NETWORK DESIGN FOR ADDITIVE MANUFACTURING ENTERPRISE: STRATEGIC LEVEL

ABSTRACT

Additive manufacturing drives innovation in industries. The insertion of companies focused on the 3D printing services business can be a challenge when deciding the location of such a venture considering the existing supply network. A supply chain project allows to assist strategic decisions regarding the determination of the ideal point of the facilities, providing an increase in the efficiency of internal and external processes. In this sense, the objective of this study is to implement the Phase I of the framework developed by Chopra and Meindl to assist in the physical network design of a supply chain. This phase has a focus on a strategic analysis for the insertion of one or more links in a supply chain. Specifically, the aforementioned phase is implemented to outline a strategic analysis of a venture for 3D printing services in the metropolitan region of Goiânia. To this end, bibliographic research was conducted together with empirical research, to identify the ideal strategies for the development of a physical supply chain network project for an additive manufacturing parts industry. As a result, a complete strategic planning was defined, which can be used to compose the other phases of the referred framework.

Keywords: Supply Chain; Physical Network Design; Additive Manufacturing; Strategy.

1. INTRODUCTION

Product manufacturing has undergone a transformation in the recurring years. With this, additive manufacturing has gained prominence by offering efficiency for industrial production processes (SCHNIEDERJANS, 2017). Also known as 3D Printing, this technique is a procedure that is characterized through the sum of consecutive layers of materials programmed by a three-dimensional project, which provides the manufacture of complex products, using various forms, techniques, and materials (VOLPATO; CARVALHO, 2018).

In search of a competitive edge, organizations are interested in using additive manufacturing during the manufacturing, inventory, and logistics processes. 3D printing provides a reduction in the lead time of machines; it also helps to reduce inventory, adding value to production processes (VOLPATO; CARVALHO, 2006). Also, 3D printing allows the physical reproduction of prototypes in projects, which makes the production of items more skillful and with more quality, by enabling the repair of possible errors in the product design phase (SARTORI, 2019).

Additive manufacturing coupled with supply chain management allows connecting the market, the distribution segment, and the production process to simplify the complex processing between transactions (COOPER; LAMBERT; PAGH, 1997). Therefore, it becomes increasingly more strategic to understand the numerous connections between the economic agents with the objective of evaluating which are the clients' demands, what are the products' characteristics and how the function of each agent impacts the performance of the entire chain. These actions aim to make the chain more responsive, able to supply both customer needs and to deal with unexpected situations, such as seasonality and demand uncertainty (CHOPRA; MEINDL, 2003).

According to Chopra and Meindl (2003), to be able to meet the customer needs that the company seeks to satisfy, it is essential to have a competitive strategy, which also defines an advantage over competitors. Still according to these authors, strategic alignment must follow objectives, based on the priorities of customer satisfaction and on the construction of the supply chain strategy and capability.

Analyzing the contribution of additive manufacturing in the activities of a supply chain is a fundamental step for organizations to have new opportunities for business innovation and development in their production processes (DURACH et al., 2017). Thus, this work aims to implement Phase I of the Physical Network Design Framework that is proposed by Chopra and Meindl (2003), promoting a strategic planning of a supply network project for the implementation of a 3D printing enterprise.

2. LITERATURE REVIEW

2.1. Phase I of the physical network design framework proposed by Chopra and Meindl (2003)

Figure 1 shows the Phase 1 of the framework proposed by Chopra and Meindl with emphasis on the more strategic issue in determining a physical network for a supply network. This phase aims to define the broad design of a company's supply chain. This includes determining the stages of the supply chain and whether each function of the supply chain will be performed internally or outsourced (Chopra and Meindl, 2003).

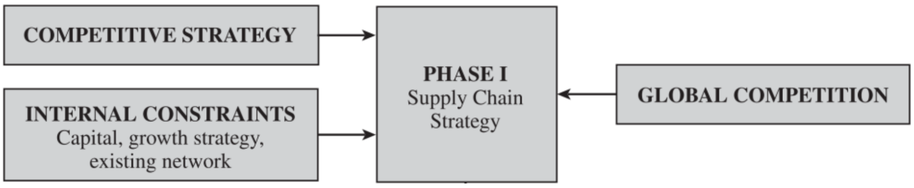

Figure 1: Illustration of phase 1 of Chopra and Meindl's framework for designing the physical network of a supply network. Source: Chopra and Meindl, (2003).

Phase I begins with a clear definition of the firm's competitive strategy as the set of customer needs that the supply chain aims to satisfy. The supply chain strategy then specifies what resources the supply chain network must have to support the competitive strategy (Chopra and Meindl, 2003).

Next, managers must predict the likely evolution of global competition and whether competitors in each market will be local or global players. Managers must also identify constraints on available capital and whether growth will be realized by acquiring existing facilities, building new facilities, or partnering (Chopra and Meindl, 2003).

Based on the firm's competitive strategy, its resulting supply chain strategy, an analysis of competitors, any economies of scale or scope, and any constraints must be analyzed to provide the basis for the supply chain design for the firm (Chopra and Meindl, 2003).

2.2. Additive Manufacturing

The fourth industrial revolution, known as Industry 4.0, also called advanced manufacturing, or smart grid in the energy sector (DE SOUZA DUTRA; ANJOS; LE DIGABEL, 2018), proposes the integration of the entire organization, from customer service, through the manufacturing process, to delivery. More than this, the concept integrates the entire supply chain digitally in the search for maximum productivity. One of the components of the advanced manufacturing concept is additive manufacturing, also known as 3D printing, which can be translated as the addition of material in the production of an object. This process is antagonistic to the subtractive manufacturing process, which has as an example the machining process, where material is removed from a part, generating waste and losses (DALLACORTE, 2019).

In recent years 3D printing has been providing numerous benefits to society, and not only in the field of computing, but also in several other areas of knowledge, such as health, architecture, among others; and is proving increasingly promising, because of the huge field of applicability and its advantages, such as gain in productivity and good cost-benefit ratio, becoming a great alternative for the creation of prototypes or even final product in the most diverse branches of activity (PAIVA and NOGUEIRA, 2021).

Because it is a relatively new area, many consumers still do not have enough information to determine which technology is the most suitable to meet their needs, whether for home or commercial use, as well as the amount to be invested in the acquisition of a 3D printer, thus avoiding the risk of investing in something that will not meet all your needs or that will do more than what is necessary (PAIVA and NOGUEIRA, 2021). Sometimes, investments are discouraged due to the lack of information or tools that helps inventors to analyze them (DE SOUZA DUTRA; ANJOS; LE DIGABEL, 2019).

In Brazil, the 3D printer topic has only gained prominence in recent years. In addition, the most affordable printers available in the country few years ago uses mostly plastic filaments as raw material. This began to change when machines that use liquid and powders to print became cheaper (FRABASILE, 2018).

In 3D printing, a variety of materials are used, such as plastic, nylon, ceramic, wax, bronze, stainless steel, titanium, wood, glass, and others. These materials are sold in the form of solid filament, liquid resin, and powder. The types of materials that will be used depend on which technology will be used by the 3D printer (PAIVA and NOGUEIRA, 2021).

After this expansion in possibility of raw material to be printed, 3D printing became more interesting for industry. The common location of 3D printing in industries are product development labs. The rapid prototyping enabled by the 3D printer gives speed in research and development and lowers the pre-production cost when compared to traditional methods. But this process tends to increasingly gain space in production environments. Thinking through the logic of material loss, 3D printing has a competitive factor. Optimizing the use of material in the production process reduces costs and increases the competitiveness of the product. On the other hand, the reduced production speed when compared to serial production in a traditional production system, for now is not competitive enough for large production volumes (DALLACORTE, 2019).

There are several types of technologies that can be used by 3D printers. Among them, the most used are: FDM or FFF, SLA, DLP, SLS and SLM. The differences between these types of technology are in the material they use and in the way the layers are built to form the printed objects (PAIVA and NOGUEIRA, 2021).

As additive manufacturing is being implemented, new avenues arise for logistics and the availability of products directly to the end customer. A retailer of parts and components for the automotive industry, for example, may have a 3D printer at the point of sale and literally print the entire part, eliminating everything from production in the industry to distribution, logistics, and warehousing. On the other hand, an industry that produces assembled assemblies will be able to manufacture custom parts that were previously produced by another supplier (DALLACORTE, 2019).

This trade-off between speed and flexibility is decreasing with increasing technology (DALLACORTE, 2019). Using hybrid manufacturing system, with machining added to 3D printing, can help create parts with noble, high-cost alloys in the exact quantity to be finished with the least possible withdrawal of materials, generating fewer losses. Today there are machines that combine the two systems and make the setup time shorter, providing greater productivity.

In this sense, (DALLACORTE, 2019) points out that this scenario can be the most transformative for the supply chain. The moment the company demanding a part starts to manufacture it through additive manufacturing, the supplier needs to change its business model. Knowing the characteristics necessary for the competitiveness of its product, this supplier is no longer a supplier of items and becomes a specialist in parts design, selling not the manufacture of the part but the design, which will be used by the demanding company to produce the items through additive manufacturing.

Broken to an apocalyptic view of the supply chain, it reconfigures to the point where the demanding company has in stock only the polymers and metals for manufacturing through 3D printing, with designs provided by companies that master the technical characteristics of each component for a final product to be sold to the customer (DALLACORTE, 2019). It is up to suppliers, which are mostly small companies, to restructure and remodel their business model thinking about a new supply chain configuration.

In general, additive manufacturing in the supply chain has the following advantages: elimination or simplification of production stages; availability of new products; changes in the waste recycling chain; minimization of tooling requirements; reduction of inventory retention, obsolescence, and parts shortages; and development of innovative products (DURACH et al., 2021).

2.3. Related Work

According to Gibson, Rosen, and Stucker (2009, p. 193-198 apud SANTOS; BELÉM, 2018), industries have adopted this 3D printing technology to reduce the development times of their products and to get them to market faster, more cost-effectively, and with higher added value due to the inclusion of customizable features. Realizing the potential of additive manufacturing applications, several processes have been developed allowing the use of various materials ranging from plastics to metals for product development.

According to Santos and Belém (2018), the concepts of Industry 4.0 and Additive Manufacturing, are well accepted by consumers, however there is a need for further study on the subject to correct flaws, aid in strategic changes of the company and increase productivity of new products and new technologies.

According to Magri et al., (2020) with the advance of this type of technology and its disruptive potential, routine processes in companies and institutions should undergo considerable changes in the near future. As an example of this, one can mention inventory control, which should become increasingly leaner. The acquisition of parts or products of low complexity, which can be printed in the business environment itself; and, probably the main one, the production process itself of the products manufactured by the companies. The authors highlight that the Brazilian Navy, in order to fulfill its institutional mission, among other activities, executes a maintenance program for its operational means, with the purpose of maintaining a high level of readiness and availability to meet the nation's interests.

Narayan (2020 apud NOGUEIRA, 2021) states that in the health area, only in 2013 approximately 70,000 three-dimensional models were produced to assist in surgeries. Additive manufacturing appears as an opportunity to take a step towards large-scale bio fabrication of human tissues and organs due to advances related to the manufacture of biomaterials such as biological tissues, obtaining through additive processes human bones and manufacturing of nano materials for regeneration. In addition, the possibility of obtaining high-resolution three-dimensional models using tomography allows scientists to tailor printed models according to the specific needs of each patient.

Already in the aerospace sector, Dsaic (2019 apud NOGUEIRA, 2021) says that the advantages of using additive manufacturing resemble the use of this technology when we refer to shorter processing time, reduced operating costs, and lower environmental impact. However, when it comes to gains in inventory reduction, simplification of supply networks, and component optimization, the aerospace industry overlaps. In this case, few parts of the same type are needed, but an aircraft, such as a model 747, can have close to 6 million components. The amount in stock for spare parts for American military aircraft, according to the department of defense, in 2016 was around $100 billion and some models such as the F/A 18 Hornet, had as much as 29% on the ground due to lack of spare parts and waiting up to 8 months for maintenance.

Complementing this, Deckard (1989 apud NOGUEIRA, 2021) and Schoffer (2016 apud NOGUEIRA, 2021) exalt that additive manufacturing has the potential to address the challenging aspects of a supply chain regarding spare parts related to capital investment in inventory, inventory cost, obsolescence, and transshipment. Nogueira (2021) says that MA is transforming each of the above areas, and it can be noted that some points of convergence arise when we refer to the use of the equipment, process, and materials employed by this technology. Regardless of the area, this technology is linked to layering and synthesizing processes, whether using metallic powder, polymers, or even molecular structures.

According to Garcia (2010 apud SARTORI, 2019) part of the academic literature on Additive Manufacturing still surrounds the technological and engineering aspects of materials or computing. The Additive Manufacturing is leaving the testing and prototyping laboratories and gaining space in production, as a useful tool in cost reduction, seeking to serve customers, especially those who need small quantities of parts or equipment.

Kelly (2020 apud SARTORI, 2019) says that in markets of high uncertainty due to demand fluctuation, Additive Manufacturing should gain competitive prominence. This market model characterized by customization is ideal for 3D printers due to their flexibility in producing complex, lower cost, low scale products. The mass production of products should not cease to exist, however the economy model based on diversification and customization exists and has a considerable demand for this type of public.

According to Sartori (2019), Additive Manufacturing allows customers to design products that fit their sometimes more demanding specifications. Companies that already offer the technology as a type of service, adjust any object to the consumer's specifications and parameters, and even if there are temporary limitations such as objects with more than one color, consumers are quite satisfied with the result.

Completing, Sartori (2019) points out that with the advancement of Additive Manufacturing technology, the printer market has offered increasingly advanced equipment at a lower price, breaking the old paradigm that technology becomes obsolete the moment it is sold. Even so, it is not possible to stop investing in the modernization of machines and equipment, as this is a business necessity that generates competitive advantage an organization (SOUZA DUTRA; ALGUACIL, 2020). Therefore, this technology, when used as a competitive advantage to maximize the company's profits, proves to be a low or medium cost investment in comparison to the dissatisfaction of not meeting the client's needs.

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3. METHODOLOGY

According to Riba et al. (2021), bibliographic research of qualitative approach is characterized by: a) reduced samples; b) no need to represent the entire sample universe; c) being able to develop a non-probabilistic sampling, indicated when there is not much information on the subject to be studied. Besides being qualitative, this work is characterized also as exploratory with aim to understand the current scenario of this market in Brazil and in the state of Goiás. This level of research is widely used when the theme is still little explored, seeking to bring a more generalized view of the study, because it would be very difficult to formulate a precise and assertive hypothesis (GIL, 2002). As additive manufacturing is still a theme little explored in in the state of Goiás - Brazil, the amount of research and documents is quite small, being necessary that the work is responsible for generating this introduction by a non-probabilistic method so that later, with a greater amount of information, it is possible to perform a descriptive or explanatory level work.

Thus, for the realization of this work, applied research was conducted with the support of a bibliographic research to define the strategies that should be taken for the development of a project of physical network of the supply chain for a factory of parts by 3D printing. Specifically, this paper contemplates the implementation of phase 1 of the framework revised in Section 2.1. To this end, the supply chain strategies for additive manufacturing were defined, based on the data found in an applied and bibliographical research to analyze the important business factors and compare the theoretical vision with the real scenarios of the companies in the selected region.

The business factors are detailed in the following subsections.

3.1. Mission, Vision, and Values

To start the definition of the competitive strategy, one must define the principles of the business. To do this, the mission, vision, and values (MVV) is developed by using a benchmark approach: an evaluation of the MVV of other competing companies is made. The information concerning the MVV is found through bibliographic research, which is made available by companies on their websites.

3.2. Identifying the target market

To define the target market, exploratory research was conducted in order to identify the characteristics of the Brazilian additive manufacturing market and understand which are the sectors that most use this product and, consequently, which public has a greater need for it.

3.3. Supplier identification

Suppliers were identified through the Google Maps platform, searching for companies that could supply 3D printers or raw material for 3D impressions in the metropolitan region of Goiânia. For this purpose, the term "3D printer resin" was searched on Google Maps. The answers from this search indicated potential suppliers. Next, it was confirmed, via the institutional site of these potential suppliers, if each of them provides printers or raw material for an additive manufacturing enterprise.

3.4. Definition of competitors

The search for competitors was also conducted via the Google Maps platform. The term "3D printing services" was searched for on Google Maps, limiting the search to the metropolitan region of Goiânia. The results of this search were inspected to verify the enterprises that actually have 3D printing activities.

3.5. Product definition

From the definition of the target market, it is possible to define the product that meets the customers' needs. Thus, to provide a suitable product, a literature search and a benchmark were performed to identify products that comply to the market that the company seeks to achieve.

3.6. Definition of the production flow

According to Rivera and Chen (2007), the production process associated with the use of resources can be determined by observing the production flow, observing its process of transformations with its peculiarities. Thus, the production flow is a form of management and organization of all production phases in order to establish an organization classifying stages, avoiding processes that do not add value. Thus, the production flow was elaborated based on bibliographic research and a benchmark in the Ambev brewery located in Anápolis - Brazil.

3.7. Definition of the plant layout

For Santos and Junior (1999), the layout is an operations management mechanism that seeks to increase the efficiency of the man-machine system through the physical arrangement of manufacturing components to achieve the desired production results. The literature classifies four main types of layouts, being linear layout, functional layout, cellular layout, and fixed layout.

In the linear layout, machines stand side by side so that everything happens in a standardized way, following a single, logical sequence. In the functional layout, machines are grouped together by similarity. The cellular layout is capable of producing different products that belong to the same family. Finally, fixed layout involves the sequencing and placement of workstations around the material or product being produced.

Like the production flow, the layout was defined based on bibliographic research and a benchmark in the Ambev brewery located in Anápolis - Brazil.

3.8. Proposition of a physical network design for supply chain

The methodology for determining a broad physical network is based on bibliographic and exploratory research in an attempt to apply Chopra and Meindl's theory to a real problem. According to (Chopra and Meindl, 2009) the physical network project seeks to meet the following criteria: general operation, inventory, transportation, facilities and handling, information technology, response time, product availability and variety, customer experience, time to market, and returnability.

4. RESULTS

4.1. Mission, vision and values

The companies that make up the benchmark for developing our company's mission, vision and values (MVV) resulted are summarized in Table 1:

Table 1: Mission, Vision, and Values of companies working with 3D printing.

Company	Mission	vision	values

Tech CD[1]	To meet our clients' needs, constantly keeping up with the advance of new technologies to offer differentiated and innovative solutions at a fair price. We want to transform purposes into projects and ideas into reality!	We believe that a company with win-win relationships and constantly developing shared values innovates to meet the demands of a modern world in "forever beta".	Efficiency; Transparency; Ethics in business; Respect for the environment; External and internal confidence; Always prioritize the customer; Expand perspectives and possibilities; offer truly innovative solutions; Concern for society in the daily agenda; Commitment to customer satisfaction.
Solid Concepts[2]	Our Mission is to add value to companies by reducing their manufacturing manufacturing time of their products, offering solutions during their development process, thus increasing their profitability. We do this with the best prototyping and 3D modeling technologies, allied to our excellent team of employees.	Our Vision is to become a company of national reference in the development of development of solutions for the various industrial sectors. For we believe in our technological capacity and in the quality of the services services provided to our customers. Thus, we wish to actively participate in the in the economic growth of Brazil.	To provide customers, suppliers, employees, and shareholders with the satisfaction. To have committed and fulfilled people in its group of collaborators. Achieve excellence in quality in everything it does. Establishing relationships based on ethics. Working for the growth and profitability of the business. Sharing the results with those who help produce them.
Vulcano EJ[3]	To collaborate with our clients' development, maximizing their success through technological innovation and the strength of the MEJ.	Leverage the Vulcano brand in the engineering market through quality solutions.	Pride in being a Vulcan; Non-conformity; Humanized Company; Transparency; Promote the best customer experience.

Analyzing the Mission of the companies we can observe that all of them are focused on customer service, seeking their evolution through additive manufacturing technologies. Regarding the Vision, we can see a consensus that they all seek continuous growth, however, the way this happens varies according to each one: Tech CD aims to achieve this through an exchange of knowledge between the company and its customers. Solid Concepts seeks to develop through the resolution of services and impacting on the country's economic growth, and Vulcano also believes it can achieve this through the resolution of projects. Regarding the values, we can identify that all of them mention quality and focus on the client, and transparency and ethics were also repeated in at least two of them.

Based on the MVV of these companies, we formulated the following MVV:

[1] https://techcd.com.br/techcd/
[2] http://solidconcepts.com.br/
[3] https://vulcanoej.com.br/45786-2/

a) Mission: Our mission is to generate a great positive impact on the lives of our customers through an innovative, technological and high-quality product.

b) Vision: We believe that thanks to technological and logistical advances, distances have become increasingly shorter. Therefore, we aim to achieve national recognition in the coming years.

c) Values: Focus on the client, Quality, Innovation, Transparency, and Ethics.

4.2. Identifying the target market

According to a survey conducted by the World Economic Forum (apud 3D LAB, s.d.), 49% of Brazilian organizations intend to invest in additive manufacturing technologies. One of the sectors that has the greatest interest, with 53% of interested companies, is the health sector. The survey indicated that by the year 2020 50% of implants would be made with 3D printing.

Thus, we chose to analyze the size of the market that needs prostheses to be implanted in amputated limbs in the state of Goiás and surroundings. According to the IBGE census of 2010 (IBGE, 2010), about 8% of the entire Brazilian population has some motor disability and due to the high cost and high demand, it may lead to a delay in obtaining orthopedic prosthesis by the Unified Health System (SUS), the public service that is free for Brazilians. In 2008, Brazil had a demand for more than 1 million orthesis, with Goiás being the state with the largest time – 3 years - in providing it to its population (COLLUCCI, 2018). Thus, the target market are people that need an orthesis via the SUS.

4.3. Supplier Identification

When conducting a quantitative survey to identify the suppliers, the 3 establishments shown in Table 2 and Figure 3 were reached:

Table 2 - Suppliers of assembled 3D printers.

Store	City	Neighborhood	Street
3D Lab	Betim	Jardim Piemonte	R. Toyota
3D Criar	São Paulo	Butantã	Av. Prof. Lineu Prestes
FilipeFlop	Florianópolis	Saco Grande	Rod. José Carlos Daux

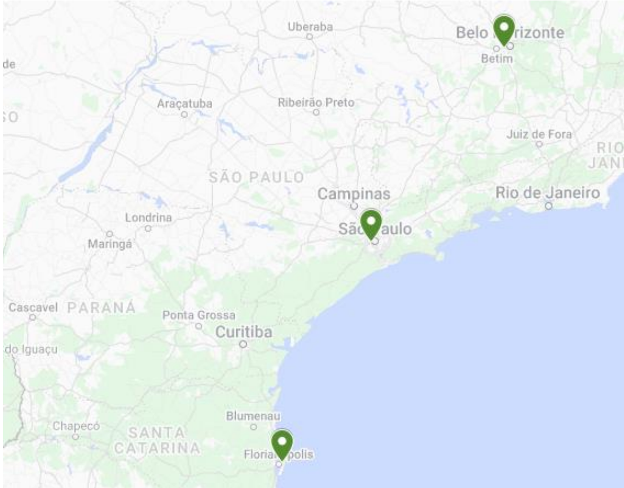

Figure 3 - Assembled 3D printer suppliers. Source: Google Maps.

4.4. Identification of competitors

The following competitors presented in Table 3 and Figure 4 have been identified:

Table 3 - Competing Stores.

Store	City	Neighborhood	Street
MBM Solução em Impressão	Goiânia	St. Sul	R. 105
Drawup	Goiânia	Jardim Goiás	Rua 2
3DGYN	Goiânia	St. Central	Av. Goiás
Fábrica de idéias impressão 3d	Goiânia	St. Sudoeste	R. Luiz de Matos

Figure 4 - Competing Stores. Source: Google Maps.

4.5. Product Definition

From the research, the use of additive manufacturing was identified mainly for the development of orthopedic prostheses for hand and foot implantation. This way, the product would guarantee a lower cost for prosthesis development and a greater agility for customer service, meeting a need of a market that faces long lines to acquire them through SUS.

An example of a hand orthopedic prosthesis is shown in Figure 5:

Figure 5 - Example of a prosthesis. Source: National Institute of Traumatology and Orthopedics - Brazil.

4.6. Defining the production flow and the layout

We analyzed the on-site 3D printing production flow at the Ambev S/A brewery to assist in the guidelines for defining the production flow for our 3D printing prosthetics products venture.

The 3D printing sector of the brewery produces spare parts for the maintenance sector, returnable containers, cans and pets. Such products are made on demand. The production process via 3D printing counts on 6 printers distributed in a functional layout as can be seen in Figure 7. The functional layout is considered highly flexible, allowing different types of products to be produced in the same amount of time.

Figure 7 - Picture of the 3D printing sector with functional layout.

The production flow, used at Ambev S/A, is illustrated in Figure 8.

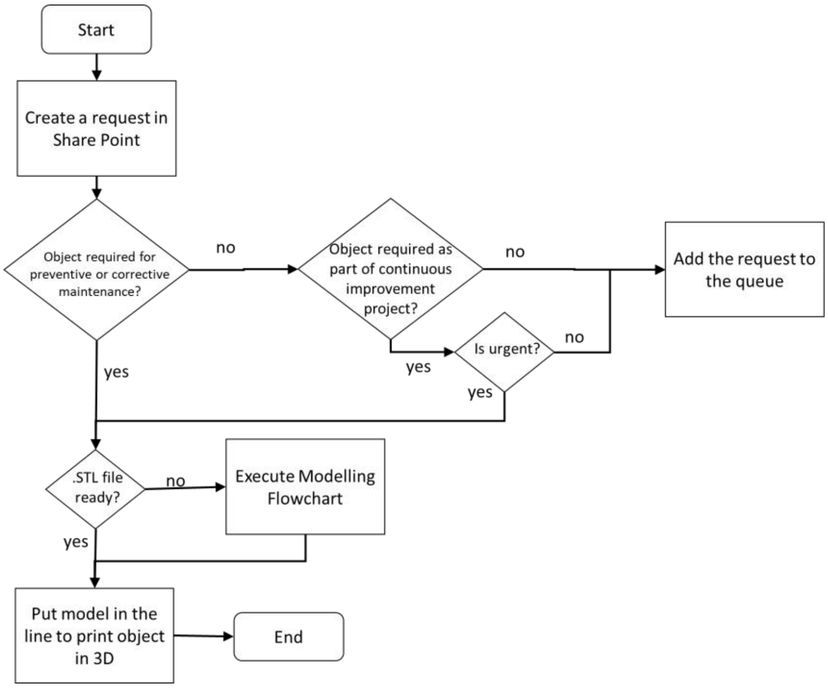

Figure 8 - Print Flowchart.

Initially, a request is received via SharePoint. Next, it is analyzed if the request is for printing a part for mandatory maintenance, in which case it is analyzed if the .STL file (computer project) exists. If the part is not for mandatory maintenance, in which case it is an improvement, the urgency is analyzed. If it is not urgent, the requisitions of these parts are queued for future analysis. However, if urgent, it is analyzed if the .STL file exists.

When the .STL file exists, the requisition will be placed in the print queue. This queue is managed by Kanban. When the .STL file does not exist, the modeling flow illustrated in Figure 9 is executed, which aims to create the .STL file.

In the modeling flow, the first activity is to understand how the part works in its real context of use. It is desired that measurements and wear characteristics are understood in order to begin modeling, that is, the computational design of the part. When this project is finished, the projections of the designed part are printed on an A4 sheet of paper. This printout serves as a visual comparison with a physical part, which is superimposed over the printout. With this, you can check whether the dimensions are correct, in which case you 3D print the part. If the dimensions of the part, compared to the A4 printout, are visually problematic, the process is restarted. Once the part has been 3D printed, finally a validation is performed, where the part's resistance characteristics and operating temperature, which implies the choice of material, are defined. As a result of this process, the print settings for this part are specified in the .STL file.

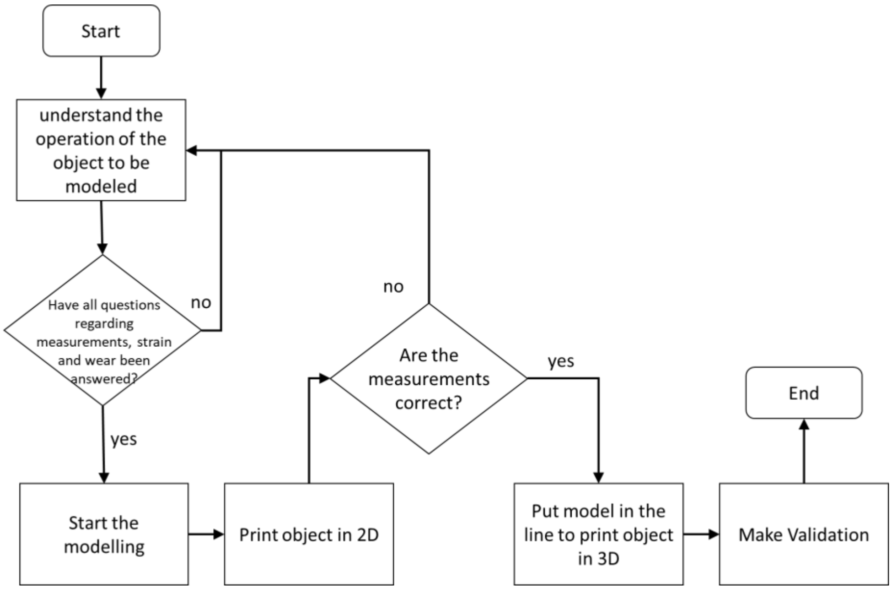

Figure 9 - Modeling flowchart.

After benchmarking the brewery and literature research it was possible to identify the most suitable production flow and layout to implement the 3D printing enterprise. The indicated production process is to divide the process into modeling and printing, as in the case of Ambev S/A. The recommended layout for the enterprise can be functional, in which a flexible process is allowed to produce the prostheses to be implanted in amputated limbs.

4.7 Proposition of a physical supply chain network design

The proposed physical network model for the supply chain is represented in Figure 11. In this figure, the retailer represents the facility of the enterprise under study. This network design is classified as "Storage at the distributor with direct delivery" by Chopra and Meindl (2003).

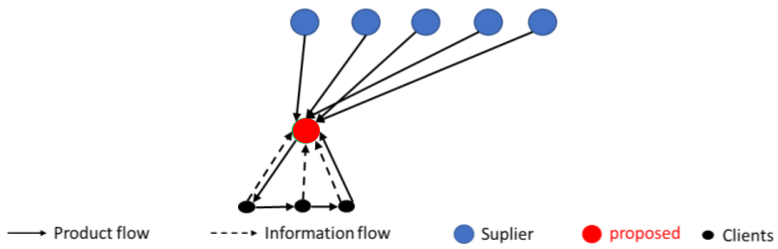

Figure 11 - Proposed network model.

From the surveys the following criteria were determined: a) structure: retail storage with customer service; b) General operation: retailer's stock, which receives orders and delivers product to the customer; c) Stock: 3D printing machines do not need a large stock due to the manufacturing model to meet a specific need; d) Transportation: larger vehicles are used for all routes, including to the retailer; e) Facilities and handling: high costs due to the machines. Online orders generate more costs for the manufacturer; f) Information technology: information infrastructure needed for online ordering; g) Response time: production of the part made on demand; h) Product availability and variety: variety depending on the type of part to be manufactured and the demand generated; i) Customer experience: purchases can be seen as a positive or negative experience by the customer; j) Time to market: average time due to the possibility of manufacturing practically any part needed; k) Returnability: easy traceability of parts due to the specific demand of each part.

5. CONCLUSIONS

The manufacturing of products has gone through constant transformations over the years. With this, 3D printing is gaining prominence by offering efficiency and low cost at the time of production and speed in research and development when compared to traditional methods. The 3D printing compared to traditional methods takes advantage by reducing material loss, material optimization and reducing delivery times, but when compared to serial production in a traditional production system, it is not yet competitive enough for large production volumes. Objectively, this work aims to implement Phase I of the Physical Network Design Framework that is proposed by Chopra and Meindl (2003), promoting a strategic planning of a supply network project for the implementation of a 3D printing enterprise.

Aiming to contribute socially in this transition, this work proposed strategies that should be taken for the development of a physical supply chain network project for a 3D printing parts factory. Results the work contemplates the implementation of phase 1 of the aforementioned project. Important business factors were compared in terms of the theoretical view with the real scenarios of companies in the Goias region. The target audience was defined as people who need orthopedic prostheses.

The use of additive manufacturing can provide lower costs for prosthesis development and greater agility for customer service, meeting a need of a market that faces long lines to acquire them through SUS. Based on this research, future research is intended to study the scalability of the product, showing what capacity of demand could be met and the quality of the product to be offered.

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