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Supply chain network design: a case study of the regional facilities analysis for a 3D printing company

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Abstract:

Abstract: 3D printing supply chain network. The objective is to analyze regional facility configurations in order to lower investment risks for an organization that aims to provide additive manufacturing The growing 3D printing market can be an attraction for investment in new businesses, which may entail strategic planning for new ventures. This paper presents a case study of designing a services for orthopedic and dental prostheses production. To this end, the competitive environment, the aggregating factor and logistic costs, tariffs and tax incentives, regional demand, political factors, the value of currency, and the demand uncertainty are analyzed. The results indicate that the adopted framework for network design decisions effectively allows the analysis of regional facility configuration. It also suggests that there are no hindering factors to the implementation of a 3D printing service company. In the region studied, there are fiscal incentives of more than 60% for taxes on the movement of goods between municipalities, which can be an advantage when locating facilities outside the capital. Competitors are well qualified, but there is room for new companies focused on quality and price, which may be a case for specialized products such as protheses. The estimated demand ranges from 146 to 509 units per month, which may be an opportunity for a new entrant given the few additive manufacturing ventures identified in the region.

Key words:

Supply chain, physical network design, 3D printing, production technology.

1. Introduction

It is not possible to stop investing in the modernization of machines and equipment, as this is a business necessity that generates competitive advantage for an organization (de Souza Dutra, 2015). This modernization brought the 3D printing, known in the industrial context as additive manufacturing, which is the process of transforming a digital model from a file into a physical object. That is, through a printer, with inputs such as resins and inks, a consumer can print an object using a digital file in his own home, producing, from this intangible digital model, a good for use and consumption (Gasparino, 2021).

In the context of Industry 4.0, also called advanced manufacturing, or smart grid in the energy sector (Souza Dutra, 2019), additive manufacturing has been widely used. Berman (2012), conducted a

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study that proposed to evaluate the characteristics and applications of 3D printing, defining it as “mass customization” as it allows the manufacturing of small quantities of customized products at relatively low costs. The positive and negative impacts of additive manufacturing on production systems have repercussions on the competitiveness of organizations, affecting competitive criteria. According to the literature review conducted by Veit (2018), the criterion most positively impacted by the use of additive manufacturing is cost. One of its consequences of its lower operating cost was reflected in the cost of the equipment itself. The cost of printers is decreasing over the years after the fall of patents (Berman, 2012).

With the advancement of this technology and the development of new software, the first mass production with 3D printers appeared and some manufacturers developed the first simulations for the formation of 3D “printing farms”. Industries in the automotive, aerospace, health, and construction fields use this technology for both prototyping and components production using topology and optimization techniques to fit three-dimensional models, seeking the maximum performance and best design (Nogueira, 2021).

According to the German portal Statista, the 3D printing market moved US $14.5 billion in 2019. In Brazil, by 2022, 49% of companies intend to invest in this technology, in view of its price reduction in recent years and the wide competitive advantage provided to the production process (Impressão, 2020). In the state of Goiás, specifically in the metropolitan region of Goiânia, this market is present in some establishments. With this, new entrants can expect fierce competition.

A plan to deal with such competition can be developed by defining a competitive strategy, which is defined as how an organization competes in the market. In other words, competitive strategy defines how the organization will be perceived by customers vis-à-vis competitors through advantage over such competitors. Therefore, according to Porter (2004), competitive strategy refers to a strategic position to compete in the market, always thinking about a vision of the future.

The study of the strategic plan for the insertion of a new entrant in a supply chain is one of the subjects discussed by Chopra and Meindl (2013). For example, these authors propose a framework, consisting of four phases, to assist in the design of the physical network of a supply chain. In particular, the objective of phase II of this framework is to determine the regions where the facilities will be located, their functionality and capacity. This is done by studying the demand and its uncertainty, exchange rate, tariffs and policies related to regional markets, export or import incentives, and restrictions for each market.

The 3D printing market in Brazil was studied by Almeida (2019). This author verified the existence of several challenges to be overcome, such as the transition from traditional production methods to the new Industry 4.0 processes. The objective of Almeida’s work is to identify the main barriers to the implementation of additive manufacturing in Brazil. On the other hand, there is no work in the literature whose focus is on 3D printing service in the state of Goiás.

The lack of information can inhibit investments (de Souza Dutra, 2022). Thus, in this paper, the general objective is to apply the aforementioned phase II to assist the installation of a 3D printing service unit in the metropolitan region of Goiânia. Specifically, considering the current context of Goiânia/Aparecida de Goiânia (Brazil) and an intention to install a venture related to the 3D printing factory in the region, it is aimed to analyze the following factors for the venture: necessary production technologies, competitive environment, aggregating factor and logistics costs, tariffs and tax incentives, regional demand, political factors, value of currency and demand uncertainty.

2. Literature review

According to Chopra and Meindl (2011), the design of a physical network for a supply chain aims to maximize the company’s profits while satisfying customer needs with respect to demand and responsiveness. That said, a model is proposed by these authors to help in such a design. This model, composed of four phases, begins with strategic decisions, such as product and target market definition, market study, and the definition of regions as potential candidates to host a new business facility. In the second phase, the potential regions are studied in detail considering logistical factors of the enterprise. The second phase of the aforementioned model is illustrated in Figure 1.

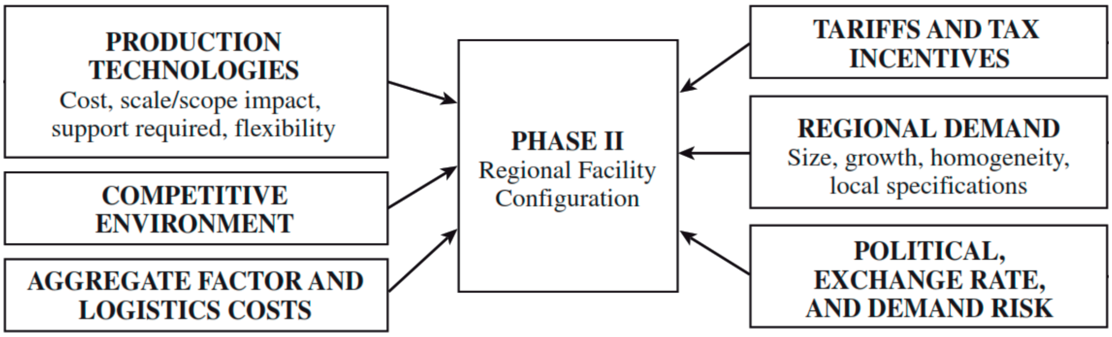

Figure 1. Phase II of Chopra and Meindl's framework for designing the physical network of a supply network. Source: Chopra and Meindl (2011).

Phase II aims to identify which region best suits the needs of one or more facilities. For this, some decision elements must be studied.

A first element to be analyzed for the definition of the network project is the demand per region. Each region will have a demand, different proportions, and different customer requirements. For some regions, the requirements may be homogeneous, which favors large consolidated facilities; comparatively, for other regions, the requirements may be heterogeneous, which favors facilities with lower capacity and more centered on certain products (Chopra and Meindl, 2011).

Another element to be analyzed is to identify the availability of production technologies and their influence on cost reduction. If economies of scale or scope are not significant, a decision tends to be that each market will have its own facility. On the other hand, if the economies of scale or scope are significant, a few facilities are expected to serve many markets (Chopra and Meindl, 2011, p. 123).

A third element of study is the identification in each of the regional markets about the uncertainties of demand, the exchange rate, and the political influence on the environment in which the markets are located. This decision element also requires studies about tariffs, tax incentives, import and export restrictions, and the legal regulations for producing in a particular region. Finally, deciding whether facilities will be closer or farther from competitors is also necessary (Chopra and Meindl, 2011).

In the following sections, the concepts of these elements for defining the configuration of regional facilities will be presented.

2.1. Regional facility configuration

According to Bavaresco (2013), the success of a venture requires an analysis such as the location and the public for which the business is intended. For this, it is necessary the anticipated study of the macro environment in which the company will operate, which includes an analysis of the social, cultural, economic, technological, and legislative potentialities. Entrepreneurs analyze the feasibility of setting up the new business based on environmental studies and research that can define the success factors of the enterprise.

These factors play an important role in the decisions necessary to build a network project. The process of evaluating the environment and the market that is intended to be reached with the new business should be considered as one of these factors because in many cases the rush to start a business causes wrong choices to delay or even annul the profitability and the return on the expected investment (Bavaresco, 2013).

Thus, an analysis of the competitive environment and an evaluation of regional facilities is as important as a business plan for the consolidation of any company's future. The importance of this plan serves not only for the company's future plans, but also as a detailed means of verifying the seriousness of the organization (Bavaresco, 2013).

2.2. Production technologies

Production technologies available in an environment or a market have a great importance on network design decisions. Their characteristics relative to the production cost are significant factors that define even the amount of facilities a company needs. Such technologies can provide economies of scale or scope, as well as influence production flexibility (Chopra and Meindl, 2011).

Economies of scale is understood as the cost reduction that occurs when companies increase production. There are many reasons why process cost decreases simultaneously with increased production volume. One example would be keeping production aligned and focused on just one product, providing cost savings associated with the exchange of raw materials and equipment between different productions (Amadeo, 2021).

In addition to economies of scale, economies of scope are also present. According to Caetano (2014), economies of scope occur when some input resources are shared in the production of goods and services.

2.3. Competitive environment

The concept of competitive environment is linked to the conceptualization and importance of what the organizational environment is. This definition, which was initially linked only to internal aspects of organizations, after the influence of the open systems theory, in the 50's and 60's, was expanded to incorporate the idea of environment. According to Lawrence and Lorsch (1967), the organization can be seen as the coordination of different individual contributions for the purpose of carrying out planned transactions with the environment.

In the same vein, research conducted by the biologist Bertalanffy (1972) conceives organizations as open systems. Thus, the author considers that organizations and their external environments are parts of a larger system that continuously interact. The organization exchanges resources with the environment, ensuring its survival, and modifies itself to adapt to the environmental contingencies that provide it access to these resources. As a result, it acquires new properties and characteristics.

Thus, organizations are open systems that relate to the external environment. The Structural Configurations Theory, presented by Mintzberg (2013), defines that organizational effectiveness is related to situational factors (linked to the organization itself and its external environment). The occasional factors linked to the organization's external environment are: complexity and technological instability, sales instability, market diversity, the degree of hostility in competition, and power relationships involving external influencers, thus defining the scenario of a competitive environment.

2.4. Aggregating factor and logistics costs

For Chopra and Meindl (2013), key logistics factors (facilities, inventory, transportation, information) determine supply chain performance as a function of responsiveness and efficiency. Similarly, Ballou (2006) defines that logistics is about adding value to products and services offered to customers. It is expected that there is a directly proportional relationship between value and integrated cost into a network project, because the higher the responsiveness of the supply chain, the higher the operational cost and consequently, the lower the efficiency.

In this context, logistics cost, which impacts decisions about the design of the physical supply chain network, is defined as equal to the sum of inventory, installation, transportation, and information system costs. The higher the logistics cost, the lower the efficiency. In general, no distribution network will outperform in responsiveness and efficiency at the same time. One way to counterbalance these performances is using aggregating factors, such as the use of warehouses for vehicle consolidation.

2.5. Tariffs and tax incentives

For Chopra and Meindl (2013), as global trade increases, macroeconomic factors such as tariffs and tax incentives contribute to the failure or success of supply chain networks. Thus, the relevance of considering these factors in making an efficient network design decision is undeniable.

The government has power to exercise when it comes to taxation. When the State exercises its power to tax, according to a specific average burden, which is applied to all without distinction, we observe fiscal activity. However, when the focus of the tax activity is to stimulate a particular activity, group or legally protected value, then there is a function that is conventionally called "extra fiscal". It is in this last aspect that the theory of tax incentives is applied (Catão, 2004, p.4).

"Extra fiscal" is characterized by Nabais (2012) as a set of rules that, although formally integrate tax law, have as its main or dominant purpose the achievement of certain economic or social results through the use of the tax instrument and not the collection of revenue to meet public expenditure. These tax incentives aim to influence business decisions taking into account the tax incidence.

2.6. Regional demand

In the economic field, "demand" means the quantity of a good or service that the market or a group of consumers wishes or wants to buy. Thus, demand is the desire or need supported by the consumer's ability and intention to buy.

Demand exists because there is, among other things, purchasing power. However, this same buying power oscillates according to the economic context of each country, region or market operation. In a crisis context, for example, it is crucial to analyze not only what the population is consuming but how consumption is being influenced (Dino, 2018).

This demand analysis impacts the design of the physical supply chain network. Chopra and Meindl (2013) cite that fluctuations in demand may exist depending on the political and economic context of a region, or even, demand may not be homogeneous across regions. For example, in 2017, Datafolha published that 46% of Brazilians surveyed believed that their economic situation would improve. However, even with falling inflation in January 2018, data released in the Employment and Unemployment Survey, pointed to a 0.7% reduction in average income (purchasing power) (Dino, 2018). Thus, the volume of demand was affected by an inflation context experienced by consumers.

As per Chopra and Meindl (2013), regional demand can influence the decision on the capacity of a facility, on the type of production technology to be used considering production flexibility vs. economies of scale and scope to meet the consumption desires of the local culture, among other decisions.

2.7. Political factors, currency exchange rate and demand risk

There are many factors that influence the planning of an efficient network project, among which political factors are present. According to Chopra and Meindl (2011), the political stability of the country plays a significant role in choosing the location of the network. Politically stable countries with free, independent and clear legal systems, in which rules of the economy are well defined, are territories that companies prefer to locate their facilities. Based on literature, political factors look at the degree of government interference in the economy and include tax policies, labor regulations, trade agreements between countries, change of government, wars, and conflicts. For the company, the greater the political stability, the more beneficial it is for its development (Oliveira, 2020). As far as inflation is concerned, its increase decreases people's purchasing power. However, one should not think that deflation (when inflation is below zero) is suitable for business. In deflation, if prices fall and this becomes a trend, people stop buying to save money, which decreases sales and the currency in circulation in the market, leading to an economic recession. Therefore, the ideal for business is for inflation to be controlled (Rocha, 2019).

Another relevant factor when choosing a network project is the value of the currency (foreign exchange). Fluctuations in foreign exchange rates happen frequently and impact the supply chain profits. An example of this is the value of the dollar currency and its fluctuation in yen, Japanese currency, during the years 2002 and 2004. The appreciation of the yen decreased revenues from major foreign markets. As a result, many Japanese companies built their production facilities spread all over the world (Chopra and Meindl, 2011). The US dollar rate is an uncertainty in the global scenario that directly interferes with the price of some imported raw materials and equipment used in additive manufacturing (Betim et al., 2019).

Fluctuations in demand caused by changes in the economy of each country also influence network design decisions. For example, during the period 1996 and 1998, Asian economies contracted, consequently decreasing the purchasing power of society. This decreased the demand in the local market, implying increased idle capacity in production facilities in Asia. Toyota, a company that had assembly plants in Asia that were only able to meet the local market, was motivated by the crisis in the continent to make its factories more flexible in order to supply the demand of other locations as well (Chopra and Meindl, 2011).

3. Methodology

As qualitative study with a case study approach, this research was conducted on the Brazilian small and medium-sized company "PRO3D". Data collection was carried out by observation, documentation, and empirical and bibliographic research. This study focuses on analyzing regional facility configurations to decrease investment risks of an organization that aims to provide additive manufacturing services for orthopedic and dental prostheses. To this end, the competitive environment, aggregating factor, logistics costs, tariffs and tax incentives, regional demand, political factors, the value of currency, and the uncertainty of demand are analyzed.

To identify the production technologies, an exploratory literature search was conducted with the topics related to 3D printers. Furthermore, considering the product and the production layout, the necessary production technologies were defined. The competitive environment was analyzed via experimental research. This field research comprises the selection of establishments that provide 3D printing services through the tool "Google Maps". Then, from the listing of these companies, visits were made to such companies for a survey of data and information about the competitive environment of the additive manufacturing market in the metropolitan region of Goiânia, capital of Goiás.

Related to the aggregating factor and logistics costs, based on initial definitions proposed by the organization concerning the network model, the possibilities that exist in the region under study regarding the consolidation of vehicles for an operation to have satisfactory logistics costs are analyzed. To study tariffs and tax incentives in the Goiás state, research was done on news portals and government websites about the current existence of tariffs and tax incentives in the state. Interviews were conducted with potential customers in order to obtain information about their interest in the product defined by the organization, that is, prostheses. From this collected information, the demand for 3D prints of this product was approximated.

A literature search was conducted in relation to Brazil Risk (Credit Default Swap Brazil) for a discussion of the influence of political factors on business. Currency value was not analyzed in this paper, as there are no envisioned facilities and markets in countries with different currencies.

4. Results and discussion

4.1. Strategic description of the enterprise

At a time prior to this work, the company's strategic analysis was carried out based on phase I of Chopra and Meindl's (2011) supply network project framework. The results of this analysis defined the strategies of a supply chain for a venture that aims to provide additive manufacturing services. To this end, it was considered data collected via applied and bibliographic research, the important aspects of the business and equating the theoretical strategic vision with the actual scenarios found in the metropolitan region of Goiânia.

The products defined by the organization are orthopedic and dental prostheses. The target market is patients in the public health system. It is estimated that potential customers will require such products being delivered to medical laboratories, dental clinics, or hospitals. Initially, 12 sub-regions with potential customers were initially identified, whose locations are illustrated in Figure 2.

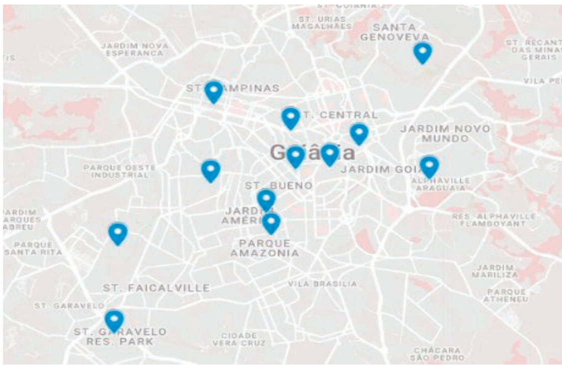

Figure 2. Potential customers. Source: Google Maps.

A benchmark performed by Silva et al. (2022) is used in this paper to assist in the guidelines for defining the production flow and the layout for the enterprise. The latter was defined as a functional layout, which is illustrated in Figure 3.

Figure 3. Layout of the facility for manufacturing parts by 3D printing. Source: (Silva et al., 2022).

The suggested production flow is illustrated in Figure 4.

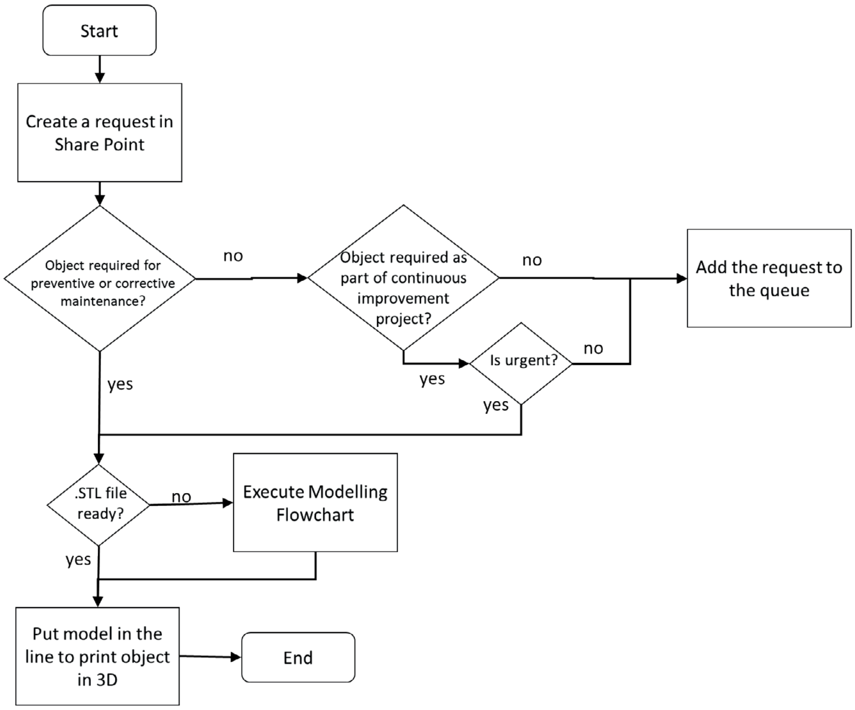

Figure 4. Print Flowchart. Source: (Silva et al., 2022).

Initially, a print request is received via SharePoint. Then, it is checked if the part is for mandatory maintenance, in which case it is analyzed if the .STL file (computational model) exists. If the requested piece is not related to mandatory maintenance, it is considered a request for process improvement purposes. Then, the urgency is analyzed. If it is not urgent, the request for this piece is placed in a queue for future analysis. However, if it is urgent, it is checked if the .STL file is already complete and ready for printing.

When the.STL file is already complete and ready for printing, the request will be placed in the print queue, which is managed by Kanban. Otherwise, the modeling flow illustrated in Figure 5 is executed, which aims to create the .STL file.

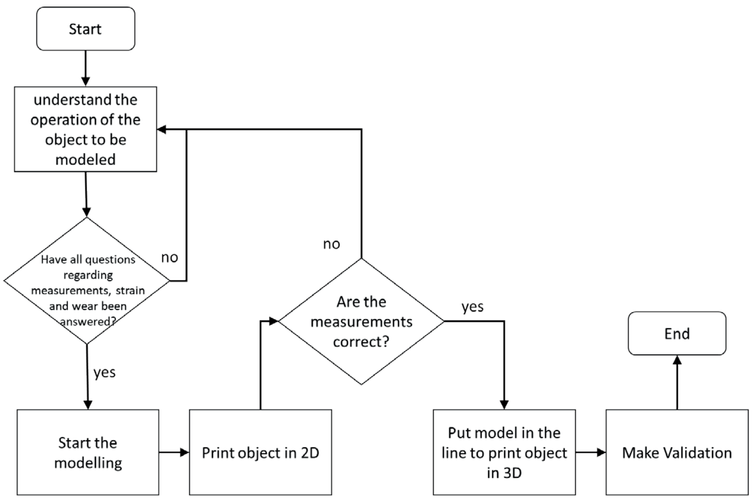

Figure 5. Modeling flowchart. Source: (Silva et al., 2022).

In the modeling flow, the first activity is to understand how the piece works in its real use context. It is desired that measurements and wear characteristics are understood in order to begin the computational modeling activity, that is, the computational design of the piece. When this design is finished, the side, top, and front projections of the designed piece are printed on A4 paper. This printout is used for visual comparison of dimensions with a physical part via overlay of the part on the printout. With this, it is possible to check whether the dimensions are correct, in which case the part is 3D printed. If the dimensions of the piece, compared to the A4 printout, are visually problematic, the process is restarted. Once the piece has been 3D printed, finally a validation step is done. In this step, the part's resistance and operating temperature characteristics are studied, which implies the choice of the material for final printing. As a result of this process, the printing settings for this piece are specified in the. STL file.

Finally, the proposed broadly physical network model for the supply chain is represented in Figure 6. This network design is classified as "Storage at the distributor with direct delivery" by Chopra and Meindl (2011).

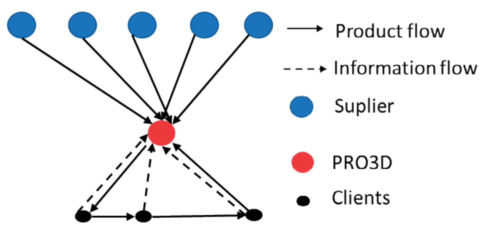

Figure 6. Proposed physical network model. Source: Adapted from Silva et al. (2022).

4.2. Production technologies

In view of the technological evolution of Industry 4.0, Betim et al. (2019) conducted a prospective scenario analysis focused on additive manufacturing in Brazil for 2024. The research was done using the Momentum methodology, which identified three scenarios. They concluded that, although this market is growing moderately, it is necessary to encompass the leading countries in this type of manufacturing, with changes in the national scenario to encourage the additive manufacturing market. These results are explained on the basis that machinery and raw material costs directly impact production, which may be dependent on imports.

Already cost-effective, the alternatives for manufacturing processes are diverse (Betim et al., 2019). There are three main technologies used for additive manufacturing operations, each with its particularities. The design features and requirements are listed in Tables 1 and 2, respectively.

For Ryan et al. (2017), three types of manufacturing operation on 3D printers can be identified:

1. Craft: low volume of products is produced by low-cost equipment. Users typically operate equipment in this type of manufacturing;
2. Job shop: the equipment, operated by specialists, has higher quality and cost, with low continuous production volume;
3. Factory, where the equipment is not only specialized, but also used by operators trained in it. The production volumes are high, so manufacturing procedures are standardized.

According to Conner et al. (2014), conventional manufacturing may be less competitive than 3D printing when it comes to manufacturing products with higher levels of customization, complexity, or a combination of both. For products with low complexity, low volume, and low customization, additive manufacturing will be desired only if it provides lower lead time and lower cost compared to conventional methods.

Considering 3D printing technologies, SLS is adopted since such technology has been used for the purpose of orthopedic prostheses, the product of the business under study. Considering the production flow, it is believed that a place that provides 3D printing service only needs, in addition to printers, a computer to communicate with such printers. Job shop may be the ideal process for the defined product.

4.3. Competitive environment

From the search conducted on Google's Maps tool, it was obtained, as a result, 9 companies that provide 3D printing services and that are located in the city of Goiânia, which are illustrated in Figure 7. The search was conducted by companies that are active in the market and have a physical store to receive customers.

Table 1. Characteristics associated with each 3D printing method.

Feature	Fused Deposition Modelling (FDM)	Stereolithography (SLA)	Selective Laser Sintering (SLS)
Working Principle	Extrusion of cast material	Light Curing Resin	Sintered Microparticles
Type of compatible materials	Thermoplastics	Light Cured Resins	Thermoplastics
Quantity of compatible materials	Very high	Medium	Low
Price of materials	Medium- Low	High	Medium
Complexity	High	Medium	Medium
Production Speed	Very high	Medium	Low
Minimum layer resolution	0.1 mm	0,05 mm	0.06 mm
Maximum XY resolution	0.25 mm	0.05 mm	0.08 - 0.08 mm
Accuracy	Low	Medium	High
Application	Rapid prototyping.	Models with small details.	Functional prototypes.
Advantages	Education.	Casting negatives for jewelry and dentistry.	Short series.
Disadvantages	Model and tool making.	Splints.	Models and tools.

Source: Filament2print (2020).

Table 2. Design requirements associated with each 3D printing method.

Feature	FDM	SLA	SLS
Minimum Wall Thickness	0.8 mm	0.5 mm in supported walls. 1 mm in unsupported walls	0.7 mm
Engravings	0.6 mm width 2 mm from top	0.4 mm	1 mm
Minimum hole diameter	2 mm	0.5 mm	1.5 mm
Tolerance on moving parts and connections	0.5 mm	0.5 mm	0.3 mm in moving parts 0.1 mm in connections
Holes in hollow parts	No need	4 mm	5 mm
Minimum Detail Size	2 mm	0.2 mm	0.8 mm
Minimum column diameter	3 mm	0.5 mm	0.8 mm
General tolerances	±0.5% (lower limit ±0.5 mm)	±0.5% (lower limit ±0.15 mm)	±0.3% (lower limit ±0.3 mm)

Source: Filament2print (2020).

Figure 7. 3D printing companies in Goiânia. Source: Google Maps.

A focus group, consisting of 12 people, visited and used the services of these 9 competitors to comparatively evaluate service-related characteristics. Table 3 shows in its first column these characteristics and in its first row a symbolic reference for the nine competitors (C1 to C9). The evaluation considers scores from 1 to 10, with 1 and 10 being the worst and the best, respectively. The result for each characteristic is given by the rounded average of the 12 individual scores. The last column of Table 3 shows the sum of the scores of all the competing companies for a certain characteristic.

Based on Table 3, there are competitors in the region with scores higher than 8 in relation to all features. Based on the sum of the evaluations, the features "product quality" and "price" have the lowest scores. Considering the specificity of the

Table 3. Competitor evaluation via focus group.

	Competitor									
Features	1	2	3	4	5	6	7	8	9	SUM
Product Quality	5	9	8	5	10	6	5	5	6	59
Price	6	7	5	6	5	6	6	8	9	58
Response Time	9	6	9	6	7	9	9	8	7	70
Location	8	10	9	8	7	8	10	5	7	72
Customer Experience (Service, Location, Ease of Payment)	8	7	8	6	7	9	7	6	6	64
Product Variety	7	10	10	10	7	7	6	8	8	73
Returnability	7	8	5	6	5	9	10	9	6	65
Order Visibility	8	9	7	7	8	9	10	9	5	72

organization's product (prostheses), a strategy in the face of the competitive environment is to focus on specialization of production as a way to target both features. It is believed that this specialization can also provide good response times and increase profitability. This decision corroborates Conner et al. (2014).

Finally, a location within the metropolitan region of Goiânia is indicated. Although this decision puts the facility close to the competitors, it also puts it close to potential customers. Thus, the facility can benefit from the flow of people. Furthermore, according to the network model proposed by the company's strategic plan, customers will receive the products at its facilities. Therefore, a location in the metropolitan region of Goiania can reduce transportation costs.

4.4. Aggregating factor and logistics costs

One of the important factors for the reduction of logistical costs is the aggregating factor, or even, freight consolidation. The suggested strategy is to perform vehicle consolidation for purchases. The network project classified as "storage at the distributor with direct delivery" foresees buying directly from manufacturers, which suggests buying according to a minimum order lot. With this, orders can be placed with a view to consolidating a vehicle. The objective is to guarantee the total occupation of the vehicle's capacity and the consequent reduction of costs in the delivery routine. Therefore, in the consolidation of vehicles, the company groups small quantities of different products, guaranteeing total occupancy of the vehicle, taking advantage of all its capacity.

4.5. Tariffs and tax incentives

All individuals and companies can apply for tax incentives. Governments are in charge of evaluating each application. Among the factors evaluated are compatibility of costs, the interest of the government, compliance with legislation, and technical capacity. Obtaining tax incentives is a good solution for organizations, and one that positively benefits the image and visibility of a business. It is essential that the organization is up to date with the tax authorities for the requested project to be approved. The processing of a tax incentive is, in general, easy and not very bureaucratic, as long as the companies meet the requirements to obtain it.

Technology policy is currently a central part of the economic agenda in developed countries and in emerging countries such as Brazil. Starting in the 2000s, it was possible to observe the Brazilian government's initiatives to transform the discourse of innovation into effective actions. Laws came into force that encourage technological production and the openness for the import of new production technologies. For instance, the Innovation Law No. 10,973, enacted on December 2, 2004, was created with the aim of providing tax incentives for innovation and scientific and technological research, and Law No. 13,243, January 11, 2016, was created to represent the new legal basis for innovation. Besides these, in Brazil there is also the Law of Good, which is a policy to foster innovation. Such a policy is part of the government's strategic expansionist policies for the scientific and technological development of the country.

In Goiás, Decree No. 9724 of October 7, 2020 decided for the adhesion of the State of Goiás to the tax benefits provided in the legislation of the State of Mato Grosso do Sul and also established procedures for the operationalization of these benefits. This legislation is part of the Regional Development Program - PROGOIÁS.

The beneficiaries of PROGOIÁS can be the establishments that carry out industrial activities in Goiás, that are framed in the referred program and that make investments corresponding to: I - implantation of a new industrial establishment; II - expansion of an existing industrial establishment; and III - revitalization of a paralyzed industrial establishment.

PROGOIÁS' incentives vary from 64% to 67%, which are applicable over the positive value resulting from the confrontation between the debits and credits of the Tax on Operations Related to the Circulation of Merchandise and the Rendering of Interstate and Intercity Transportation and Communication Services (*Imposto sobre Operações relativas à Circulação de Mercadorias e sobre Prestações de Serviços de Transporte Interestadual e Intermunicipal e de Comunicação*) known, in Brazil, as ICMS.

With this, facilities set up in municipalities neighboring the capital city can benefit from cheaper real estate costs and take advantage of the aforementioned incentives. Thus, it may be a tradeoff between transportation cost and fixed cost. Compared to its neighbors, the capital may face higher real estate rental or acquisition costs, but it will have lower transportation costs.

4.6. Regional demand

About 50 potential clients, among dental and medical offices, in the regions indicated by the organization were prospected. Among these, 47 were interviewed about the usability of printed prostheses in their patients in order to estimate a demand for such impressions. The individual demands resulting from the interviews were estimated by the number of patients who consulted in their offices and whose diagnosis indicated the need for a prosthesis. The demands of each medical office were aggregated considering the 12 regions identified in Figure 2, whose results are summarized in Table 4. The second column of this table gives the minimum, mode and maximum values.

Table 4. Estimated demand for each potential customer subregion.

Subregion of potential customers	Monthly demand (min, mode, max)
D1	(18,25,48)
D2	(15,20,24)
D3	(31,35,42)
D4	(15,22,30)
D5	(0,17,20)
D6	(5,40,81)
D7	(12,35,49)
D8	(15,19,33)
D9	(0,8,12)
D10	(10,30,66)
D11	(15,40,58)
D12	(10,30,46)

Adding the minimum values gives an aggregate minimum demand value. Proceeding similarly with the maximum values, it can be stated that the aggregate demand ranges from 146 to 509.

4.7. Political factors

CDS Brazil, also known as Credit Default Swap, is a derivative security in the financial market. It works as an insurance, with the objective of avoiding default in credit operations. Thus, the CDS offers some protection for those seeking to reduce the risks of a credit portfolio. This is done through the issuance of a bond by an insurance company. This institution assumes the function of guaranteeing the redemption of the amount invested in cases of default for any reason.

The CDS is measured in points. If the CDS is high, this means that there is a greater risk that the investor will not receive payment. Thus, this number is also often used as a risk indicator in the economy, particularly in international investments. Thus, the CDS price is directly related to the possibility of a country not paying its debts. Therefore, the lower the CDS, the more optimism there is about the economy.

Brazil's CDS between April 2017 and April 2022 is shown in Figure 8.

For Brazil, the CDS increased in 2020 probably due to the pandemic situation, since the CDS for other regions such as EUA, Germany, United Kingdom, Australia had similar peak. Since 2020, the CDS Brazil has fluctuated with the increase of vaccinated

Figure 8. Brazil CDS between April 2017 and April 2022. Source: http://www.worldgovernmentbonds.com.

people, relaxation of isolation measures, and discoveries of new COVID-19 variants. However, before 2020, Brazil's CDS showed a downward trend. With this, it is expected this trend in the long term. Thus, Brazil's economy may be favorable to industry, including 3D printing enterprises.

5. Conclusions

Based on the framework proposed by Chopra and Meindl, which is composed of four phases and assists in the projection of the physical network of a supply chain, this paper proposes a case study focused on the application of phase II of the aforementioned framework to assist in the installation of a 3D printing company in the metropolitan region of Goiânia. Specifically, considering this region, and an interest to install a venture related to a 3D printing service facility aimed at the production of orthopedic and dental prostheses, the following factors were analyzed for the venture: required production technologies, competitive environment, aggregating factor and logistics costs, tariffs and tax incentives, regional demand, political factors, and uncertainty of demand.

Data collection was carried out by empirical and bibliographic research, observation, and documentation. The results indicate viability of the region for such a venture. In the region studied, there are fiscal incentives of more than 60% for taxes on the movement of goods between municipalities, which can be an advantage in locating facilities outside the capital. The estimated demand ranges from 146 to 509 units per month, which may be an opportunity for a new entrant, given the few additive manufacturing ventures identified in the region. Competitors are well qualified, but there is room for new companies focused on quality and price, which may be a case for specialized products, as protheses. Finally, job shop is indicated as the type of manufacturing operation, where recruited workers are trained by the company.

As future work, phases III and IV of the framework proposed by Chopra and Meindl should be developed for the company studied in this paper. This will spell out the logistics costs and infrastructure required and define specific locations that implement the company's strategic plan. In addition, the final phase will choose a location for a facility.

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