Supply chain management: potential locations for setting up a 3D printing service

Matheus Roberto Campos Chaves[a], **Stephanie Aparecida Campos Chaves**[b], **June Marques Fernandes**[c], **Michael David de Souza Dutra**[d*]

[a] Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, Av. Barão Homem de Melo, 329 - Nova Granada, Belo Horizonte - MG, 30431-285, Brazil. matheusalisebrae@gmail.com

[a] Serviço Brasileiro de Apoio às Micro e Pequenas Empresas, Av. Barão Homem de Melo, 329 - Nova Granada, Belo Horizonte - MG, 30431-285, Brazil. stephanie.alisebrae@gmail.com

[c] Federal University of Ouro Preto, Rua 36, 115 - Loanda, João Monlevade - MG, 35931-008, Brazil. june@ufop.edu.br

[d] Polytechnique Montréal, 2500 Chem. de Polytechnique, Montréal, QC H3T 1J4, Canadá. michaeldavid.dutra@polymtl.ca

Abstract: The Fourth Industrial Revolution brought with it the integration of virtual and real-world production. One of the technologies that best illustrates this scenario is additive manufacturing, which enables the production of parts by printing, from a virtual project. This technology has gained visibility in the Brazilian scenario. Thus, this study aims to suggest potential locations for a venture that provides 3D printing services. To assist in this process, Chopra and Meindl propose a general framework composed of four phases to create a physical network project for a supply chain. Considering that a strategic planning of the enterprise covers all the issues of the first two phases of the aforementioned framework, this work specifically analyzes the issues that support decisions for the third phase of the framework The city chosen as a case was Goiânia/GO, a place where tax incentives and the available infrastructure position the municipality as an attractive city for entrepreneurship. Empirical research was conducted, analyzing the local infrastructure for installation of a factory/store, specialized in 3D printing using the SLS technology. Thus, promising locations were selected to host the new venture, seeking to maximize its chances of success. Results indicated 16 potential locations, which can be input to a mathematical programming problem to decide the best location for a future facility installation.

Keywords: Supply chain; Physical network design; Industry 4.0; Facility Location; Additive Manufacturing.

1 Introduction

For Conner et al. (2014), additive manufacturing, also known as 3D printing, involves manufacturing a part by depositing material in layers. This differs from conventional processes such as subtractive processes (such as milling and drilling), formative processes (such as casting and forging), and joining processes (such as welding and fastening). Ferreira et al. (2020) state that additive manufacturing is part of the Industry 4.0 revolution, also known as smart grids in the electrical sector (Souza Dutra; 2019). According to CNI (2016), additive manufacturing has been receiving enormous attention recently and has stood out in several applications, such as in toy manufacturing, dental/orthopedic prosthetics, and teaching aids.

The Brazilian market shows promise for the growth of additive manufacturing. According to reports published by Estadão newspaper (Dino, 2019) and Veja magazine (Schlindwein, 2020), there has been a consolidation of additive manufacturing as a trend, even in a context of economic crisis. According to Schlindwein (2020), 41% of companies worldwide should adopt the use of the 3D printer by 2022, and in Brazil it could reach 49%. The sectors that are most likely to adopt the technology are: transportation (61%), chemicals and biotechnology (58%), oil and gas (57%), and health (53%). Dino (2019) also lists segments such as food, aerospace, and fashion as contributors to the expansion of additive manufacturing.

To take advantage of this expansion, new ventures involving additive manufacturing may be a desire of entrepreneurs. In fact, investing in the modernization of machinery and equipment is a necessity for companies (de Souza Dutra; 2015) and the lack of adequate information can inhibit investments (de Souza Dutra, 2022). Thus, strategically defining how to initialize such a venture can be a complex task. According to Chopra and Meindl (2016), one of the strategic decisions is the potential location of multiple links in a supply chain. Thus, deciding where to set up 3D printing shops/industries is a strategic decision. To assist in this process, Chopra and Meindl (2016) propose a general framework consisting of four phases for creating a physical network design of a supply chain.

The scope of this paper is to apply one of the phases of the aforementioned framework to the insertion of a 3D printing factory/store in its respective supply chain. More specifically, considering some strategic decisions already defined, such as the definition of the product, the market study, a layout and production flow of the facilities, it is intended in this work to present a case study focusing on applying third phase of the Chopra and Meindl' framework for a venture involving 3D printing services. This phase aims to suggest potential locations to install facilities, focusing on an analysis not only of a propitious infrastructure, but also of production methods.

Infrastructure is understood as the systems and objects functionally related, such as buildings, facilities, equipment, production systems, and services necessary for the functioning of the economy, the state, and its citizens. As for production methods, Chopra and Meindl (2016), state that they are formed by the union of characteristics related to machinery and personal skills for the execution of production flows.

Thus, the objective of this article is to analyze possible locations for the installation of a company in the metropolitan region of Goiânia, which seeks to operate in the additive manufacturing segment. Specifically, we will analyze the appropriate production methods, the necessary infrastructure, as well as the restrictions imposed by the organizational strategy to suggest potential locations that could serve for an additive manufacturing process.

2 Literature review

According to Chopra and Meindl (2016), during the execution of phase III of their framework, it is necessary to analyze infrastructure factors along with factors related to production methods of the venture under study to meet the needs of a possible location that may be suggested as a result of this phase.

Some of these factors are closely related to the physical infrastructure of the region proposed by the strategic study developed in the previous phases of the framework, such as the availability of transportation services for product flow, the proximity of ports, airports, and highways, the availability of communication services and means of transportation for workers, and the existence of warehouses built or areas to build such facilities. Other factors touch on issues of production methods, such as the necessary skills that employees must have to operate the facilities, the turnover of the workforce (considered to be the

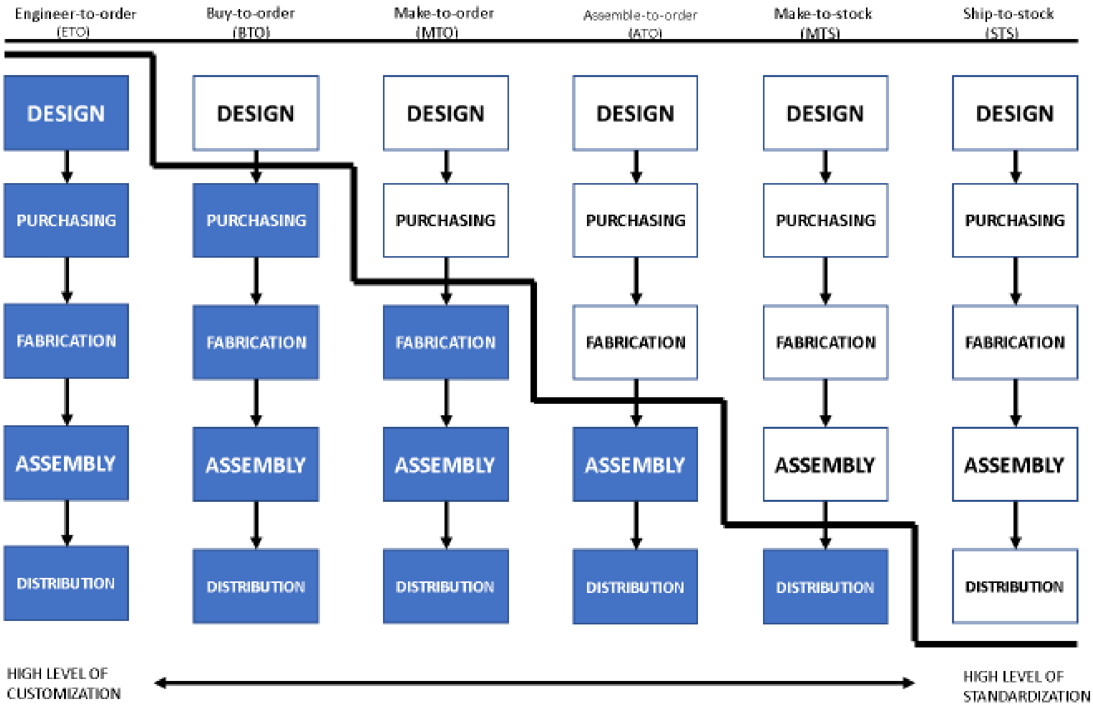

Figure 1: Process categorization according to customer involvement. Source: GOSLING et al. (2007) apud RYAN et al. (2017).

time interval between an employee joining and leaving the organization), the responsiveness of the community to the facilities that will be installed, and the response time that we will have at such facilities.

The importance in analyzing these factors is to ensure that the suggested locations have infrastructure and resources consistent not only with the business requirements, but also with the production methods that will be adopted in such locations (Chopra and Meindl, 2016).

Bearing this in mind, three key aspects for Ryan et al. (2017), related to operation of additive manufacturing: customer involvement in the manufacturing process; plant distribution; and types of manufacturing operation; are discussed next.

2.1 Customer involvement in the manufacturing process

Ryan et. al (2017) states that the degree of customer involvement in the product manufacturing process is divided into six categories. These categories are distinguished according to the level in the supply chain at which it is necessary to wait for the order to happen before production can then take place. In other words, each category is distinguished from the others according to the stage at which the product customizations take place. This categorization applies both to cases where customization is only possible at the final point of distribution (Ship-to-Stock - STS), and to cases where customization occurs early in the product manufacturing project (Engineer-to-Order - ETO). Figure 1 illustrates how the 6 categories of supply chain structure are divided and how they are related to customization.

Figure 1 shows a customization continuum. The higher the level of customization, the greater the participation of the customer since the initial stages of production or even in product design. In Figure 1, it can be seen that the ETO category has the highest level of customization, while the STS category works with more standardized products. The ladder-shaped line, which divides Figure 1, illustrates the point where the customer's direct influence is requested. According to Sen et al. (2021), these categories are characterized thus:

● Engineer-to-Order: Products and services categorized this way are unique and usually have demand fluctuation, inputs are particular to each product, and lead-time is high;

● Make-to-Order (MTO) / Buy-to-Order (BTO): In these configurations, products share the same raw materials, customers can specify what will be manufactured, but have slightly shorter lead-time than the ETO configuration;

● Assembly-to-Order (ATO): The decoupling point is closer to the final consumer, that is, the manufactured components do not follow the customer's specifications, but the final products are assembled according to the customers' wishes. This configuration offers even shorter lead-times than the ETO, MTO, and BTO configurations;

● Make-to-Stock: In supply chains categorized in this way, the demand forecast is of great importance in determining the inventory volume. This is because the products are standardized and one of the main objectives is to eliminate excess inventory;

● Ship-to-Stock: In this configuration, standardized products are allocated to fixed destinations.

Although the categorization is applied to processes, the same can be generalized to sequential supply chain processes. For example, Ikea's supply chain operates under the ATO category (Ikea, 2022).

According to Ryan et al. (2017), one of the main advantages that additive manufacturing has is its high flexibility, and it can adapt to the specific requirements of each customer. 3D printing technology can be successfully applied in supply chains called Make-to-Order (SCOTT and HARRISON, 2015), and even Make-to-Stock (EYERS et al., 2018), but it is on ETO chains that most studies focus. The adoption of a chain model, such as ETO, carries implicitly a number of characteristics associated with production methods and thus contributes to the definition of 'Production Methods', which is one of the inputs proposed, by Chopra and Meindl (2016) when designing a physical network.

Finally, Gosling and Naim (2009) suggest that the Lean production method (Lean) has a better conceptual fit to the characteristics of Engineer-to-Order (ETO) supply chains, that is, producing only what is demanded by the customer. According to the authors, Lean avoids waste, especially waste associated with inventory maintenance and overproduction.

2.2 Plant Distribution

According to Ryan et al. (2017), discussions in the literature on the geographic distribution of 3D-printed parts factories show that there are several possible configurations. There is everything from the possibility of home consumers using printers at home to manufacture custom items, to large factory environments operating on a national scale, as well as levels in between the extremes mentioned. This distribution of factories is influenced by a series of supply chain decisions at the strategic, tactical, and operational levels.

According to the reach and strategy of the company, the physical distribution of the plants is also defined. A factory with national reach will possibly have higher logistics costs to distribute its products, but it can obtain economies of scale and offer a product with a lower sales price. On the other hand, a local factory may have lower distribution costs and more agile service, but may incur high manufacturing costs, which reflect in the product's sale price. The distribution mode of the factories (as well as the production systems associated with it) also contributes to the definition of the 'Production Methods', fitting the framework proposed, by Chopra and Meindl (2016), for the design of a physical network.

2.3 Types of additive manufacturing operation

Three main technologies used for operations as well as three types of additive manufacturing operations were detailed in Sá et al (2022). Among the technologies discussed are Fused Deposition Modelling, Stereolithography and Selective Laser Synthesizing. The authors concluded that Stereolithography is more suitable for prosthetics because, compared to these other technologies, the resolution capability is low, the material quality is reasonable, among other characteristics that allow better applicability in objects to be printed with a higher level of detail. For Ryan et al. (2017) and Sá et al (2022), there are three types of manufacturing operation in common 3D printers. The first of these is Craft, which operates with low-cost, usually customer-operated equipment for low-volume production of products. The second type of manufacturing operation, indicated by Sá et al (2022) for the enterprise in question, is Job shop, in which there is low volume production on more costly and higher quality equipment, which are operated by specialists. Finally, the last type of manufacturing operation is the Factory, where the volume production of standardized products is high, equipment is specialized, and operators are trained and specialized in its use.

3 Methodology

As qualitative study with a case study approach, this research was conducted on the Brazilian small and medium-sized company "PRO3D". The data collection was carried out by observation, documentation, and empirical and bibliographic research. This study focuses on analyzing features described on the third phase of Chopra and Meindl's framework for supply chain network design. The goal is to decrease investment risks of the company aiming to provide additive manufacturing services for orthopedic and dental prosthesis. To this end, infrastructure and production methods, accordingly to the definition of Chopra and Meindl (2016), are analyzed.

To determine the availability of suppliers, it was checked whether, in the enterprise strategic plan description, there are input suppliers for the production flow of a 3D printing factory in the metropolitan region of Goiânia. If the description of the enterprise does not include suppliers, Google Maps is used to search for suppliers of inputs for 3D printing in the metropolitan region of Goiânia.

In relation to the existence of transportation services for the product, considering the location of suppliers and customers, it is analyzed which means of transportation best meet the transportation needs of inputs and the final product. To this end, the characteristics of the raw material and the final product are identified in terms of special transportation needs. Next, vehicles that meet these needs are listed. Finally, it is verified if there are such vehicles in the metropolitan region of Goiânia.

In this work, it is adopted as proximity to ports, airports and highways the distance that the region under study is from ports, airports and highways. This will be determined using the "Google Maps" distance calculation tool. Next, a brief analysis of the importance of proximity to ports, airports and highways will be performed.

Considering the production flow of the enterprise, the communication services needed by the employees were analyzed. Next, it was verified, if there are any communication companies that offer the aforementioned services. Finally, an analysis was made of the prices of such services.

In relation to the means of locomotion for workers, the site of the company responsible for public transportation in the metropolitan region of Goiânia was consulted, to verify the existence of means of locomotion.

The existence of warehouses built or areas available to be built were verified via visits to made to real estate agencies located in the metropolitan region of Goiânia, as well as research through the "Google Street" tool, available inside "Google Maps", to make virtual visits to streets in the metropolitan region of Goiânia.

Labor force turnover is a movement of replacement of part of the labor force through layoffs and hires of workers in a certain time interval. This recurrent replacement movement is measured by means of the turnover rate, or informally, turnover. In order to estimate workforce turnover, a literature review was carried out and a relationship was established between the degree of workforce turnover, from the perspective of a HR consulting firm, and the competencies required for the production flow of the enterprise under study.

In this paper, "community receptivity" is considered as the perception that the community has regarding the installation of a new company in the vicinity. For this, the tool "Google Maps" will be used to verify if there are more factories in the metropolitan region of Goiânia. Then, the evaluations of these companies, if available at Google, is reviewed to get an insight about what the residents and frequenters of the locations have as an opinion.

The response time is considered to be the delivery time from the input supplier plus the time required for the printing process. The modeling process is analyzed separately to compute the time to market. For this, empirical research was conducted with potential suppliers to find out their delivery times. The delivery time of competitors was used to get an approximation of the time required to print a 3D object.

In this paper, necessary competencies were treated as the technical interpersonal skills that the employee needs to perform his or her job. For this, an analysis of the activities of the production flow was conducted to identify the knowledge required in each activity. Next, a job profile was identified via consultation with specialized HR companies.

4 Results and discussion

4.1 Strategic description of the enterprise

This section provides a description of the more strategic context of the organization that support the analyses performed throughout this paper. We will briefly describe the product, the location of suppliers, the layout and production flow, the production technologies, the location of potential customers and expected demand, and the type of network design used by the organization.

In a previous moment to this work, the strategic analysis of the enterprise was carried out based on phase I of Chopra and Meindl's (2011) supply network project. Results of this analysis defined the supply chain strategies for a venture of a facility providing additive manufacturing services, taking into account the data found in applied and bibliographic research, considering the important aspects of the business and equating the theoretical view with the real scenarios found in the metropolitan region of Goiânia.

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

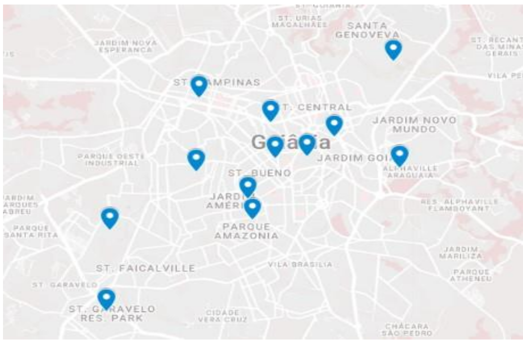

Figure 2: Potential customers. Source: Google Maps.

In these 12 sub-regions with potential customers, Sá et al. (2022) estimated an aggregated monthly demand as shown in Table 1.

Table 1. 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)

Source: Sá et al. (2022).

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

Table 2. Assembled 3D printer factories.

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

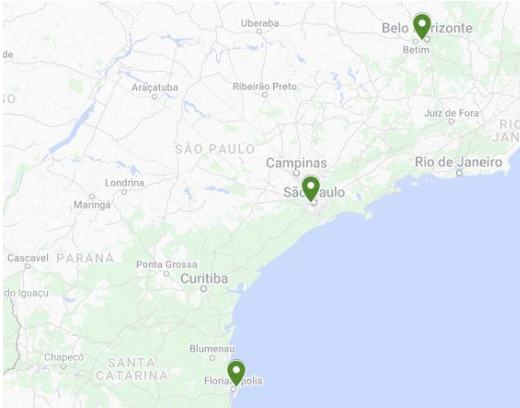

Figure 3: Assembled 3D printer factories. Source: Google Maps.

A benchmark performed by Silva et al. (2022) is used in this paper to assist in the guidelines for defining the production flow and layout for the enterprise focused on 3D printing of prosthetics. The layout for the enterprise was defined as a functional layout, which is illustrated in Figure 4.


Figure 4: Layout of the facility for manufacturing parts by 3D printing.

The suggested production flow is illustrated in Figure 5.

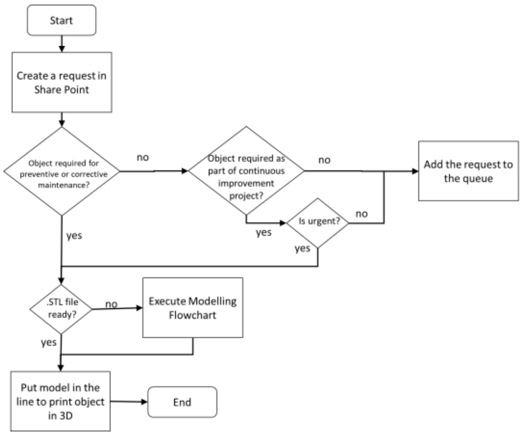

Figure 5: Print Flowchart. Source: (Silva et al., 2022).

Initially, a print request is received via SharePoint. Then, it is checked if the piece is for mandatory maintenance, in which case it is analyzed if the .STL file (computer project) 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 urgent, the request is analyzed to see if the .STL file exists.

When the .STL file exists, the request will be placed in the print queue, which is managed by Kanban. When the .STL file does not exist, the modeling flow illustrated in Figure 6 is executed, which aims to create the .STL file.

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 print serves for visual comparison with a physical piece, which is superimposed over the print. 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 is done, where the resistance characteristics and operating temperature of the piece 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.

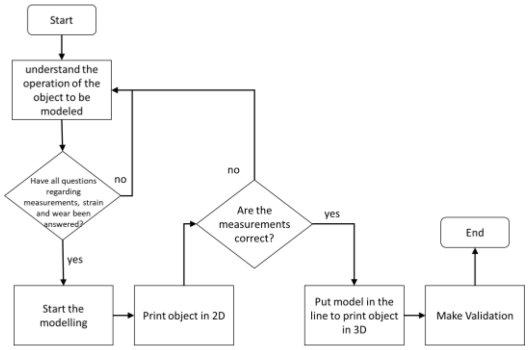

Figure 6: Modeling flowchart. Source: (Silva et al., 2022).

Finally, the proposed broadly physical network model for the supply chain is represented in Figure 7. 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 (2011).

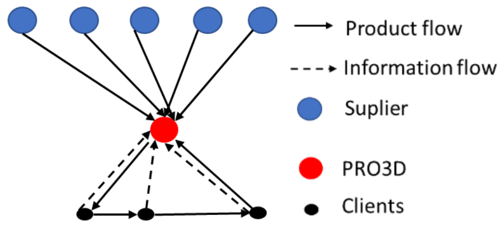

Figure 7: Proposed network model. Source: Adapted from Silva et al. (2022).

4.2 Infrastructure and production methods

The availability of suppliers is shown in Table 4. It turns out that suppliers of 3D printers are located in states other than the one in which the installation of a 3D printing enterprise is intended. In relation to inputs, a search on Google for "resins for 3d printing" was performed. The locations of the 20 suppliers closest to Goiânia are illustrated in Figure 8. It is observed that only one supplier is located in Goiânia, most of them being located in São Paulo and Belo Horizonte. Details of each of these suppliers are summarized in Table 3.

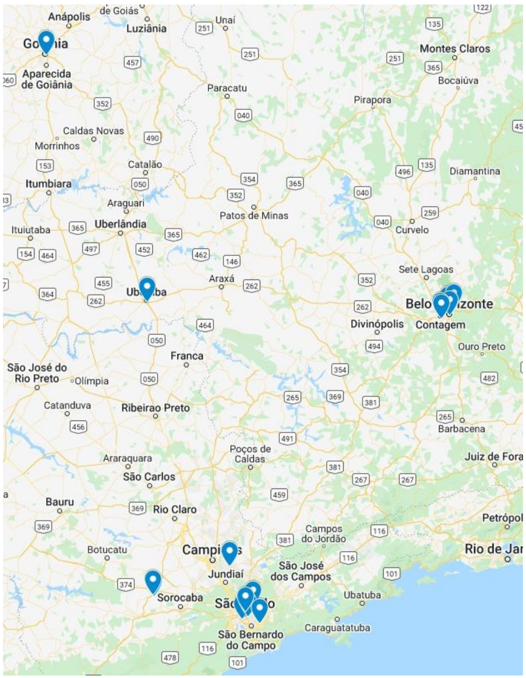

Figure 8: Suppliers of inputs for 3D printing services. Source: Google Maps.

Given the small number of local suppliers, it may be frequent the need to buy from another state. Thus, it may be important to consider a future need of storage inputs for freight consolidation and, possibly, for decreasing the time response. The delivery time, which depends on the service, may affect the time response and the logistics costs. A faster service is more expensive than a normal service.

The analysis about transportation services for the product is based on the needs of protection during transportation. The product of the business is prosthetics in solid material. Thus, any vehicle can transport the product to customers. Therefore, as the chosen means of transportation, one can use product shipping apps such as Uber and independent transportation.

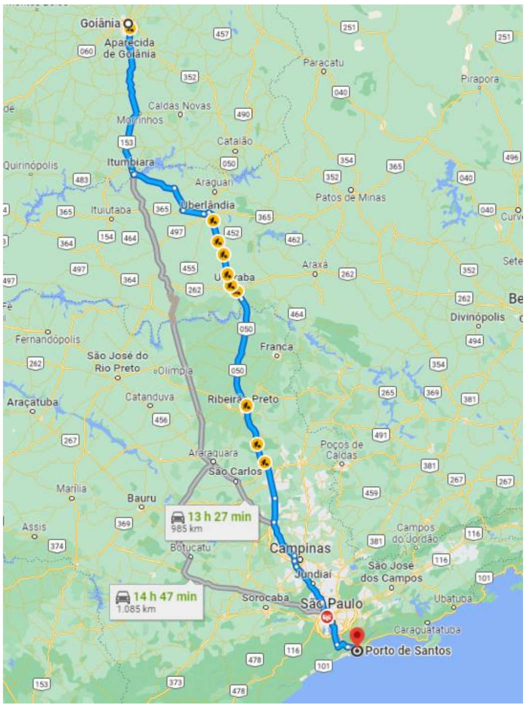

Figure 9: Distance from Goiânia to the Port of Santos. Source: Google Maps.

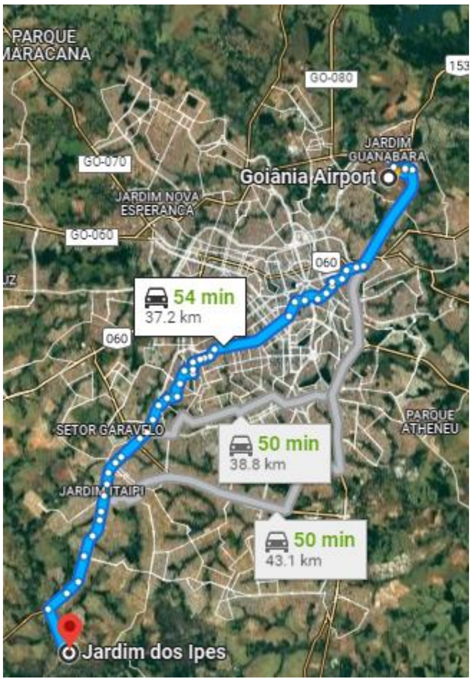

Figure 10: Distance from the farthest outskirts of the metropolitan region of Goiânia to the closest airport in the region. Source: Google Maps.

In this initial stage of business implementation, it is not intended to work with international suppliers. However, in a future context in which there may be competitive advantages for importing inputs or exporting products, it may be necessary to use ports and airports. Thus, the distance to those facilities is described. As illustrated in Figure 9, the city of Goiânia is located approximately 1000 km from the port of Santos, located in the state of São Paulo. In relation to airports, the furthest point on the outskirts of the metropolitan region of Goiânia is 37.2 km from the closest airport in the region, as illustrated in Figure 10. Finally, regarding the proximity to highways, Goiânia is a city crossed by about 10 highways.

Table 3: General information from input suppliers for 3D printing services.

Supplier	Address	Delivery time (working days)		
		Post office fast service	Post office normal service	Carrier
Fast Cril	Av. Mutirão, 3231 - St. Marista, Goiânia - GO, 74150-340	7		10
Astroscience 3D	R. José Bonifácio, 1404 - Abadia, Uberaba - MG, 38025-185	6	10	
Quanton3d	Av. Augusto de Lima, 1288 - Barro Preto, Belo Horizonte - MG, 30190-003	3	7	6
3D Fila	R. Padre Leopoldo Mertens, 1600 - São Francisco, Belo Horizonte - MG, 31255-200			5
Escolha 3D	R. Maria Nazaré, 39 - Nazare, Belo Horizonte - MG, 31990-100	5	11	
Triadimension	R. Santa Catarina, 1627 - Loja 07 - Lourdes, Belo Horizonte - MG, 30170-081			
3D LAB	R. Toyota, 490 - Dom I. Jardim Piemonte / Norte, Betim - MG, 32689-354	4	8	6
Cubo 3D	Avenida Marte, 1125 - 2° piso loja 18 - Jardim Riacho das Pedras, Contagem - MG, 32241-395	5	9	9
3D Applications	Av. Emílio Ribas, 828 - Jardim Tijuco, Guarulhos - SP, 07020-010	3	10	5
Red Resinas	Rua José Selega, R. Adelelmo Corradini, 51 - Parque Industrial, Itatiba - SP, 13257-593	2	6	5
ARTBOX3D	Avenida Santo Amaro, 4644 Lojas 1, 2 e 3 - Brooklin, São Paulo - SP, 04702-000	3	9	9

Analyzing the production flow, it is understood that only basic communication services are required, such as mobile phone and internet. Communication with other links in the supply chain are to receive requests, contact clients and buy inputs. A few numbers of suppliers use Electronic Data Interchange, being e-commerce more common.

These basic communication services are offered only in Goiânia by companies such as Algar, LinQ, and Vivo. According to the site web of these companies, these services are not provided in many locations of neighbor municipalities. The values of the services for Goiania are summarized in Table 4.

Table 4. Values of the communication services of some companies of the sector that serve the metropolitan region of Goiânia.

Company	**Monthly price of internet service package accordingly to broadband speed (R$)**		
	300 MBs	**600 MBs**	**1000 MBs**
Algar	109.90*	129.90*	239.90*
LinQ	-	119.99	179.99
Vivo	119.99*	159.99*	-

* Unlimited mobile telephony included.

With this, it is expected that internet and mobile phone services will be available in the metropolitan region. It is believed that Algar's 600 MB service is the cheapest given the need for communication in the enterprise's activities.

Regarding the means of transportation, it was found that there are public transportation services, as illustrated in Figure 11, as well as individualized public transportation services offered by Uber and taxi drivers.

About warehouses built or areas to build one, in this initial stage of business implementation, it is not intended to work with high volumes of stock at the beginning of the life of the enterprise. The stock can be stored within the production facility itself. However, in a future context of business expansion, it may be necessary to use larger warehouses. In consultation with the Viva Real site , an real estate agency, the number of lands for sale is 3,351 and the number of sheds/depots/warehouses for rent is 173. With this, a warehouse-type facility is available in the metropolitan region of Goiânia.

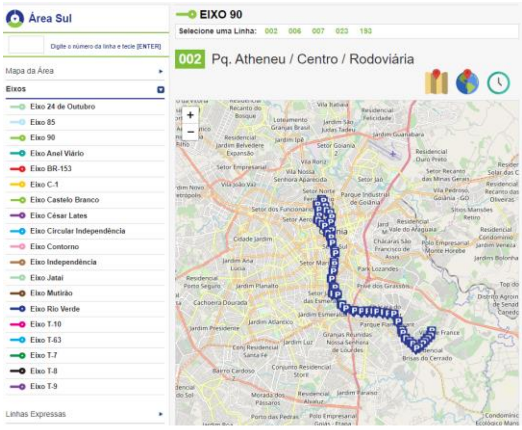

Figure 11: Demonstration of the existence of public transportation in the metropolitan region of Goiânia. Source: RMTC (2022).

Workforce turnover may be a challenge for the business. According to the Radford Global Technology Survey apud Pieczynski (2016), between 2012 and 2016, the turnover rate of the Brazilian workforce decreased from 18.9% to 12.8%, putting Brazil performing better than Argentina and Mexico. However, focusing on sales staff in the Brazilian technology sector, turnover among employees has increased between Q1 2012 and Q1 2016, going from a 14.6% turnover rate to 17.6%.

According to the HR consultancy Gupy, among the most common reasons for turnover are the job description incompatible with the real work, lack of feedback, absence of career plan, a hostile environment, poor leadership and a repetitive routine (Dias, 2022).

Describing the job in a way that is inconsistent with the actual work to be performed can cause a lack of transparency and distrust, causing misappropriation of duties. This leads to friction and misalignment of expectations between the employer and the employee (Dias, 2022).

It is generally expected that employees will seek to develop their competencies in order to take on positions with greater responsibilities and new challenges. Constant feedback helps employees to correct possible mistakes in this development. If the manager does not provide such feedback, or worse still, makes demands without any basis or does not make clear what his expectations are, it is natural that employees become discouraged and carry out their tasks carelessly. Over time, the tendency is of increasing resignation requests in search of opportunities in which there is concern with the valorization and growth of the professional (Dias, 2022).

The absence of a career plan is another problematic factor because the employee will have no incentive to work harder in their deliveries. The situation is worse if, in the organization, promotions are made based on favoritism or family and emotional connections. To minimize these effects, an organizational chart can be created to facilitate the visualization of the job hierarchy. In addition, one can create internal policies of promotions or internal recruitment to encourage meritocracy (Dias, 2022).

Hostile environment is an unpleasant situation. When the space makes the employee feel oppressed, cornered or humiliated, naturally their departure from the organization will be brief (Dias, 2022).

Bad leadership increases turnover. Leaders affect too much the turnover rates of a company. Extremely authoritarian leaderships usually have negative results in engagement and retention. To avoid such results, it is necessary that leaders know the qualities and limitations of each employee, in order to know exactly what and how to charge in relation to the delivery of each one, that is, it is essential to draw a profile of each one to take advantage of their efficiencies and deficiencies in favor of the company itself (Dias, 2022).

Finally, repetitive routines are a last problem. No matter how much your employees love the activities and feel comfortable in their tasks, everything that is repeated daily leads to exhaustion. Keeping an employee for two or three years on the same tasks, with no challenges or learning opportunities, is a very short path to their departure. Many times, this situation occurs due to the comfort of the manager, who believes that if the employee is performing the function well, he or she should remain in it, or due to lack of planning of the company, which does not have a job rotation project or training (Dias, 2022).

Considering the enterprise under study, the discussion in Pieczynski (2016) and all these common causes for high turnover, it is concluded that some causes are more managerial, such as lack of feedback, poor leadership and hostile environment, which can be improved or eliminated through training or changing managerial processes. Other causes can be categorized as more structural, such as repetitive routines and lack of a career plan. Under the assumption that a new venture for 3D printing services will have a lean hierarchical structure, few employees would take on several activities. For example, the buyer could also work in sales. Thus, the routine could be quite diverse. On the other hand, the career plan, if it exists, may have few promotion levels. Considering, on the other hand, a larger enterprise, more specialized sectors may exist, which provides job rotation, but less flexible routines. Therefore, for the company under study, there seems to be a trade-off between some of the causes listed that lead to a higher turnover.

Although to business may face a considerable level of turnover, community receptivity may be good. In a Google search, it was identified that there are 9 competing companies in the city of Goiânia. The evaluations found on Google are focused on the services provided by such companies, and no comments from the community complaining about inconveniences caused by the stores were identified. Thus, by analogy, it is expected that our business has a good receptivity from the community.

Related to response time, as a result of the empirical research with suppliers, it was found, by Table 3, that the maximum delivery time for supplies is up to 11 working days.

For an approximation of the printing time, nine companies that provide 3D printing services in the metropolitan region of Goiânia were consulted regarding the time to deliver a 3D printing order of multiple parts that compose dental prostheses and orthopedic prostheses. As a result, all companies reported that all parts needed to assemble a single prosthesis will occupy a single 3D printer for a maximum of 1 day, once the computational design is ready. Therefore, it can be concluded that the response time can be around 12 working days.

Regarding the modeling time (time to market) for the computational design, according to the nine companies consulted, this time can vary considerably, depending on the level of detail of the object. Considering prostheses, the companies report a modeling time varying between one and three weeks for all pieces that compose one prosthesis.

Finally, required skills for the business are soft. Analyzing the flow of activities for an enterprise with purpose in 3D printing services, it is observed, in terms of more general activities, that there is the request for a print, the creation of the computational project and the printing itself. With this, it is expected that a manager, an assistant, and a designer would be necessary positions. The manager would oversee the purchasing, customer sourcing and operations processes. The helper would be in charge of receiving customer requests, carrying out the sales process, as well as the printing tasks themselves. The designer, who could have an institutional link as a freelancer, would be responsible for the creation of the computer modeling project.

When it comes to labor for modeling 3D printing computer projects, there is a very favorable scenario. Although there are few people with experience in the market, the technique of modeling and using the printer does not require an academic background. Courses lasting about 8 theoretical hours, found on digital platforms like Udemy , can be found for less than R$30.00. Today there are repositories on the Internet such as Thingverse , Thangs and Youmagine that provide the computer project ready to print several objects, making the work even easier. Thus, a person with little or no experience can learn to work in the area in a short time and in a cheap way. According to the Glassdoor website , the salary of a Print Solution Electronics Technician at two competitors ranges from R$1,500.00 to R$2,000.00. Thus, this market does not have high wage costs for skilled employees.

With regard to the manager and assistant positions, communication skills are necessary. Training should be conducted in a way that does not limit the recruitment process. With this, people without higher education can be targeted, which reduces payroll costs. Salaries on Glassdoor site range from the legal minimum to R$2,500.00 in competitors.

It is concluded that the necessary competencies do not limit a 3D printing business in the metropolitan region of Goiânia.

4.3 Potential Sites

From the aforementioned partial results, a list of potential sites was drawn up for the location of parts factories by means of 3D printing. The criteria to selected sites considers places that are able to provide the defined product to potential clients, and profit from some other benefits, such as crowded places or with cheaper rent price. Such locations are illustrated in Figure 12, where the red dots are the possible locations in Goiânia and the black dots are the possible locations in Aparecida de Goiânia.

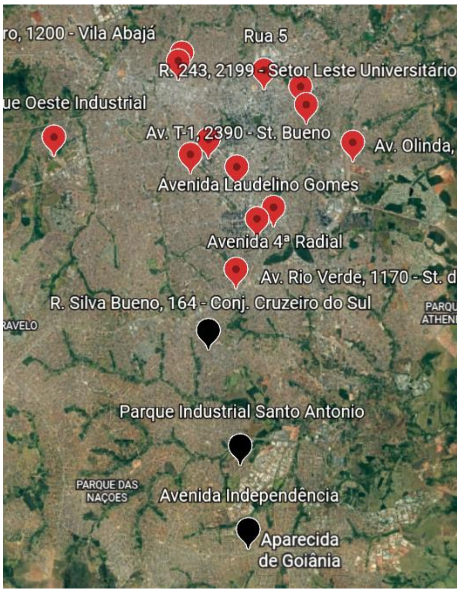

Figure 12: Suggested potential locations for the development of a 3D printing factory. Source: Google Earth.

The characteristics of each site are summarized below.

1. Av. Universitária, 933 - Qd 88 - Setor Leste Universitário, Goiânia - GO, 74610-100: Location with high circulation of researchers, professors, and students, as well as health professionals. The installation of a factory/store in this location can attract visitors that circulate around the surroundings, as well as can offer better delivery times and prices to a large number of clients.

2. R. Silva Bueno, 164-388 - Jardim Nova Era, Aparecida de Goiânia - GO, 74916-150: Being located in Aparecida de Goiânia, but still near the capital, a store/factory in this location could serve customers from both cities. A facility in this location can present lower costs with rent, which may be a considerable factor for being a new venture.

3. T-2 Avenue, 1.461 - St. Bueno, Goiânia – GO, 74230-257: Setting up a store/factory in one of the noblest regions of the city shows potential for conveying a good impression to customers, as well as for the possibility of adding more value to the products. In the Bueno Sector are located several schools (that can order materials and generate demand in school projects), offices (that can demand customized utensils for brand promotion, prototypes, etc.), stores (that can also generate demand for marketing items), among others.

4. T-1, 2390 - St. Bueno, Goiânia - GO, 74215-022: The reasons to install a factory/store in this location are similar to the previous case, with the addition that this location is close to the SEBRAE, an institution that helps microentrepreneurs business development, which may attract small entrepreneurs as new customers.

5. Laudelino Gomes - St. Bela Vista, Goiânia – GO, 74830-090: Locality of high population density, as well as offices and hospitals. This location is also near the Training Center and the store of the sports institution "Goiás Esporte Clube", which can generate demand for customized accessories for customers, as well as for marketing items.

6. Av. 24 de Outubro, 1200 - lote 09 quadra 48 - St. Campinas, Goiânia – GO, 74505-100: Located in a very intense commercial area and crossing one of the main avenues in Goiânia, this location has easy access. It has a not so high square meter value. The Setor Campinas region is historically known for its commercial potential. There are many stores here that may demand marketing items or other customized products.

7. Santo Antônio Industrial St., Aparecida de Goiânia – GO, 74983-360: Being located in the Business Pole of Goiás, the company can serve several different companies, as well as individuals. The region has easy access to the main roads of the region (BR-153, ring road) and has potential to cover both Goiânia and Aparecida de Goiânia.

8. Parque Oeste Industrial, Goiânia - GO, 74375-150: Region that houses several factories

and is close to residential regions. The installation of a factory/store in this region can serve legal entities and individuals. The proximity to logistics companies can also contribute to a better flow of raw materials and distribution of finished products.

9. Rua Santa Luzia, Quadra D Lote 01 - Campinas, Goiânia – GO, 74525-040: The region is predominantly commercial, with 64.13% of commercial establishments. 100.00% of the residences are made up of houses. Located in the Campinas Sector, it is close to the central sector and is an area of intense commerce. Good coverage area and well known place in Goiânia.

10. Ambassador Gallery - R. 5, 15 - St. Central, Goiânia – GO, 74020-130: Located near the University Sector, it can attract a lot of university clients and meet demands, such as printing models and college projects.

11. Av. Rio Verde, 2014 - Jardim Atlântico, Aparecida de Goiânia - GO, 74840-150: This location is a very relevant point within the local trade, because it is the avenue that divides the two largest cities in the state of Goiás, Goiânia and Aparecida de Goiânia. In this sense, for having an intense traffic of vehicles and people daily, it is an interesting place for commerce.

12. Av. 4ª Radial, 1035 - St. Pedro Ludovico, Goiania – GO, 74830-130: This location stands out for being on an avenue with a great flow of people and with easy and fast access. Besides, a positive point of this place is its proximity to one of the most known and densely populated neighborhoods in the capital, the Bueno sector.

13. C-205 Avenue, 413 - Jardim América, Goiânia – GO, 74270-020: Densely populated region and close to avenues, which tends to facilitate access to commerce.

14. R. 243, 2199 - Setor Leste Universitário, Goiânia – GO, 74603-200: Located in the sector with the highest density of students in the city, it becomes a great option considering the students' work at the university and it is in a place of easy access and flow of people and cars.

15. Olinda, 350 - qd 09 lt 01 - Jardim Novo Mundo, Goiânia – GO, 74715-350: Located near one of the main luxury condominiums in Goiânia. A store in this region can capture customers willing to disburse significant values for a service with differentiated quality, besides being located in a place of easy access via Transbrasiliana highway.

16. Independência Avenue Qd1 Lt8 - Jardim Ipiranga, Aparecida de Goiânia – GO, 74968-150: This place is located in one of the main commercial centers of Aparecida de Goiânia. Besides having the stores and offices in the region as potential clients, it can also serve the Aparecida de Goiânia Emergency Hospital, an IPASGO children's clinic, a campus of the State University of Goiás, and a campus of the Federal Institute of Goiano.

5 Conclusions

The Brazilian market shows promise for the growth of additive manufacturing. Considering this context, this study aimed to suggest potential locations for a venture that provides 3D printing services. 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 work proposes a case study focused on applying the phase III of the aforementioned framework to assist in the installation of a 3D printing facility in the metropolitan region of Goiânia. To do so, empirical and bibliographical research was carried out, analyzing the local infrastructure and production methods for the installation of a factory/store, specialized in 3D printing using the SLS technology.

Results showed that among the 16 suppliers of inputs for the operation of services in 3D printing closest to the metropolitan region of Goiânia, only one is in Goiânia. A good portion of input suppliers are in São Paulo and Belo Horizonte.

The skills required for the enterprise are technical knowledge for computer design of objects to be printed, as well as managerial and communication skills with the public. Employees can be trained at low cost to acquire these competencies, in order to facilitate the recruitment process. The enterprise may experience employee turnover, due to the possibility of the work routine being repetitive or due to the limitation of career plans depending on the size of the business. Finally, there is public and individual transportation for the locomotion of workers in the region studied.

The region under study is less than 40 km from the airport, but it is distant about 1000 km from the nearest port. On the other hand, there are 10 federal highways that cross or encircle the periphery of the region, providing quick access by road. Communication services needed for the development have been defined as mobile telephony and internet, which are offered at monthly rates close to 10% of the Brazilian minimum wage. The number of plots of land available for sale for possible warehouses or other facilities exceeds 3000, and there are more than 150 storage facilities available for rent. Furthermore, there is no evidence that the community's receptivity to such an enterprise is negative.

Considering all this empirical evidence, 16 promising sites have been selected to host a new facility for 3D printing services to maximize success. Such locations can be input for a future work in which a mathematical programming problem can be formulated to decide the best location for a future facility installation.

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