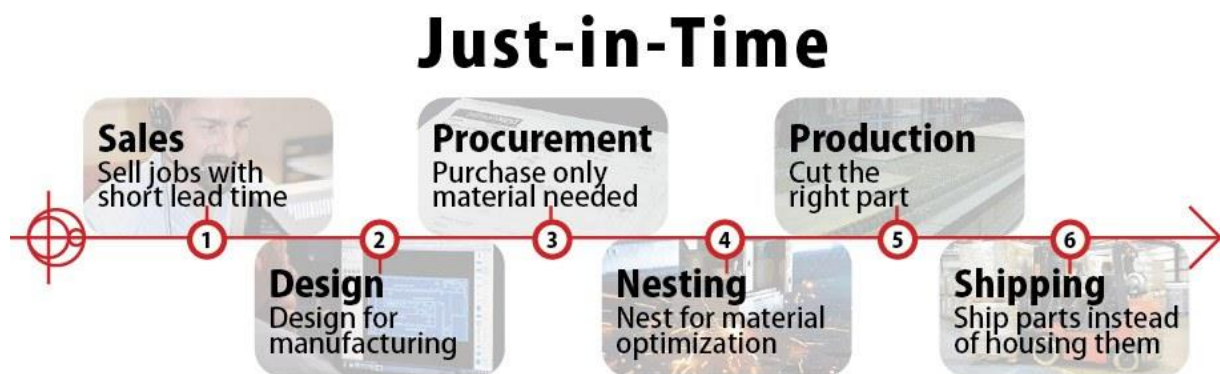


Figure 3.1: Map of just-in-time

Source: EQMS, 2014

The achievement of just-In-time on the manufacturing stage in decreasing costs, increasing quality and raising responsiveness has led many companies to try to widen the ideology to the whole supply chain. The usage of just in time to the sourcing field has become more necessary in the past few years because the cost of procured inputs, as a percentage of costs of goods sold, has raised firmly in many manufacturing environments. Analysis has showed that a company will source outside its home

borders if it expects to accomplish exciting and instantaneous advancement in four vital field: (Humphreys & Yeung, 1998)

- Decreasing cost
- Increasing quality
- Raised liability to technology
- Freight and reliability developments

The indispensable goal of just-in-time procuring is to make sure that manufacturing is as close as possible to a steady progress from delivery of raw materials/parts over to the transportation of finished goods. The achievement and resulting performance of procuring system is established on collaboration between the buyer and supplier. Some of the aspects of this system are divided into five parts:

- Perfect flow of materials between purchasers and suppliers
- Decrease of order costs
- Decrease of stocks
- Increase of quality
- Simplification of goods and services (Gunasekaran, 1999).

The JIT method was initially used by the Ford Motor Company as defined specifically in the book *My Life and Work* (1923) by Henry Ford: *"We have found in buying materials that it is not worthwhile to buy for other than immediate needs. We buy only enough to fit into the plan of production, taking into consideration the state of transportation at the time. If transportation were perfect and an even flow of materials could be assured, it would not be necessary to carry and stock whatsoever. The carloads of raw materials would arrive on schedule and in the planned order and amounts and go from the railway cars into production. That would save a great deal of money, for it would give a very rapid turnover and thus decrease the amount of money tied up in materials. With bad transportation one has to carry larger stocks."* This explanation also defines the approach of "dock to factory floor" in which arriving materials are not even gathered or stocked before beginning manufacturing. The idea required an efficient freight management system (FMS) that Henry Ford's 'Today and Tomorrow' defines one.

The method was at a later date internalized and announced by Japanese based Toyota Motor Corporation as combined with its Toyota Production System (TPS). Still, Toyota did not totally internalize the process from Ford, but from Piggly Wiggly company. Despite the fact that Toyota visited Ford as part of its tour of American corporations, Ford had not entirely embraced the JIT system, and Toyota management was frightened due to the amount in inventory and irregular work schedule of

the workers of Ford. Toyota also inspected Piggly Wiggly, and it was there that Toyota management initially noticed an entirely working and successful JIT system, and designed TPS after it.

Although Toyota Production System was built almost a hundred years ago, it has not antiquated. Contrarily, with the developments of 3D printing manufacturing, it is possible to put the thought of just-in-time production to another level. The essential factors of 3D printing manufacturing will get rid of the variable of time of shipment and make the system easier, cheaper and more flexible. Furthermore, if there are any errors in the production of 3D printing system, it can be fixed and could improve faster (Zortrax Blog, 2017). It decreases the costs of reverse logistics in case of found error of a product just like Samsung Galaxy Note 7 explosions. As a result, using just-in-time and 3D printing together, the costs of such operations could decrease.

Just-in-time signifies inventory as one of the seven wastes which are manufacturing, waiting time, shipment, inventory, processing, motion and product defect), and by definition its method includes the ideological goal of decreasing input buffer inventory to zero. Zero buffer inventories indicate that manufacturing is not secured from external impacts. As a consequence, external impacts decreasing the supply of input can simply reduce or stop manufacturing with substantial negative outcomes. For instance, Toyota experienced a vital supplier breakdown as a consequence of the 1997 Aisin fire which effected one of its suppliers inadequate of accomplishing Toyota's orders. In the U.S., the 1992 railway strikes ended in General Motors having 75000 ineffective employees due to not receiving supplies.

3.1. Advantages of Just-In-Time

As nearly all firms adopt an inventory system the most suitable for their organization, the JIT can have a lot of advantages resulting from it. The major advantages of Just-in-time are lined up below.

- Setup times are considerably decreased in the manufacturing plant. Lessening the set-up time to be more productive will let the firm to make better their bottom line to show more effective and concentrated on other fields that might need development. This allows the inventory held downgrading or totally removing to compensate the transition time, the SMED is being used in this process.

- The movement of products from storages to shelves are enhanced. Having workers concentrates on particular parts of the system will let them to process products rapidly rather than having them vulnerable to fatigue from multitasking at once and makes easy the tasks in the process. Small scaled individual piece lot sizes decrease lot suspension inventories which smooths inventory flow and its monitoring.

- Workers who have multiple skills are utilized more effectively. Having workers qualified to work on various sections of the inventory cycle system will let firms to use employees in conditions

where they are required when there is a lack of employees and an extreme demand for a specific product.

- Improved steadiness of scheduling and working hours. If there is no demand for a good at the time, employees don't need to be occupied. This can manage the organization capital by not paying employees for a task not finished or could have them concentrate on other tasks around the storage that would not certainly be done on a regular day.

- Raised the understanding of suppliers' perspective. No firm wants a gap in their inventory system that would make a deficit of supplies while not having inventory put on shelves. Having a reliable supplier relationship implies that you can have confidence in products being there when you require them for pleasing the firm and have the firm name in good condition with the public.

- Perpetual continuing supplies making employees productive and businesses concentrated on output. Having management concentrated on carrying out deadlines will make workers work hard to achieve the organizational aims to have advantages such as satisfaction, promotion or increased in wages.

3.2. Disadvantages of Just-In-Time

The biggest issue with JIT procedure is that it includes the both sides of supply chain which the supplier and end customers open to Supply Socks and big supply or demand adjustments. For internal causes, this was thought as a characteristic instead of a bug by Ohno used the metaphor of diminishing the amount of water in a river for revealing the rocks to demonstrate how eliminating inventory showed where flow of manufacturing was suspended. Once the barriers were displayed, they could be eliminated; considering one of the primary barriers was rework, minimizing inventory made it mandatory to each department to enhance its own quality or lead to a bottleneck in the next downstream operation. The other essential mechanism to handle this weakness is Production Leveling to eliminate these fluctuations.

JIT is a way to increasing performance of the system. With minimized amount of stocks mean that there are transportations of the same material receiving a few times per day, Toyota is specifically exposed to a suspension in the flow. Thus, Toyota is cautious to use more than one supplier for nearly all assemblies. There was an exclusion to this regulation that put the whole firm at risk by the 1997 Aisin Fire. Still, considering Toyota also underlines keeping high quality relations with tis whole supplier network, various other suppliers rapidly took up manufacturing of the Aisin-built materials by using current capability and documentation. Therefore, a healthy and longstanding relationship with several suppliers is chosen to temporary and price-based relationships with challenging suppliers. This longstanding relationship has also been used by Toyota to move Toyota personnel into their suppliers to enhance their suppliers' progresses. These mediations have currently been occurring for twentyfive

years and produce enhanced margins for Toyota and the supplier together with minimized end customer costs and a more trustworthy supply chain. Toyota advocates their suppliers to do the same method with their own suppliers.



4. 3D Printing

3D printing is a type of additive manufacturing (AM) style for manufacturing a large scope of forms and complicated geometries from 3D model input. The procedure involves printing consecutive layers of materials that are placed on top of each other. The beginning of this three-dimensional technology was advanced by Charles Hull in 1986 in a process recognized as stereolithography (SLA), which was tracked by consecutive improvements progressively like powder bed fusion, fused deposition modelling, inkjet printing and contour crafting. 3D-printing, which includes different techniques, materials and supplies, has developed over the decades and can convert producing and supply chain progresses. Additive manufacturing has been broadly adapted in various industries such as construction, dentistry and prototyping. The evolution of 3D printing in the construction has been with very heavy and inadequate even though the benefits of having fewer waste, freedom in composition and computerization.

New methods are appearing as new materials and additive manufacturing techniques are constantly being grown. One of the essential reasons for this technology to turn into more usable is referred to the termination of previous patents, which has provided producers the skill to establish new 3D printing machines. New developments have decreased the cost of 3D printers, by that increasing its operations in universities, houses, libraries and workshops. At the beginning, 3D printing has been broadly adopted by architects and engineers to manufacture esthetic and practical models because of its swift and cost-efficient modeling effectiveness (Mellor et al., 2014).

The 3D printing usage has diminished the extra costs that are obtained in the progress of developing a good. Nevertheless, it is just in the previous decade that 3D printing has been totally took advantage of its benefits in different industries from prototypes to products. Product modifying has been a tough for producers because of the huge costs of manufacturing special products for end-users. Contrarily, additive manufacturing is capable of 3D printing small numbers of special products with comparatively fewer costs. This is especially beneficial in the biomedical industry, where there is a need for unique designed products for every customer. Personalized useful goods are nowadays having an increase in 3D printing as forecasted by Wohlers Associates, who anticipated that about half of 3D printing will rotate around the production of commercial goods in 2020. This new technology has obtained the attention of the workplaces in the medical industry as a result of possibility to manufacture a wide scope of medical implants. Lately, 3D printing is efficiently being adapted in the construction fields. A small number of comparatively cheap houses in China were printed as mass production by WinSun in less than 24 hours.

The increasing general agreement on using the 3D producing system over traditional styles has many benefits such as manufacturing of complicated geometry with better accuracy, highest material savings, resilience in design, and private customizing. A broad scope of materials that are presently used in 3D printing are metals, polymers, concrete and ceramics. Mostly adapted polymers in the 3D printing are polylactic acid (PLA) and acrylonitrile butadiene styrene (Weller et al., 2015). In aerospace engineering industry, advanced metals and mixtures are commonly being used instead of traditional manufacturing progresses because the old versions require more time, cost and tough processes. Scaffolds and concrete are the mostly adapted ceramics which is being used in 3d printing and in additive manufacturing of constructions. Nevertheless, second-rate automated characteristics and anisotropic filtering of 3D printed basic parts quite restrict the reach the potential of massive printing. Thus, an advanced design of 3D printing is significant to manage flaw sensitivity and anisotropic texture filtering.

Changes in the 3D printers have an affect on the quality of finished goods. Additive manufacturing can produce parts of different sizes from the smallest to biggest. Still, the accuracy of the printed parts is reliant on the precision of the adopted technique and the scope of printing. For example, smaller 3D printing gives threats with the resolution, layer bonding and surface finish, which occasionally need processing style afterwards as sintering. Contrarily, the narrow materials usable for 3D printing create challenges in taking advantages of this technology in different sectors. Therefore, there is a requirement for advancing convenient materials that can be operated in 3D printing. New advancements are also essential to improve the mechanical features of 3D printed parts. The benefits of 3D printing of additive technology will proceed to rise through enduring study aspirations, which must be begun to figure out and remove limitations the use of this additive manufacturing technology.

An outstanding power of 3D printing is mass customization that is manufacturing of a series of personalized products like that each good can be divergent while managing to have a lower price because of mass manufacturing. 3D printing is free from the added cost by the reason of mould making and tooling for a customized good. As a result, mass manufacturing of a number of alike parts can be as cost friendly as the exact number of different personalized products. The difference between the designs is simple with slightly added cost and no require for extra arrangement. Additive manufacturing also has the ability for mass manufacturing of complex figures like lattice structures, where the use of traditional procedures of production is not simple and need additional time and procedure. Nonetheless, developments in the production speed and cost reduction has to be fixed over the development of machine design. Furthermore, the large cost and time factors of the additive manufacturing progress is still biggest barriers that prevent mass production.

4.1. History of 3D Printing

Even though 3D printing (additive manufacturing or rapid prototyping) is more famous lately, the first 3D printer was built in 1984 by 3D Systems Corporation. It was named as Stereolithography Apparatus (Bogue, 2013). Unfortunately, the technology for 3D printing was extremely expensive and not beneficial for any industries till 2000s. Nevertheless, in the 21st century, costs intensely diminished, letting 3D printers to meet with many industries. The 3D printer operates very much alike to the 2D inkjet printers and the most important difference is that 2D printers are printing layers of ink on paper materials, on the other hand, 3D printers use some materials to create 3D objects (Berman, 2012). The concept Additive Manufacturing contains many technologies with 3D printing such as, rapid prototyping, direct digital manufacturing, layered manufacturing and additive fabrication. AM is known as the industrial version of 3D printing and previously operated to create some niche materials in a lot of industries. The phrases AM and 3D printing have developed into alternate for each other. The phrase AM means that the technology or the additive progress of installing consecutive thin layers of material consequent to each other, manufacturing an end 3D product. Each of these layers are more or less 0.001 to 0.1 inches in depth (Wohlers Associates Inc., 2013). A large variation of materials can be used, specifically: plastics, resins, glass, ceramics, rubbers, concretes and metals (Bogue, 2013).

Rapid prototyping deals with the application of the technology. It is also known as the first application of Additive Manufacturing which also help to have its place in the market in an innovative way. It can be entitled to as the progress of rapidly building a model or prototype of a part of finished product. This part of finished product will be additionally tested and examined before mass manufacturing happens. Most of the commercial 3D printers, more or less, are having the same service capabilities. The 3D printer works with a computer-aided design (CAD) to convert the structure into a 3D item. Afterwards, the design is split into numerous 2D plans, which order the 3D printer where to locate the layers of material. In the recent years, many firms have welcomed Additive Manufacturing technologies and are starting to take advantage of the investment. The technology is developing and has found its route into many industries. Currently, it is being used in proto-typing and distributed production, aiding the next generation of customers use Additive Manufacturing. The 3D printing technology is moderately developing as a valuable method to advance internal effectivenesses which makes it now one of the trendy and most attractive enhancements in the design and marketing world currently.

3D printing is an industrial production progress with the potential to considerably decrease resource and energy requirements besides process related CO₂ emissions per unit of GDP (Baumers et al., 2011; Baumers, 2012; Campbell et al., 2011; Petrovic et al., 2011; Kreiger and Pearce, 2013). Opposite to traditional production subtractive processes, 3D printing contains additive means of manufacturing.

3D physical items are manufactured over layer by layer technique of material based on a digital blueprint. The technology developed throughout the 1980s when computing and control structures improved (Hopkinson et al., 2006). 3D printing has lately obtained much attention as the progress has demonstrated to be suitable with industrial production over just prototyping (Berman, 2012; Gershenfeld, 2012; Reeves, 2008).

So far, it is known that there are two different thoughts about the meaning of the concepts “3D printing” and “additive manufacturing”. On one hand, some researches think these concepts are interchangeable (Weller et al., 2015), on the other hand, some researches explain their dissimilarities (Mellor et al., 2014). AM basically identifies as the progress of joining materials to create objects from 3D model data, generally layer over layer. Meanwhile, even though 3D printing has a similar explanation, it also identifies as a form of technology which engages AM together with stereolithography, fused deposition modelling and selective laser sintering (Mellor et al., 2014; Kulkarni et al., 2000). Since the beginning of 2010, the phrase “3D printing” has evolved into a keyword promoted by experts and is probably one of the more known phrases for the whole society (PADT, 2016).

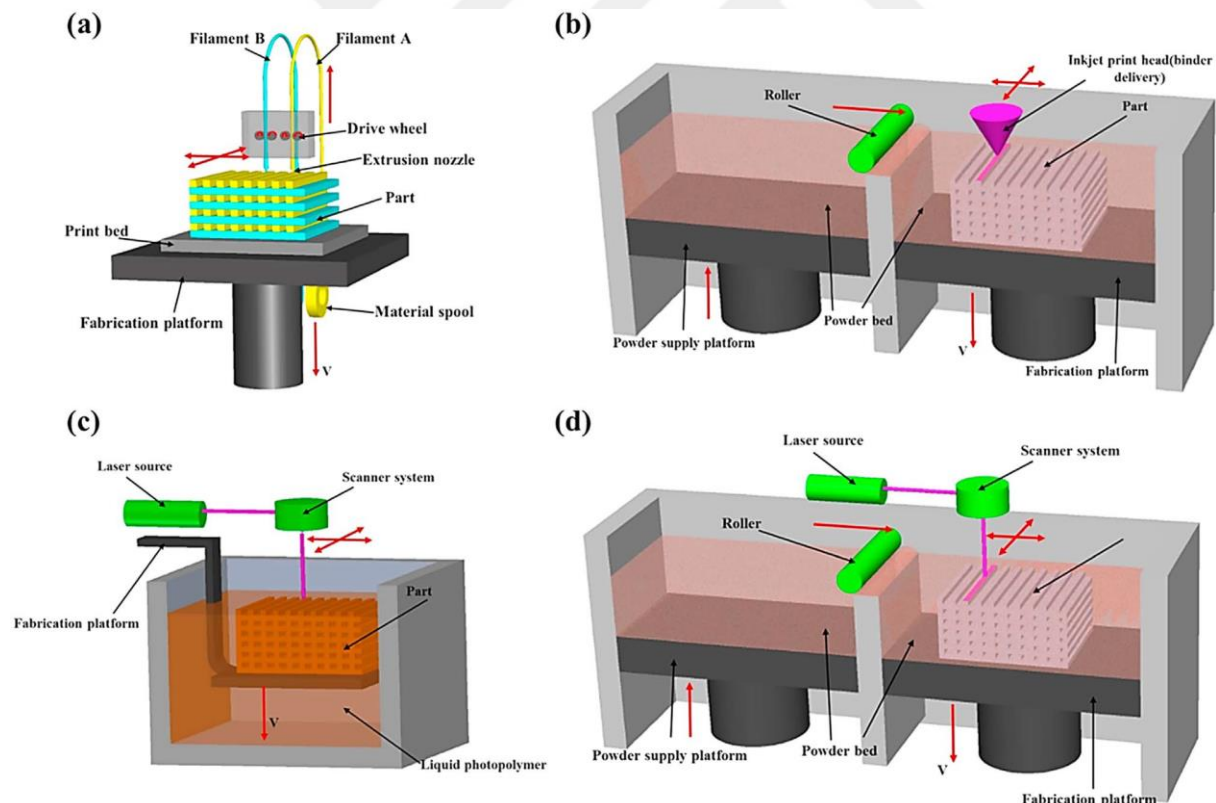


Figure 4.1: Schematic diagrams of four essential techniques of additive manufacturing: a) Fused deposition modelling, b) Inkjet printing, c) Stereolithography, d) Powder bed fusion

The capability of 3D printing literally lies in the truth that it considerably decreases the time interval between tool changes on a bigger scaled manufacturing line and grants for numerous innovations on a material during the production process; while keeping the degree of customization of resulting mass manufacturing is greater (Hasiuk, 2014; Rayna and Striukova, 2016; Kapetaniou et al., 2018).

The economic advantages from 3D printing technology especially contain the further promotion and enhancement of production, retailing and health care (Jia et al., 2016). Allied Market Research (AMR) indicates the difference of 3D printing market value between 2013 and 2020 from 2.3 billion to 8.6 billion US\$ at an annual rate of 20.6%.

Even though 3D printing has gathered a lot of benefits for enterprises, it has not been extensively utilized. For instance, Wohlers and Gornet indicated that the share of 3D printing in the production market was less than 2% in 2014. Furthermore, a lot of factory companies are still troubled to combine this up-and-coming technology into their manufacturing lines and optimization of goods. In general, it appears that the acceptance of 3D printing has become a big challenge for industries.

While the technology has considerably improved in recent decade, thus costs are also decreased undoubtedly, so the manufacturing of some low-volume and complicated parts by 3D printing is a new way as economically has benefits while decreasing the costs and complicatedness in materials management.

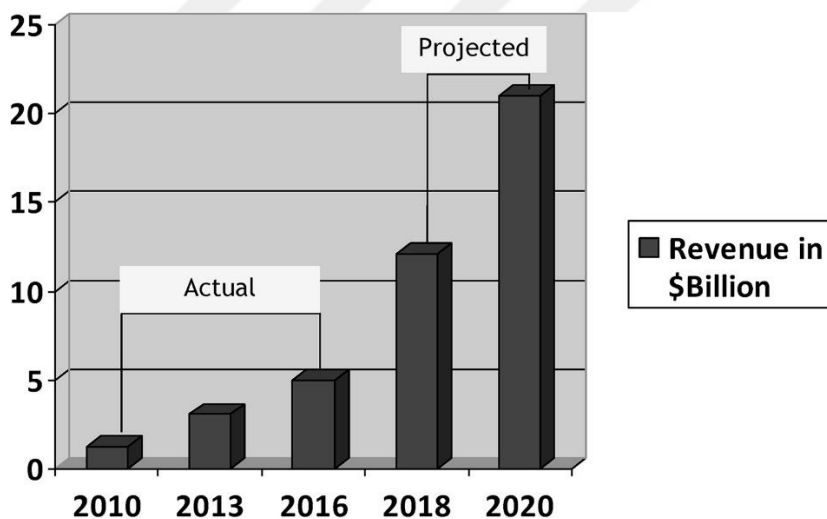


Figure 4.2: Expected worldwide revenue of additive manufacturing

Source: Wohlers associates inc., 2014

The international revenues from additive manufacturing were \$3.07 billion in 2013, and was anticipated to grow into \$5 billion by 2016, \$12.08 billion by 2018, and reach more than \$21 billion by 2020 (Figure 4.2). Unfortunately, the anticipated growth did not happen greatly and by 2019 the worldwide revenue of AM is \$10.41. This time it was expected to be \$32.89 by 2025 and \$53.84 by

2029 (Figure 4.3) but due to Covid-19 issue all around the world, it may end up with less than these figures. Both figures illustrate that the additive manufacturing market that is increasing strongly. Drivers for the fast growth are the decline in cost to reach the technology besides the increase in applications (Wohlers, 2014).

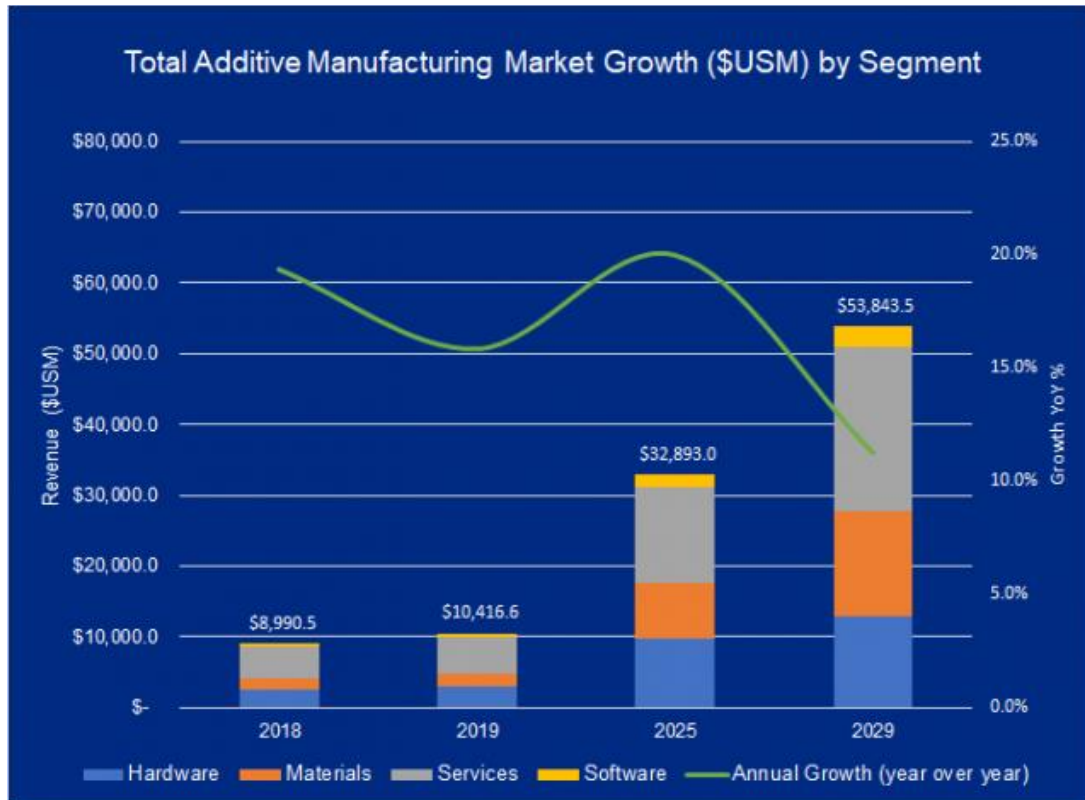


Figure 4.3: Total additive manufacturing market growth by segment

Source: 3druck.com

4.2. Types of 3D Printers

There are 18 different types of 3D printing processes according to Hopkinson et al., (2006). These types can be separated by the physical condition of the printed material (liquid, solid and powder-based techniques) and by the used procedure to fuse material on a molecular level (thermal, ultraviolet light, laser or electron beam) (Hopkinson et al., 2006). The most frequently used processes are: Fused Deposition Modelling (FDM), Powder Bed Fusion, Selective Laser Melting (SLM), Electron Beam Melting (EBM), Selective Laser Sintering (SLS) and Stereolithography (SLA, Petrovic et al., 2011).

Polymers, alloys of aluminium, steel and titanium together with ceramic composites are presently possible to print out at a minimum layer thickness (20-100 μm) subject to the process and the physical condition of the material (Hopkinson et al., 2006). Thus, 3D printing can be used to numerous production industries. It capacitates a potential replacement of traditional manufacturing

processes. 3D printing has the considerable benefit of facilitating the achievement of complex free shape geometries, as the production process is not blocked by the technological barriers of traditional production processes (Reeves, 2008).

Techniques of additive manufacturing have been grown into to satisfy the demand of printing complex forms at great determinations. Additive manufacturing has developed well with the help of essential determinants like rapid prototyping, the capability of printing large forms, decreasing printing defects and developing mechanical properties. The most known technique of 3D printing that generally uses polymer filaments is noticed as FDM. Furthermore, AM of powders by SLS, SLM or liquid binding in 3D printing, together with inkjet printing, contour crafting, SLA, direct energy deposition and laminated object manufacturing are the common techniques of additive manufacturing.

Fused Deposition Modelling

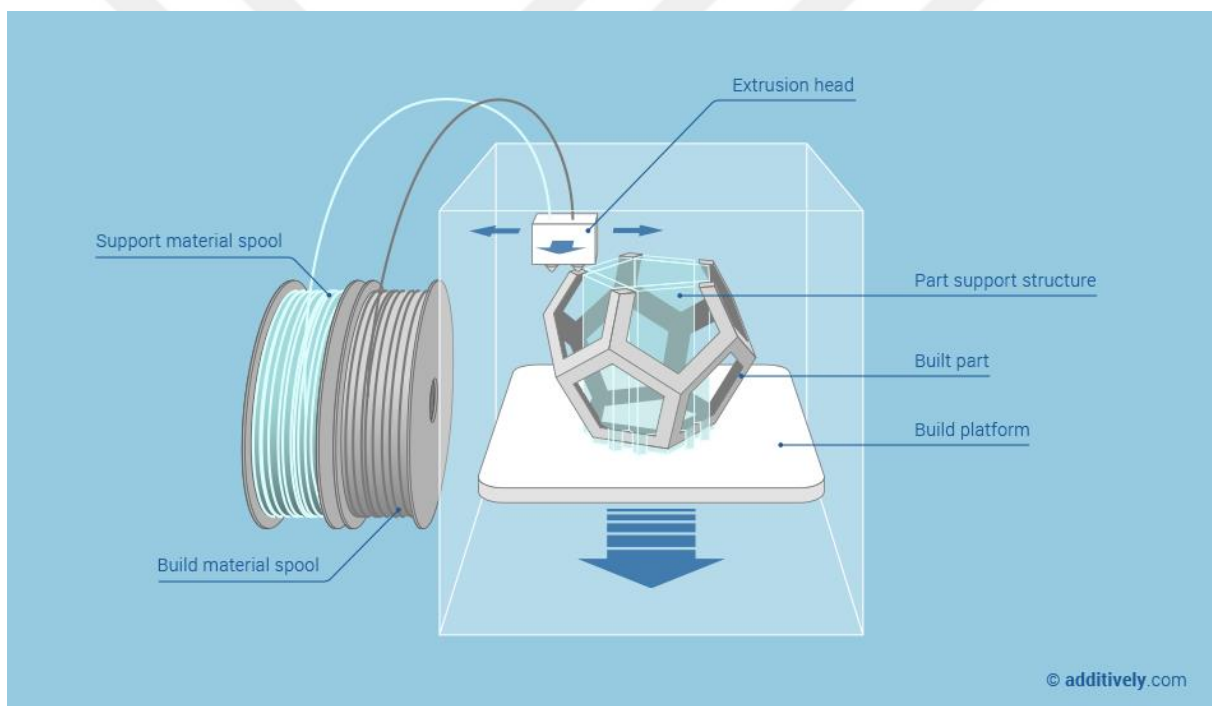


Figure 4.4: Fused Deposition Modeling

Source: additively.com

In fused deposition modelling technique, to 3D print layers of tool a repeated filament of a thermoplastic polymer is being operated. The filament is warmed at the nozzle to become a half-liquid condition and afterwards ejected on the stand or on top of formerly printed layers. The most important tool for this technique is definitely the thermoplasticity of the polymer filament, that lets the filaments to fuse all at once in the moment of printing and from then on, harden at 20-22 centigrade after printing. There are three essential processing criterions influence the mechanical characteristics of

printed units: The layer thickness, width and adjustment of filaments, and air gap. Inter-layer deformation was established to be the leading reason of mechanical weakness. Fused deposition modelling's essential advantages are being low-cost, rapid and having a simple process. Contrarily, the biggest disadvantages of FDM are unsteady mechanical characteristics, layer-by-layer appearance, inadequate surface quality and a limited amount of thermoplastic materials. The advancement of fibre-reinforced fusion adopting Fused deposition modelling has reinforced the mechanical characteristics of 3D printed units. Yet, fibre orientation, void formation and connecting the fibre and matrix are the major threats that appeared in 3D printed composite materials.

Powder Bed Fusion

Powder bed fusion processes contain thin layers of exceptional powders, that are spread and intimately loaded on a platform. In each layer, there are powders involved and those powders are fused jointly before the final 3D unit is made. After the printing process, the remaining powder is then evacuated by a vacuum and if required, additional processing and analyzing like coating, sintering or infiltration are accomplished. To increase the efficiency of Powder bed fusion technique, powder size distribution and packing are the most important factors which is directly affecting the density of the printed units. The laser can only work with the powders with a low melting temperature which is below 232 centigrades, considering that a liquid binder should differently be used.

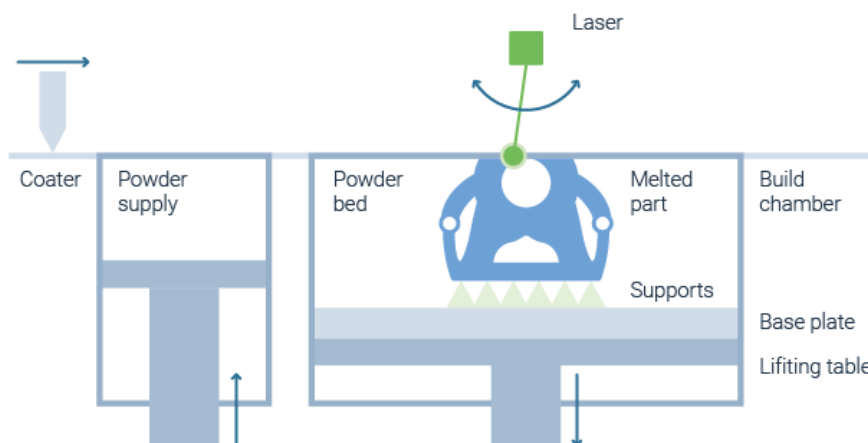


Figure 4.5: Powder Bed Fusion

Source: additive-manufacturing-report.com

Selective Laser Melting

SLM is known with many other names such as “Direct Metal Laser Sintering” and “Laser Cusing”. The process of SLM was described as a thin layer of metal powder is selectively melted by a laser and those

layers are built up layer by layer in the powder bed (Figure 4.6), and it is being used mostly in the areas of prototypes, support parts, small series parts and tools (Additively.com, 2018). The SLM technology produces parts in standard metals with more than 99% density, and generally has better mechanical properties than conventional manufacturing processes. On the other hand, selective laser melting is comparatively more expensive and slower than traditional production processes. It is being expected to get better over post-processing.

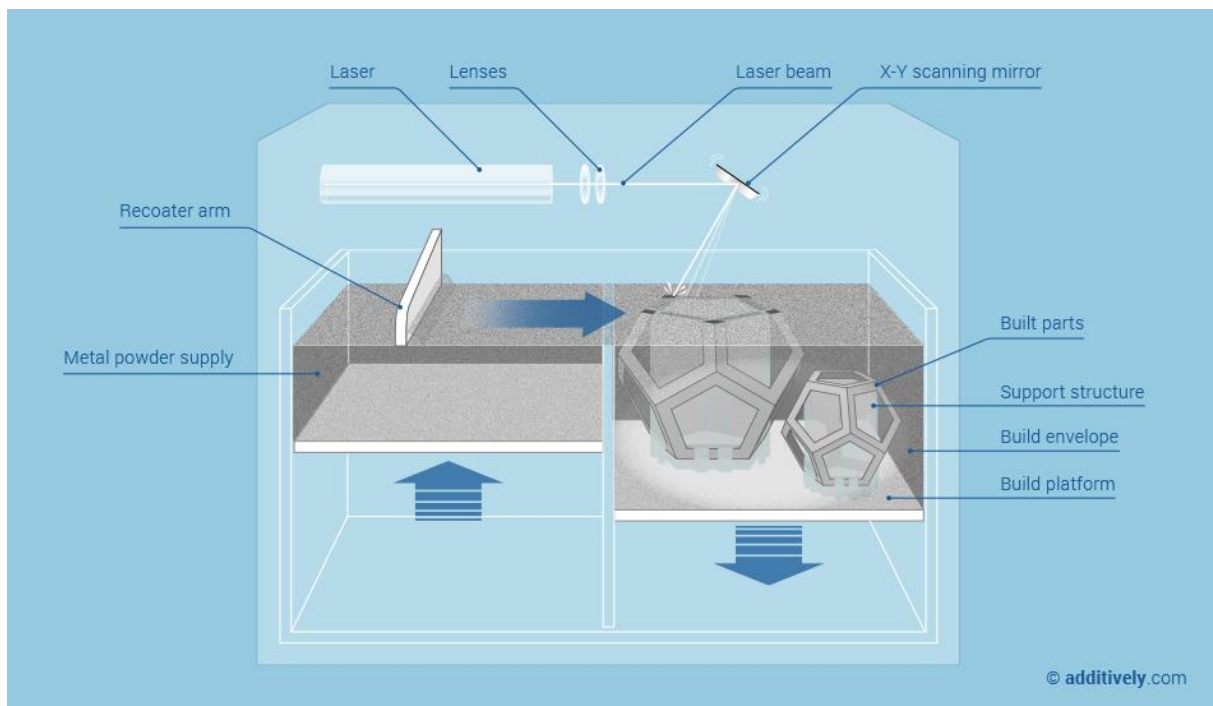


Figure 4.6: Selective Laser Melting

Source: additively.com

Electron Beam Melting

The Electron Beam Melting process is described as a thin layer of metal powder is selectively melted by an electron beam. In EBM, the parts are built up layer by layer in the powder bed just like in the SLM. The difference basically between is instead of laser melting, EBM is working with an electron beam (additively.com, 2018). The requirement of support structures in EBM allows the send away from where the powder is melted which as a result decreases thermal stresses and eliminates warping (Figure 4.7). EBM has generally the same advantages and disadvantages. The only extra disadvantage is that the EBM technology does not achieve equally good surface finishes in comparative with SLM (additively.com, 2018).

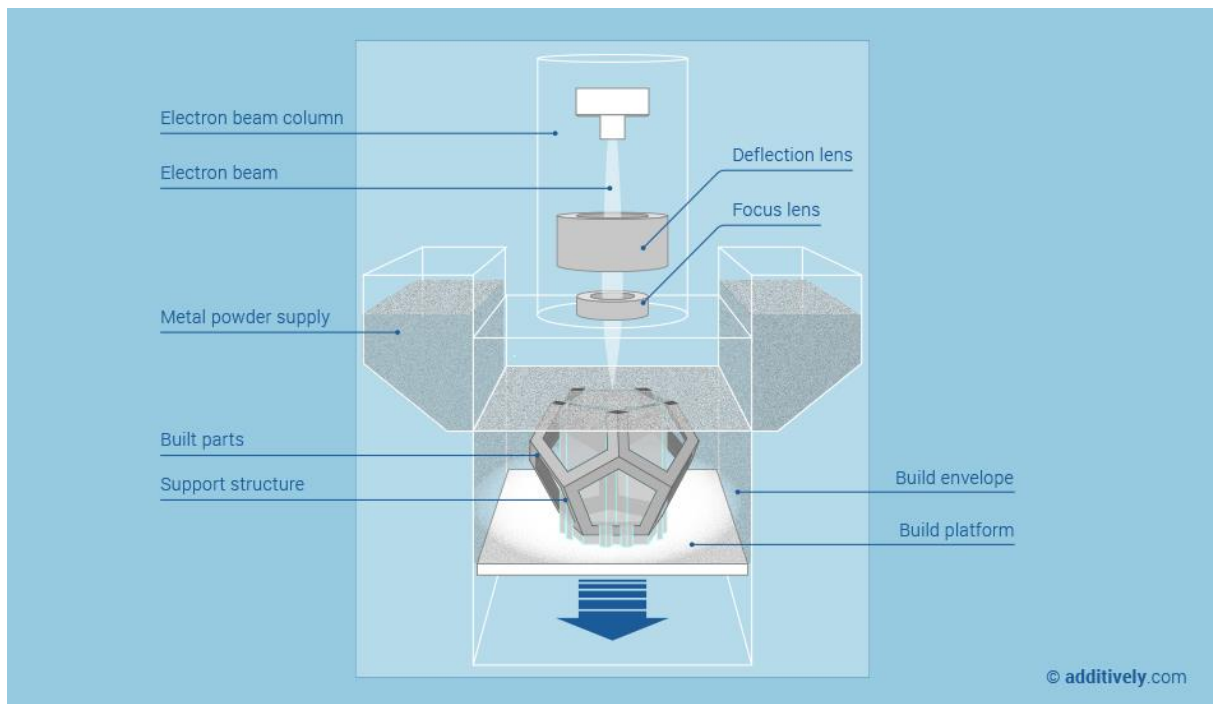


Figure 4.7: Electron Beam Melting

Source: additively.com

Selective Laser Sintering

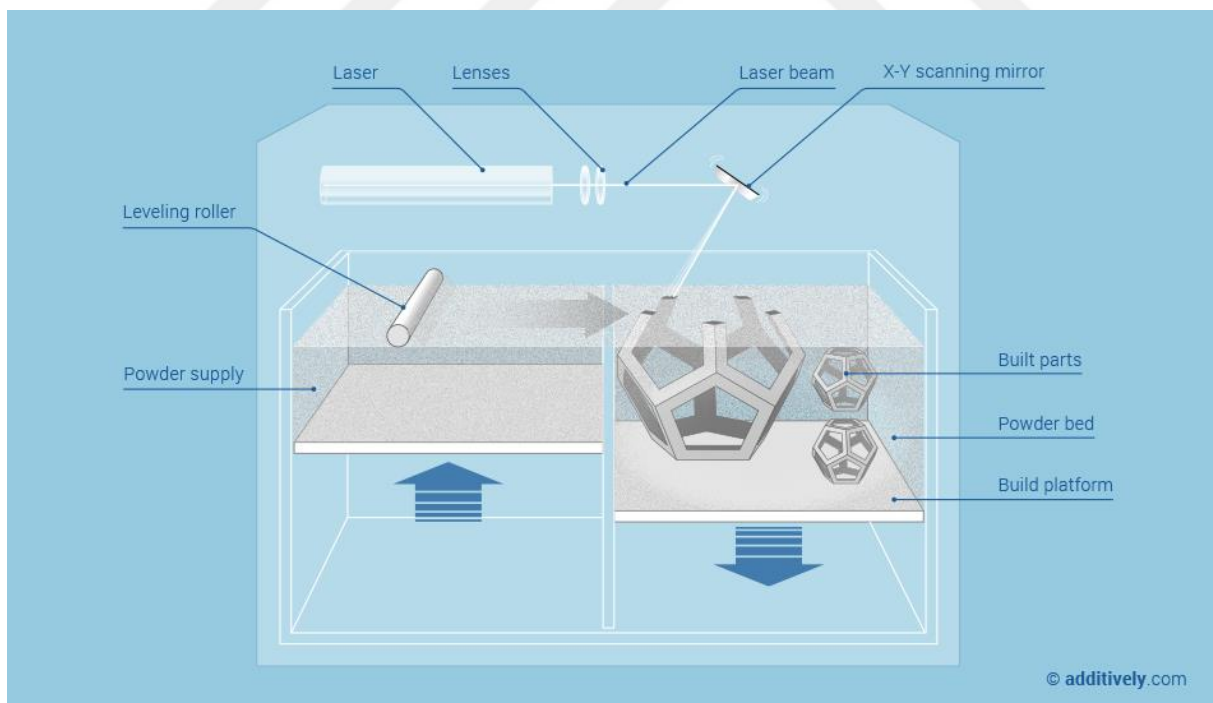


Figure 4.8: Selective Laser Sintering

Source: additively.com

Selective Laser Sintering is one of the most known 3D printing techniques. Its fame arises because SLS can produce parts in standard plastics with good mechanical properties. The best advantage of SLS is especially being cheaper for small sized products. It can be used in the areas of prototypes, support parts and small series parts (additively.com, 2018).

Stereolithography

Stereolithography process is defined as an ultraviolet laser is curing a liquid photopolymer in a vat and that part is built by lowering the build platform into the vat (additively.com, 2018). It works by controlling a very strong laser to harden liquid resin that is included in a tank to build the forecasted 3D shape (Figure 4.9). Stereolithography together with FDM and SLS is one of the three main technologies adopted in 3D printing. The SLA was found in 1986 and first version of itself built in 1992. The biggest advantage of SLA is the scale of products which means the more expensive the 3D printer, the higher quality product will be produced. On the other hand, the biggest disadvantage is that printing takes a long time in this technology.

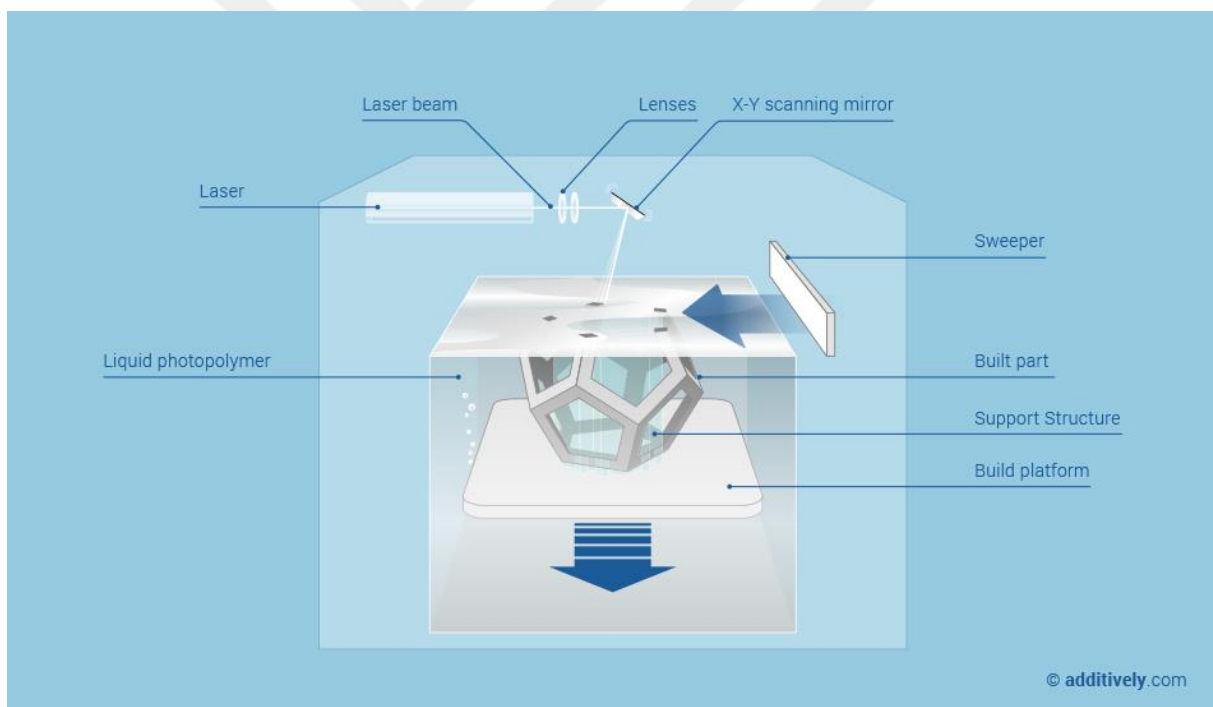


Figure 4.9: Stereolithography

Source: additively.com

4.3. Impact of 3D Printing on Spare Parts and Assembling

The future of spare parts supplying will be insufficient. Some of the manufacturing companies already started investigating of their own spare parts with 3D printing. Moreover, globalized firms are using all their products that might be needed in any locations of the world. When a consumer demands a

specific part, it is being challenging to supply a predetermined high level of service at the same time having a minimized cost (Pwc's, 2017). The most important part is manufacturing the spare parts equally close in the supply chain of a company which can be rapidly transported. Using 3D printing for spare parts and assembling helps to decrease costs and increase customer satisfaction because the stocks and lead time will be decreased while the process will be accelerated. Some companies still prefer using make-to-order over make-to-stock which is also decreasing the inventory costs but increasing the transportation time which at the same time decreasing the level of the service. On the other hand, 3D printing will be used for bigger companies especially for the huge equipments to decrease the total cost.

A recent study shows that, in five years of time, more than 80% of spare parts manufacturers will integrate 3D printing into their enterprises (Pwc's, 2017). The beginning of using 3D parts will be the especially complex parts which will be easier than manufacturing in old ways.

In next five years, 3D printing will be used as a serious complementary method besides normal manufacturing, and it is being forecasted as year by year the usage of 3D printing will be increased.

The introduction of 3D printing will be about low, complex and high-performance parts. The important point about 3D printing is that firms can begin printing spare parts in any of the products' life cycle because 3D printing does not need tooling. According to a study about 3D printing usage about spare parts in the close future will be 10 to 25 percent, and at the same time almost all the companies will start assimilating 3D printing (Baya et al., 2014).

The technology will affect the usage of 3D printing in product life cycle stages' where will be used mostly. Spare parts will have an uprise with 3D printing in the business because materials management system will shift to 3D printing (D'Aveni, 2015). 3D printing of spare parts will be faster and and at the same time logistics waste will be decreased. There will be many advantages of printing spare parts in the future. Most important one is, the inventory levels and costs that firms have will be decreased because make-to-stock strategy will be transformed to make-to-order with decreasing lead times. Furthermore, the needed parts can be produced anywhere needed. This will end up with decreasing lead times and less complex logistics strategies. Thus, for manufacturing companies, assembling huge equipments with the help of 3D printed parts will be easier. Transporting a huge equipment from the production place till the end customer has many problems. Time and cost are the most critical ones. But in the future, assembling the 3D printed parts anywhere needed in the world will be easier, cheaper and faster. This will also provide customers a higher level of service.

There is already a sample case about 3D printing. It can be seen in the case of world's first 3d printed injection nozzles for production jet engines at General Electrics Aviation that how 3D printing worked (Pwc's, 2017).

General Electrics Aviation is the world's biggest jet engine manufacturer. Before 3D printing, the injection nozzles had 18 different parts which all of them had to be supplied from various merchants before assembling stage. 3 years ago, GE started to use 3D printing to manufacture the same tool. 3D printing helped to decrease 18 different parts into one. Extra benefit of 3D printing in this case was reduced weight. New injection nozzles produced by 3D printers were 25% lighter. To sum up, durability of the product was increased conversely reduced costs.

The case was simple; thus, it can be seen that the future of materials management will include 3D printing for sure with reduced supply chain complexity. When 3D printing is going to be used efficiently in full potential with increased production, the costs will have an extra decrease as it was described as economies of scale.

3D printing will not be shifted in the industry of assembling and spare parts instantly. Those companies who will add 3D printing into their supply chain even though it would be slowly, will sustain an advantage in the competition as using first-moving as a trump card in the technology stage of global materials management.

In the last stage, there will be another question between outsourcing the printing of raw materials and spare parts or owning 3D printers and manufacturing. In that case, partnering would be an essential step towards to profitable future.

4.4. 3D Printing Adoption

There are many motives why 3D printing acceptance has escalated in the previous years. Initially, year by year, the broadcasting of 3D printing in social media in addition to industry conferences is increasing (Columbus, 2015). The recognition of 3D printing technology and its potential is expanding over digital platforms where people from higher management to lower level workers are enlightened of the different purposes and advantages of 3D printing developments. Secondly, the cost of 3D printers is currently very expensive, for example, comparatively smaller 3D printers are priced between \$500 and \$10,000, considerably less than five years old (Columbus, 2015). While this expensiveness has slowed down the swift adoption of 3D printing in the industry, customers are now understanding the reasons of 3D printing usage besides potential utilization for their daily lives.

Logistics companies are currently embracing 3D printers for customer use, creating a new market demand for production to making use of the advantages of 3D printing for better customer

collaboration besides having the competitive benefits in a brand-new industry which demands rapid, effective and personalized products. Nevertheless, determined the huge cost implications of 3D printing, the thought of its profitability still remains doubtful.

4.5. Advantages of 3D Printing Investment

With the public division trying to reinforce 3D printing usage along with customer interest the personalizing advantages that it provides, the production industry is noticing the increment of external demands for adoption (Columbus, 2015). Even though the current promotion of 3D printing in production, companies will need to regulate a cost benefit analysis to figure out the profitability that an organization can accomplish in adoption of 3D printing.

Additive manufacturing is doubtlessly innovative; it creates new opportunities and grants itself to many chances for firms searching to develop production effectiveness. AM unquestionably reduces traditional manufacturing techniques and has the capability to become the main manufacturing method over the next decade. Many researches believe that, additive manufacturing is a strong tool to decrease complexity in the supply chain over different ways.

There are mainly five essential advantages that additive manufacturing has more than traditional manufacturing: Cost, speed, quality, transformation/innovation and impact. 3D printing will not take the place of traditional manufacturing techniques, currently. Still, it is predicted to be change year by year in the next decade. More than replacing the conventional production method, it is anticipated to reform many niche industries. A growth is expected on 3D printing in many areas, especially with the spare parts production. Studies clarify that savings in cost and time have been forecasted.

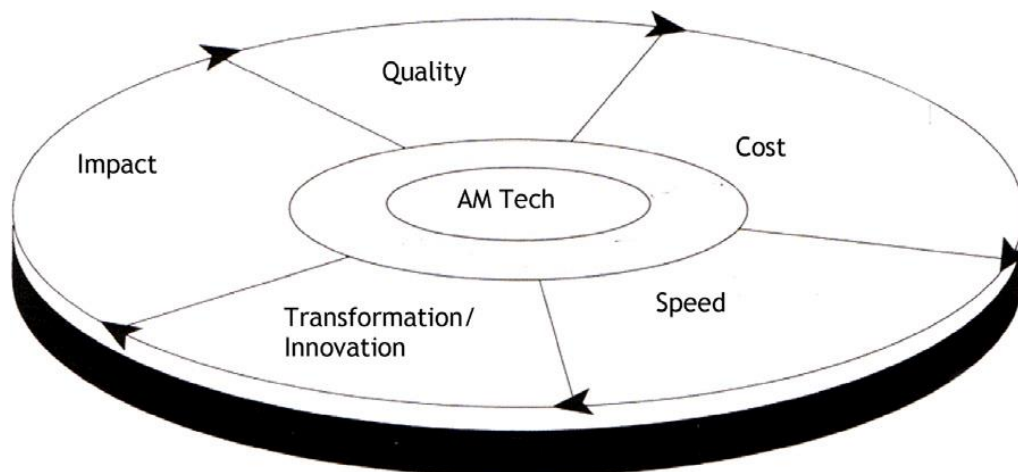


Figure 4.10: Five essential advantages of additive manufacturing over traditional manufacturing

Source: Business horizons (2017)

4.6. Potential of 3D Printing and The Challenges Over Conventional Manufacturing

3D printing, is a freshly built manufacturing process (Petrick and Simpson, 2013; Ford, 2014; Rayna and Striukova, 2016). 3D printing is a compilation of digital production technologies that manufacture layer-by-layer parts with utilizing the all materials and is formed on computer generated designs. A digital design can be reformed with the help of unification of materials with an energy source (Berman, 2012; Pearce et al., 2010). This production method requires a laser, binder or an electron beam to harden the item after being scanned over in the design process. The potential of 3D printing basically indicates that polymers, metals and ceramics were the most successful application samples amongst all.

Mellor et al. (2014) determined a way for implementing determinants linked with materials from additive manufacturing technology. The researches proved the influence that additive manufacturing technology has in both economic and technological industries is also displayed. There are eleven critical capabilities of additive manufacturing and 3D printing to challenge many conventional production restrictions below:

Industrial Effectiveness

3D printing of spare parts achievable to the customers could be an extra feature of the industry reformed by 3D printing technology which would make it attainable for customers to print their own spare parts for repairing their bought products. In the beginning, basic spare parts will be sold internationally by just downloading a 3D printing file which will make customers a micro-manufacturer.

Mass Customization

The 3D printing technology allows mass customization at low cost. Designers can change and personalize products without extended delivery times.

On-Demand Production

3D printing simplifies easy, on-demand production of spare parts. The additive manufacturing technology makes it real to have spare parts printed in far locations by local distributors and service providers. Thus, the shipment of goods is not a barrier anymore. This eventualizing in the reduction of the supply chain and saving as transportation and reserving inventory is not required. The demand for large bulk inventories will stay in the history.

Decentralized Production

The technology could possibly decrease the requirement for logistics as designs could be supplied digitally, proceeding to a decentralization of production. By producing products closer to the final

destination, it is possible to decrease the logistical costs and environmental impact. This also diminishes the time from manufacturing to marketing (Paris et al., 2016).

Component Production

The manufacturing of component parts is one of the essential functions of 3D printing. Industries that mostly use this technology need low quantities of basic parts that must be printed to specific requirements with little patience. More than 20% of the additive manufacturing market is consisting of component part manufacturing for the aerospace and automotive industries (King, 2012). The Aerospace industry had as well as 22,000 parts in use (Royte, 2013). The degree of accomplishment and development of additive manufacturing in these industries is a signal that the degree of quality increasing from additive manufacturing parts is adequate against difficult industry standards.

Printing Whole Systems

3D printing technology has the capability to print entire systems or subsystems. This multimaterial power will aid since most end products are built from more than one material. Other fields being processed on involve materials, printing techniques and merging additive and conventional techniques of production.

Quality Enhancement

The 3D printing technology has the capability for increasing quality. For instance, in medical cases, patients are getting a better treatment with 3D printed implants and prosthetics. Furthermore, it also aids firms to advance their aftermarket services. As production stage is getting closer to the customers which makes them potential producer-customers.

Adjustments and Redesigns Without Penalties

3D printing is not just about the physical manufacturing of a unit. It simplifies design and innovation with less time and cost. This is very crucial when you think that more than 60% of designs for manufacturing are rechanged in the production process which can directly lead to raising the costs and time delays. 3D printing allows engineers to test different repetition with less costs than conventional manufacturing methods.

Increased Supply Chain Efficiency

3D printing could facilitate the production parts at a digital plant near the production place when and where they are required, getting rid of lost time and costs related to transportation of parts globally. Moreover, 3D printing allows for real-time visibility to manufacturing and delivery of parts. In the process of 3D printing, regular production time and cost are minimized over the process.

Environmental-friendly Production Initiatives

3D printing leaves less environmental footprint than traditional manufacturing due to not wasting material more than needed in the production process.

Production of Parts on Demand

Being able to reach basic parts almost promptly permits for a more adaptable product enhancement and design process.

Furthermore, the advantages of 3D printing to production have evolved into more productive as the technology progresses to enhance in adaptability and efficiency. 3D printing has gathered an epidemic development in the amount of materials a 3D printer can use to create units (Columbus, 2015). This development in the amount of materials has helped improve operations in a range of production industries (Bourell et al., 2009; Campbell et al., 2012; Gardan, 2015; Starr, 2015). The industries had the most improvement amongst those are: the aerospace and defense, construction, automotive and healthcare industries. So far, 3D printing has been utilized to build topographical models, airplane engines, aerodynamic car bodies, personalized prosthetic tools and actual living quarters (CSC, 2016).

Future paths are concentrated on military utilizations containing the printing of substitute parts in the combat zone instead of counting on restricted spares and supply chain effectiveness (CSC, 2016). These utilizations, still, are relied on the corresponding benefits 3D printing supplies through conventional production involving: the capability to print spare parts in a less duration (Bernard and Fischer, 2002), and advancing the producibility of very complex goods. Eventually, this advantage will rely on the next developments of 3D printing technologies. Nevertheless, with the late arrival of 3D printing enterprises who concentrates on advancing the complexity of 3D printed items, other possible advantages of producing might appear (Reese, 2016). These advantages consist of decrement in time to market, material savings by having less production processes, fewer demand for tools, molds or punches, advanced density of end product and creation of free-form designs (Petrovic et al., 2011).

Even though these advantages have helped and continue to boost the volume of attention to 3D printing in production, the technology still has yet to attain high levels of acceptance (Ders, 2014). Together with the advantages, disadvantages have to be deliberated for determining the suitability of 3D printing adoption in production.

Significant benefits of 3D printing, in comparison with traditional manufacturing methods is cost efficiency and speed. On the contrary of conventional production, 3D printing requires comparatively low fixed costs as it does not demand high-priced production. Therefore, it is specifically cost efficient for very small manufacturing lot sizes, allowing companies to profitably handle niche markets and satisfy very personalized consumer demands. Compared to conventional production techniques, 3D

printing wastes less material especially decreasing the waste of metal applications by 40% (Petrovic et al., 2011). One of the best uses of 3D printing is, more than 95% of waste material in the production process can be reused. In comparison with traditional manufacturing techniques, the costs per part do not reduce with the size of the manufacturing lot considering a little or no change at all over time. Furthermore, 3D printing aids to decrease the time-to-market, taking advantage of fast prototyping. The most applicable industry for 3D printing technology is specifically the aircraft, automotive and the electronics industries due to serial manufacturing. These sections exceptionally profit from weight savings without a need to assembling.

4.7. Disadvantages of 3D Printing and Elements Affecting 3D Printing Implementation

Since it is a kind of brand-new technology, studies about 3D printing is just in its infancy but there are widely known disadvantages of it. External force, technological, organizational, strategic and operational factors, and supply chain are the elements that are influencing 3D printing implementation (Mellor et al., 2014). Muita et al. (2015) mentioned that the implementation of rapid production is influenced by business problems like business models, industry characteristics, and goods or service conversions, while some other studies about supply chain as the slightest affected section of this type of production. Meanwhile, Attaran (2016) identified the main barriers for 3D printing implementation as technology, cost and material. Furthermore, the size of manufactured products, government regulations and restrictions on cost also affect 3D printing implementation.

Founded upon the technology acceptance model, both direct determinants and influential impacts affect 3D printing implantation for Chinese consumers (Wang et al., 2016). Considering the research of Wang et al., 3D printing implementation is sloped down to be influenced by the external reasons where the business companies exist. Moreover, other researches attended on another singular element: Technology. In this manner, more studies should be committed to the introduction and analysis of business relevant determinants for the problem of 3D printing implementation.

Technology-organization-environment (TOE) framework is considered as a strong instrument for evaluating the elementary determinants when adapting new technology in a given enterprise. Covered by this framework, analyzers are inclined to select numerous organizational, technological and environmental determinants for different technologies for making the TOE framework adaptable in extensive circumstances (Baker, 2012). Based upon TOE framework, this study provides and investigates an implementation technique for 3D printing.

Besides the TOE framework, together with other technologies, cost factor is having an essential role in 3D printing implementation (Kreiger et al., 2014; Brooks et al., 2014; Weller et al., 2015). More correctly, numerous kinds of costs for things such as hardware or materials are included in the entire

cost of 3D printing implementation. Furthermore, over the concept of cost-benefit analysis, Thomas (2015) analyzed and described societal investments and outputs of 3D printing implementation, whereas Weller et al. (2015) indicated the economic and technological aspects of production companies during the process of 3D printing implementation. In this circumstance, various determinants correlated with the costs of 3D printing implementation require to be considered before extensive application of the technology shows up.

The application of 3D printing in production is still a novel concept that can take some time to being widely embraced. On one hand, advantages help the process of adoption, on the other hand, potential costs and disadvantages slow down its extensive use. Initially, in terms of environmental problems, modern 3D printers waste 50 to 100 times more electrical energy than traditional manufacturing for creating a product with the same size and weight (Gilpin, 2014). Additionally, contingent upon the kind of material used, 3D printers might also decelerate the movement over ending dependence on plastics (Gilpin, 2014).

Other disadvantages contain regulatory and legal problems that have appeared because of the increment usage of 3D printing. For instance, regulation will need to improve, to look after producers' intellectual property as customers might collaborate with companies to build black illegal sales copies. Furthermore, liability of the producer becomes an issue with 3D printed items that can sabotage customers through a decrease in quality or usage of agents. There are still a lot of filaments that are BPA-free are not ready to use in 3D printers. For instance, 3D printed kitchen equipments have been demonstrated to include empty spaces where microorganisms conveniently appear (Gilpin, 2014). Additionally, Petrovic et al. (2011) has clarified other ongoing disadvantages containing: the surface quality and roughness of 3D printed units and the variety of support structure used. These quality concerns might cause legality problems for production.

Last but not least, the cost of initial investment is one of the drawbacks of 3D printing implementation. 3D printers are currently made possible to be utilized in the consumer market. This possibility has considerably changed the viewpoint of initial investments in 3D printing technology for production use. Customer level 3D printers may change between \$500 as a small desktop printer to amounts between \$7000-10,000 for middle class 3D printers. Though, these are not the prices which are being used for practical quality prototyping. 3D printers which are related to manufacturing have larger print volumes, and better resolutions. Even though prices are usually not easy to determine because of 3rd party sales, in some studies the prices were approximately categorized between \$250,000 and \$850,000 (Sculpteo, 2014).

Enterprises have to consider not only the advantages and disadvantages to 3D printing adoption, when analyzing the 3D technology's RoI, but also considering its practicality in the business. Every year more diverse industries are adopting the 3D printing technology in their production techniques. So far, the researchs indicated that 3D printing is being used eighteen of twenty-one North American Industry Classification System production industry categorizations. As mentioned above, 3D printing applications are speedily developing and becoming more accepted in the aerospace, automotive and heal care industries but, lately there has been a progress in the food manufacturing as well as petrol production (Shell, 2015). Studies signified that 3D printing is starting to show-up in industries that were once treated not applicable to the 3D printing industry. In a nutshell, producers have to consider the adoption implications of 3D printing, as conception of 3D printing is expected to affect an increasing amount of production industries. The usefulness of 3D printing to production is driven by the advantages. Fundamentally, 3D printing proceeds to be utilized in many industries. The issue of localization of production has led the direction towards 3D printing. Still, adoption of the technology is at its beginning times yet, even with the reality that 3D printing has been alive for decades.

4.8. Socio-Economics Perspective of 3D Printing

Currently, by reason of limited manufacturing agilities and other technological barriers 3D printing is primarily suitable to small manufacturing amounts, customized and/or high-value products (Berman, 2012; Hopkinson et al., 2006). Forecastings define 3D printing as a new technology planned to create shifts in manufacturing designs over more complex figures (Berman, 2012; Hopkinson et al., 2006), reasons for the consumer involvement in manufacturing processes over digital platforms including reorganization of supply chains over more online and localized ways (Campbell et al., 2011; Reeves, 2008). Some studies regard the digitalization and adjusting of production driven over 3D printing a crucial form of the "Third Industrial Revolution" (Rifkin, 2011). The TIR is being specified by Rifkin (2011) as an era of a renewable energy powered economy, which distributes its information on digitalized tools. 3D printing allows an innovation in material, energy and greenhouse gas intensities with the same importance as labour capacity raises.

3D printing is believed to be a new industrial revolution as Anderson (2012) indicates the potential of equalizing production processes over digital-distributed blueprints and localized manufacturing. 3D printing is being defined as section of a social change, which transforms data into units and units into data and for that reason it provides a knowledge-based economy (Gershenfeld, 2012). Furthermore, Gershenfeld (2012) foresees a planet where decentralized physical manufacturing and internationally distributed information improve the barriers of socio-economic activity.

4.9. Cost Dimension of 3D Printing

Cost is also another essential prospect for finding out the gain of 3D printing. The cost of 3D printing is determined on the basis of various elements such as the fixed cost of printing resources, operational and maintenance costs. Moreover, 3D printing implementation is correlated with different types of associated investment like hardware, software or system integration investments (Baumers et al., 2016; Heath, 2015; Ruffo et al., 2007; Thomas, 2015; Allen, 2006). Depending on the various and broad types of costs, companies may imagine a considerable number of expenses linked to this kind of project like material, machine and labor cost.

The reduction in the amount of parts besides having less assembly steps result in a considerable decrease of manufacturing costs as compared to traditional production techniques. Merging an assembly into one spare part may also decrease subcontractors in the supply chain besides diminishing costs of coordination. 3D printing lets firms to serve small market segments effectively with custom-made goods as it does not need high-costed tooling in fixed costs which makes the launch of new goods with less risk potentials. With 3D printing on demand, there are not any capital costs and demolishing risks because of the fact of remained finished goods inventories. Alternatively, companies are having digital 3D data in their inventories. So, 3D printing is specifically applicable for product types distinguished by a high mix of variants and a low amount for each variant.

4.10. Evolution of 3D Printing

Initially, there has been poor effort to learn how the evolution of 3D printing affects companies' behavior and provides to the grow of a new classification of production industries. 3D printing brings an update to the categorization of industries and companies based on new dimensions like the localization of manufacturing in the supply chain and customer involvement in the growth of the goods and competing dynamics is essential. Therefore, the adaptation of 3D printing in industries will be leading by industrial/business machines, aerospace, motor vehicles, consumer products/electronics and medical/dental products.

3D printing technology is still in need of technological developments such as decreasing costs of printers and printer materials besides raising printer effectiveness to be quicker, more accurate, and being able of autonomous utilization. Additive manufacturing technologies are creating new opportunities in the concepts of manufacturing model and possibilities. There are massive opportunities in range of industries, for additive manufacturing technologies to form an important affect on the technique that products are built, and the method firms do business.

Industries, markets, companies and customers are ready to start a decentralized industrial reform. Still, experts do not forecast additive manufacturing to replace traditional manufacturing processes

completely. The way it will be is, the combination of traditional and 3D printing manufacturing techniques by completing each other's weaknesses. 3D printing technology will settle itself in niche sectors like minimal spare parts with less differences. Furthermore, 3D printing is creating new opportunities for production and global materials management. It creates current products in a better way besides allowing companies to produce totally new ones that were before unthinkable to make. Nearly every part of the industry is hoping that the 3D printing for bringing innovations to reality in industries such as automotive, aerospace and in this case specifically medical. While 3D printing initiated primarily as a way to build prototypes, latest technological developments and applications of 3D printing technology brings offers that the technology has a huge potential to revolutionize a lot of different surfaces of future.



5. Case Analysis: Calculation of Cost and Time Differences

5.1. Company Profile

Hologic Inc. is a medical technology organization mainly concentrated on women's health, develops, produces and sells medical devices for diagnostics, surgery, and medical imaging. It has sales internationally but mostly in the United States, Europe and the Asia-Pacific.

"The company offers Aptima molecular diagnostic assays to detect the infectious microorganisms; Aptima quantitative viral load tests for HIV, Hepatitis C, and Hepatitis B; ThinPrep System for use in cytology applications; and Rapid Fetal Fibronectin Test that assists physicians in assessing the risk of pre-term birth; and various diagnostic tests for a range of acute respiratory ailments. It also provides breast imaging and analytics, such as 2D and 3D mammography systems and reading workstations, minimally invasive breast biopsy guidance systems and devices, breast biopsy site markers and localization, specimen radiology, ultrasound and connectivity solutions; and breast conserving surgery products. In addition, the company offers aesthetic treatment systems, including SculpSure, PicoSure, and MonaLisa Touch, as well as provides TempSure, a radio frequency energy-sourced platform, which offers non-surgical and surgical aesthetic treatments and procedures. Further, it offers NovaSure Endometrial Ablation System for the treatment of abnormal uterine bleeding; MyoSure Hysteroscopic Tissue Removal System for the removal of fibroids, polyps, and other pathology within the uterus; and Fluent Fluid Management System that provides liquid distention during diagnostic and operative hysteroscopic procedures. Additionally, the company offers Horizon DXA, a dual energy x-ray system; and the Fluoroscanner Insight FD mini C-arm to perform minimally invasive orthopedic surgical procedures. It sells its products through direct sales and service forces, and a network of independent distributors and sales representatives. The company was incorporated in 1985 and is headquartered in Marlborough, Massachusetts."

Furthermore, in March and May 2020 respectively, Hologic obtained "emergency use authorization" from the Food and Drug Administration twice for a test to aid reducing the COVID-19 pandemic. Afterwards, in June 2020, Hologic worked together with Grifols to raise the testing numbers for COVID-19 in Spain.

5.2. Product Profile



Figure 5.1: 3Dimensions mammography system

Overview

“The new 3Dimensions™ system is designed to provide higher quality 3D™ images for radiologists, a more comfortable mammography experience for patients and enhanced workflow for technologists. Discover how sharper images and smarter technologies continue to help find invasive cancers – regardless of age or breast density.”

The “3Dimensions Mammography System” is being transported in two parts as the product and its acquisition station. Product’s weight and dimensions are “634kg – 224cm X 97cm X 160cm – 3476m³” and its acquisition station’s weight and dimensions are “250kg – 122cm X 115cm X 152cm – 2133m³).

5.3. Transportation Routes

The Sea Route between New York, USA – Antwerp, Belgium

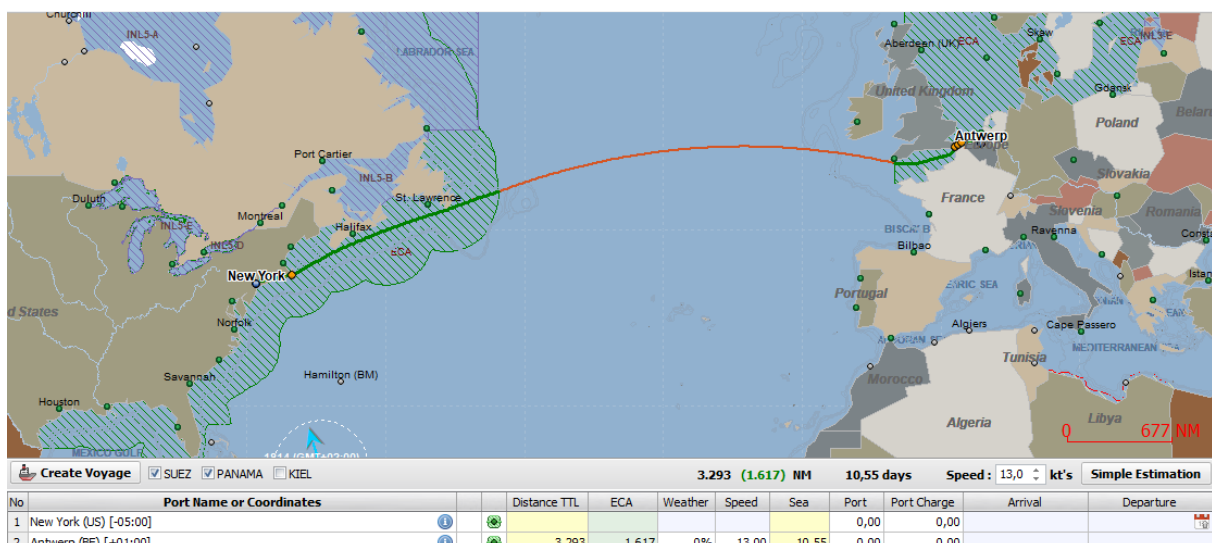


Figure 5.2: Details of sea transportation

Source: Netpas Distance Application

The optimized sea route of shipping the 3Dimensions Mammography System of Hologic is between the Port of New York, USA and Antwerp, Belgium. The details can be seen below as in normal studies it takes 10,55 days with 13,0 knots speed.

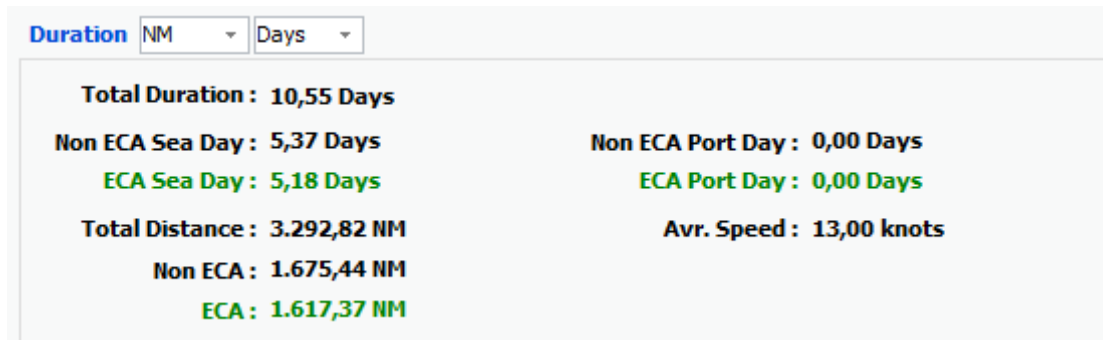


Figure 5.3: Results of sea transportation

Source: Netpas Distance Application

On the other hand, Hapag-Lloyd estimated the transportation days as 18 as it can be seen on the figure below:

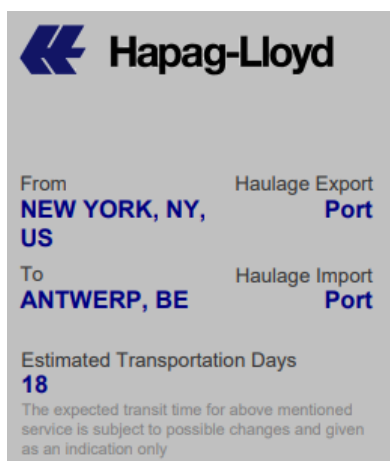


Figure 5.4: Estimated transportation days of Hapag-Lloyd

The Air Route between Danbury, USA – Brussels, Belgium

The usual air route is between Danbury Municipal Airport, USA and Brussels International Airport, Belgium.

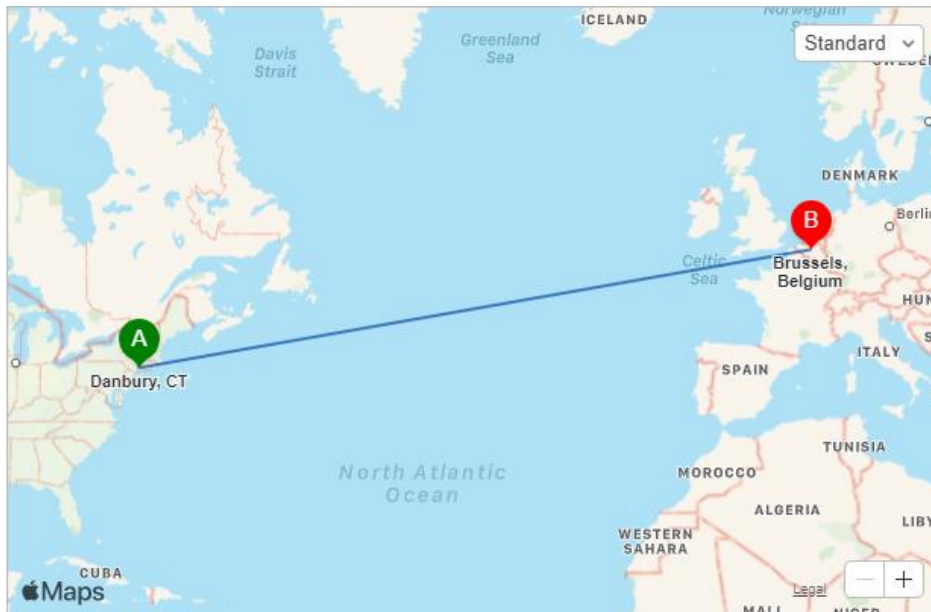


Figure 5.5: Flight map from Danbury, Connecticut, USA to Brussels, Belgium

Source: Travelmath.com

Change your flying speed:

mph
 knots
 km/h

take-off and landing: minutes

Figure 5.6: Flying speed, take-off and landing times

Source: Travelmath.com

The details can be seen above and below as in normal measures it takes 7,44 hours which is 0,31 days in translation with 500 mph speed.

✈ Flying	
Flight Distance	3,617 miles / 5820 km
Flight Time	7 hours, 44 minutes
Time Difference	Brussels is 6 hours ahead
Airports near Destination	Brussels Airport (BRU) Antwerp International Airport (ANR) Brussels South Charleroi Airport (CRL)

Figure 5.7: Flight details

Source: Travelmath.com

The New Route with 3D Printing Manufacturing

Since the idea of having a 3D printing manufacturing hub in Europe there will not be a transportation cost of the final product for the reasons of eliminating the issues, decreasing the time and costs.

Even though it is not possible to produce this product with 3D printers currently, the optimistic and futuristic plan in this case is transporting all the raw materials before the production and using just-in-time technique to assemble as much as needed and especially directly when it is required. The transportation of raw materials will also take some time but with forecasted demands and using 3D printing with just-in-time manufacturing method will make the time factor irrelevant for customers' waiting time. Both sea and air shipments could be used for raw materials transportation. The hub would be in Belgium since the company's warehouses are in it.

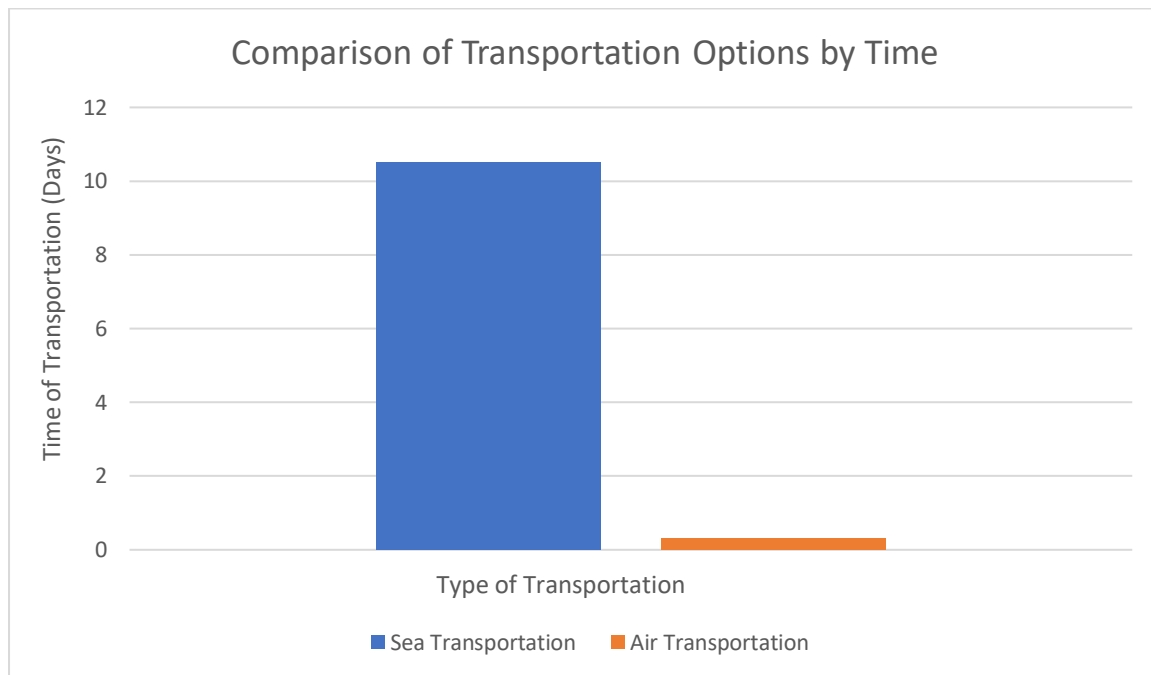


Figure 5.8: Time differences of transportation

Above in the graph it can be seen that sea transportation option takes 10,55 days which may have lower costs than air transportation but takes many days. Meanwhile air transportation takes only 0,31 days which is 7,44 hours but it costs a lot. Thus, 3D printing production is an option in both cases that can decrease time and cost if it is planned very well.

5.4. Transportation Costs

The Cost of Transportation with Traditional Manufacturing (Sea)

The cost for sea transportation of 2 parts of the product are divided into three options: 20' standard container, 40' standard container and 40' high cube container. The prices were checked as a collect shipment, so the cargo was moved on FOB terms. The shipper in the U.S. pays everything up to a second before the container touches vessel. Customs were not included, neither are detention nor demurrage. Total cost of transportation is basically the sum of seafreight cost, freight surcharges and

import surcharges which is 506 Euros for 20' standard container, 482 Euros for 40' standard container and 492 Euros for 40' high cube container.

From NEW YORK, NY, US (Port) to ANTWERP, BE (Port)

Freight Charges	Curr	20'STD	40'STD	40'HC
Seafreight	USD	190	70	80

Unless otherwise specified, all rates are subject to all surcharges as they are valid at time of shipment. The currently applicable surcharges are:

Freight Surcharges

Marine Fuel Recovery	USD	96	192	192
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Import Surcharges

Terminal Security Charge Dest.	EUR	15	15	15
Terminal Handling Charge Dest.	EUR	185	185	185
Equipment Inspection Fee	EUR	20	20	20

The Lumpsum is not subject to the following assessorial charges:

Caf Seafreight, Carrier Security Fee, Forwarding Agent Commission, Imo2020 Transition Charge, Document Charge, Ny Pass Through Charge Origin, Operations Cost Recovery, Security Manifest Document Fee, Terminal Handling Charge Orig., Terminal Security Charge Orig.

Notes

Subject to Administration Fee Destination: EUR 40 per Bill of Lading

Figure 5.9: Hapag Lloyd's Transportation Cost Numbers with FCL

The Cost of Transportation with Traditional Manufacturing (Air)

The speed factor of air transportation is crucial upon immediate demands, but the costs are also increasing a lot, especially in heavy equipments. According to shipnex.com estimated air freight shipping costs to Belgium have four different factors. First of all, minimum price can be \$144. If the product is +45 kg the total cost is calculated by \$3.92 per kg. If the product is +300 kg then total cost is calculated by \$1.98 per kg, and finally if the product is +1000 kg then total cost is calculated with a decrease by \$1.78 per kg. In our case we have two kinds of packages of the same product which are 634 and 250 kg respectively.

The calculation is basically the sum of 634x\$1.98 and 250x\$3.92. After the convert of US Dollars to Euro (1 Euro is considered as 1.18 Dollars) the total transportation cost becomes 1886,28 Euros.

The Cost of Transportation of Materials and Manufacturing with 3D printing

Below in the graph it can be seen that sea transportation option costs 506, 482 and 492 Euros in three different options. Meanwhile air transportation costs 1886,28 Euros. Once again, 3D printing production is an option in both cases that can decrease time and cost if it is planned very well, but without forgetting the raw materials' transportation and warehousing costs and times.

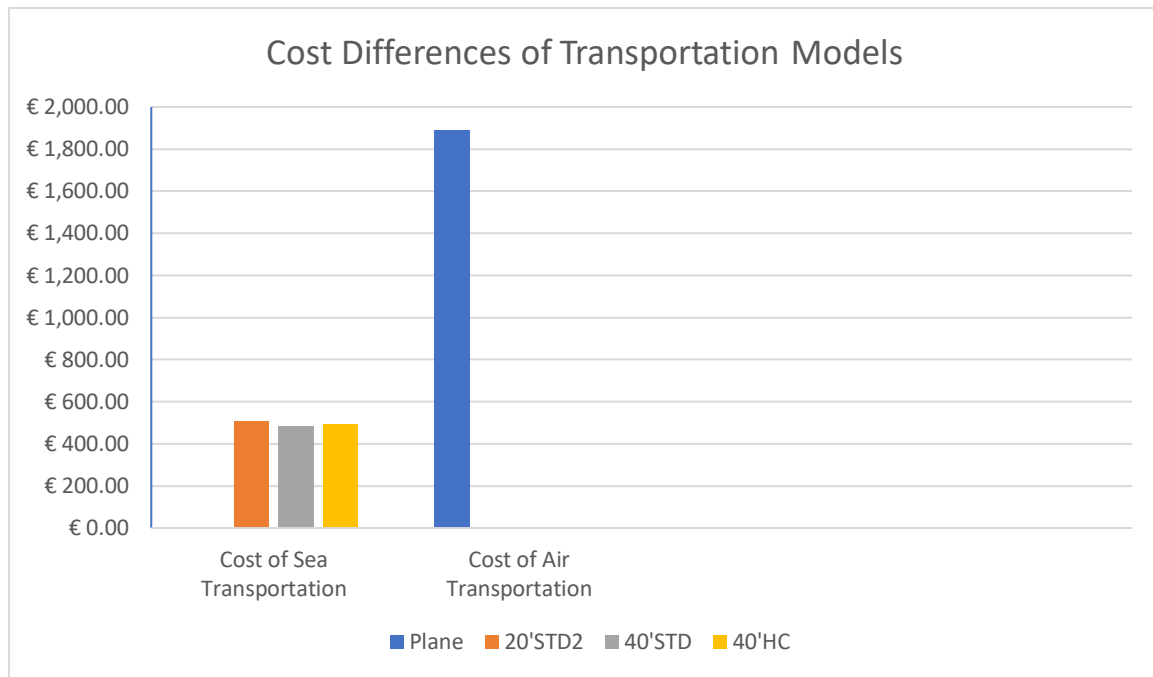


Figure 5.10: Cost differences of transportation

5.5. Final Notes

Transportation of heavy equipments were always a bit tough even for the biggest organizations especially when considering the international enterprises' global materials management systems. The idea of the thesis is, if 3D printing manufacturing and just-in-time production technique is adapted, it may help to decrease costs, transportation and customer waiting time. On the other hand, it should not be forgotten to how and where to transport raw materials for 3D printing manufacturing besides where to store them. The final parts of the case study will be investigated furtherly in the SWOT methodology below.

6. Research Methodology

6.1. SWOT Analysis of the Case Study

In this part of literature, strengths and weaknesses of internal factors, opportunities and threats of external factors of 3D printing and assembling production over traditional manufacturing methods were examined. Under this intention and found on earlier analyses, a SWOT analysis is operated, as it is the most useful technique that helps in determining and creating strategic plans on a rational basis. This study looks up to examine the current situation and the essential components of the 3D printing by determining its four principles. First, strengths or components that differentiate it from the conventional manufacturing. Second, weaknesses or deficiencies that are existent in it. Third, opportunities and pros that hail from external factors and are utilized to apply and grow the industry, and finally, threats or unfavorable factors that derive from outside and prevent its function. These aspects play a direct role in growing a methodological suggestion for the application of 3D printing manufacturing. The table 6.1 below displays an examination of the SWOT analysis of 3D printing production.

The SWOT was integrated from information picked out from studies and researchs about the 3D printing and additive manufacturing versus traditional manufacturing as well as various other resources. The results of the SWOT are utilized for explaining the research question regarding the opportunities and challenges for companies to adopt 3D printing manufacturing or not.

Internal	External
Strengths	Opportunities
- Cost decrement for custom-made small batches - Changeable product design without charge - Prototype design without manufacturing and getting faster feedback from the consumers - Reduction in the time of design-to-production cycle - Removing the requirement of screwing and welding various parts of an end product	- Increasing demand for the fields of designing, engineering and information technologies - Home relocation of offshore manufacturing - Producing infrastructure units on site for space programs - Manufacturing simple lab devices - Utilizing the crowdsourcing from customers for organizations' research and development functions

- Being able to manufacture products that were moulded separately as one piece - Utilizing lighter, stronger and long-lasting materials - Decreased building time - Diminished expenses - Increased efficiency - Easiness of manufacturing complex designs - Reduction in development time for firms - Removing tooling expenses - Removing the waste that gathers in traditional production - Environmental advantages from decreased shipment needs - Helps organizations manage and strengthen control of the whole value chain - Raised flexibility in production - Developing number of countries and firm that seek to adopt 3D printing technology - Constant and fast changes and advancements	- Manufacturing complex products in far places with less expenses of electricity and labour - Improvement of global printing standards - Diminished tooling expenses - Testing low amount of products - Development in open source files to print units - Creation of new printing materials - Shipment cost savings - The customers' capability to afford the products - Contributing small production runs therefore making even mass-production without the need of outside investment - Marketing campaigns -
Weaknesses	Threats
- The printed units need to fit inside of the total size of 3D printers - Raw materials of 3D printing are noticeably costing more than raw materials in traditional production - The expense of future materials - The low speed of 3D printing for mass production - The price of 3D printers	- Differentiations at governmental levels - Governmental protection of the companies with the laws - Customer regulations - Trade barriers - Patent issues - Manufacturing control - Capability of printing weapons - Possibility of losing jobs in traditional manufacturing industries - Possible piracy of 3D printing designs - Quality issues of the brand and product

- Currently, only being able to manufacture a product if it is totally made of the same material - Current slowness of additive manufacturing speed which takes hours or days to produce - Less knowledge in designing units for additive manufacturing - Lack of channel partner support has been limiting the development of the market - Constant change of 3D printing devices - Decrease in employment capacity - Need of trained professionals to use software and the 3D printing devices	- Not being able to control or regulate manufacturing of medical tools or food - Influence on agriculture from printing foodstuff - Economic constraints - Resistance to change - Human resources are not suitable for technological enhancements - The need to build your own nodes of manufacturing
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Table 6.1: Detailed SWOT analysis for the action of adopting 3D printing manufacturing

Source: Author's own composition based on the information gathered from studies.

6.2. Further Elaboration

Strenghts

The absence of industrial waste is one of the most powerful advantages of 3D printing technology. It can easily be said that 3D printing is an entirely green procedure due to the added layer by layer printing materials. 3D printing manufacturing is using the precise amount as needed by the manufacturing requirement, under digital control. Moreover, with 3D printing technology, identical products can be printed in any location around the world since the manufacturers need only these three things: A printer, a digital copy of the product and the raw materials. 3D printing can build products no matter what the shape, restraints that presently endure in many industries. With this proficiency, manufacturers can utilize the 3D printing production for making it easier to produce complex products without having any extra expenses, time and raw materials.

Furthermore, promoting 3D printing in any industries will directly have a few industrial and location leverages. Even though, currently most of the companies are using the traditional manufacturing techniques with solid industrial designs, some organizations started to combine the conventional and additive manufacturing techniques in their production cycles to promote the rapid development and boost the upgrading of 3D industry.

Weaknesses

First, in the associated planning about the switch of conventional manufacturing, the general planning on 3D printing manufacturing is still not flawless because of the reasons like technical standards and development platforms and low level of industrialization. Furthermore, 3D printing manufacturing allow companies to produce in smaller scales comparatively to traditional production techniques. Adopting time of a new technology is also one of the reasons that directly affects the development of 3D printing manufacturing because of the expenses of R&D, skilled personnel and initial cost of 3D printers.

Table 6.2 below indicates that USA, Germany and Japan are the countries that are patent applicants in 3D printing which may be the fact of an issue of patents in future. Moreover, top 10 is basically divided into 3 countries that can cause a problem of non-competition in some industries.

Rank	Applicant	Origin	First fillings
1	3D Systems	USA	200
2	Stratasys	USA	164
3	Siemens	Germany	145
4	General Electric	USA	131
5	Mitsubishi	Japan	127
6	Hitachi	Japan	117
7	MTU Aero Engines	Germany	104
8	Toshiba	Japan	103
9	EOS	Germany	102
10	United Technologies	USA	101

Table 6.2: Top 10 companies by patents investing on 3D Printing

Source: World intellectual property organization, 2015

Opportunities

There are many opportunities that were mentioned above on the table 6.1, but the most important opportunity is the transformation of the market from a niche one to a global one. This development is driven by the lessening in the price of the 3D printers for home use. Still, it is crucial to know that these devices have narrow functionality such as printing, small and low-quality units plus lasting longer to produce than the industrial ones. Contrarily, the firms that lead the additive manufacturing industry, utilizing the most expensive 3D printers that has higher quality and more expensive raw materials, leading the industry (Deloitte – 2015). The opportunities may also differ from region to region. In last decade, China accelerated the development of 3D printing technology industrialization by introducing policies to support the growth of 3D printing market.

Threats

The most thought threat of 3D printing manufacturing is “Global public safety”. There is not any legislation about the regulation of 3D printing production so that means anyone can produce anything and in anywhere. In 2012, one of the companies in US created a file of 3D printable gun. It was taken down after a while but before almost 100000 people all around the world were already downloaded the file. Secondly, the piracy of digital design files is really tough to control. Organizations will need to guarantee themselves through this risk and find creative methods to secure intellectual property. Finally, some printers may harm consumers due to not having a proper ventilation. Those health risks are asthma, heart disease and stroke.



7. Conclusion

3D printing as one of the parts of additive manufacturing is nowadays a global trend, which has developed very quickly over the last demand and is expected to continue growing. The manufacturing industries are no with regards to this condition. Along with that, transportation costs, transportation time and customers' waiting time are the concerns of organizations which most of them are definitely trying to decrease those numbers. Thus, more and more enterprises are committing themselves into research and developments, especially 3D printing manufacturing. Adopting 3D printing with just-in-time manufacturing model is having many strengths and opportunities as it was pointed out in this case by decreasing the transportation time and costs, but on the other hand has many doubts about the steadiness of the technology. Indeed, major companies worldwide have been giving a chance to 3D printing with an increased percentage day by day. However, the success of such technique does not rely on the only companies' hands but rather on other various determining components. The scope of this study aimed on examining if 3D printing manufacturing makes a difference or not. Through a case and SWOT analysis, certain outcomes were regulated as shown as below.

The basic disadvantages and threats are insufficiently identified materials for goods and components provided by manufacturers of raw materials for the health industry. It should be distinguished that the adaptation of this 3D printing technology depends on manufacturers of raw materials, because it may increase the expense of manufacturing. On the other hand, the 3D printing technology implementation has decreased risk due to the 3D printer availability because there are no technical limits. It should also be underlined that the companies of health sector have also affected the legislation development stage of 3D printing.

Found on the examinations of key features and various factors of SWOT analysis for 3D printing manufacturing, three main outcomes are listed below:

- 3D printing manufacturing has many extraordinary strenghts that must be known by stakeholders to accomplish the anticipated advantages at all levels.
- There are a lot of powerful opportunities that are used when arranging the proposed framework.
- In spite of the truth that there is a list of strengths and opportunities that make 3D printing manufacturing interesting, but there are still a few weaknesses and threats that the research is trying to lessen by remodeling as much as possible into strengths and opportunities.

Extensive SWOT analysis outcomes indicate that organizations have great opportunities for the 3D printing manufacturing. However, to answer the question, we can somehow relate 3D printing with the internet revolution. Consumer adaptation process takes time so in the time of internet's development, most of the users did not recognize its potential in the way the enterprises did. As the

new technologies grew and the industries began utilizing and developing the new high technology techniques, people became more attentive of internet just like 3D printing is going to be.

Even though the internet revolution needed around 15 years to be utilized, this time may change about 3D printing because technology adaptation process is decreasing year by year. The fact of most firms is using inventories to supply constantly goods to their consumers, let's think about the fact that firms would be able to instantly print the products whenever needed which in this case it means no inventory requirement. Thus, that would consequently decrease the costs for the firm.

Currently, the biggest issue that appears when examining the 3D printing production versus conventional one is the cost per unit. Despite the fact that 3D printing is costing more than conventional manufacturing, it does not have a tooling cost which is an indication that for small manufacturing runs, conventional production will stand more expensive than 3D printing production. Even for larger manufacturing runs, the 3D printing manufacturing still has a competitive advantage if we consider the 3D printing time that could be less than the overall time for tooling the firm.

After all, this revolution will change our planet. For the firms functioning in the additive manufacturing industry and for the ones that supply the printing materials will have very profitable venture. Other companies will lose if they are not able to adapt the new technologies and stuck the traditional techniques. The difference of the industries also is a big game-changer about 3D printing usage. For example, in the defence and aerospace industry 3D printing manufacturing is being used about the weight decrement on aircraft and low volume parts. In the automotive sector, 3D printing is being utilized about design and prototyping and vehicle restoration. For consumers, mostly it is customized products and innovative marketing.

Consequently, the scale between the traditional manufacturing and 3D printing manufacturing in long-term is still a big question that needs to be answered. The effectiveness of 3D printing manufacturing needs more practical experience and the results will be received in long-term. Would it be the case that 3D printing manufacturing will be adopted fully or partially. Lesson learned from the current 3D printing investments might be perceived as an opportunity for developing this technology in terms of adopting 3D printing manufacturing in the future.

7.1. Limitation and Recommendations

The study was carried out through desk research and with the help of colleagues, but it had to be limited and not contain manufacturing prices since most of the data and statistics are confidential and may harm any companies in the industry. Therefore, it negatively affects a quantitative approach as the accuracy of the input data for calculation is insecure. Moreover, the majority of companies newly adopted the 3D printing manufacturing, and currently it is not enough to produce most of the products

100% with 3D printers. Thus, production cost of any product with both traditional and additive manufacturing methods are not available to analyze the efficiency of such techniques. Future researchers should have more access to manufacturing costs to reach the desired outcomes.

This study was subjective to a heavy equipment in the case. Other cases such as smaller and lighter products is obviously different as of the diverse characteristics. Further researchs are highly needed for those kinds of products with regard to this topic.



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