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Systematic Analysis of the International Purchasing and Transportation Process

The Case Study of Blocks Technology

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Abstract

The year 2009 transformed 3D printing into a booming industry after the patents holding the technology proprietary expired. As more and more players try to seize a market share, gaining a competitive edge becomes a greater challenge. While globalization interconnects more buyers and suppliers worldwide it intrinsically creates opportunity and a complex supply chain network for companies to operate in. More often than not, the development of a comprehensive optimization strategy for purchasing becomes essential for sustainable profit-oriented growth.

This paper addresses the case study of the 3D printer manufacturer startup Blocks Technology, that aims to reduce operating costs while increasing gross profit margins. The analysis of their supply chain network clearly characterized the study problem as lying upstream of the supply chain, revealing mainly international purchasing and transportation activities as key elements in need of improvement.

Therefore, this paper develops an analytical model to analyse, emulate and showcase the international purchasing and transportation process cost of Blocks Technology. The model supported by a computer-based tool aims to help decision makers reduce operational expenditures, through the analysis of the model's results according to the user's data input.

Keywords: supply chain management; international supply chain; purchasing management; transports; cost modeling supply chain logistics

1. Introduction

It is possible that the majority of consumers will have access to 3D printing by 2025 (McKinsey Global Institute, 2013), turning it into one of the most relevant disruptive trends to have an impact on the logistics industry (DHL Trend Research, 2016).

Lower prices will be critical for a mass adoption of 3D printing (DHL Trend Research, 2016) bringing increasing revenue for manufacturers like Blocks Technology – Portuguese 3D printer manufacturer startup. To ensure this revenue flow companies will resort increasingly to the outsourcing of components and finished products (Kotabe e Murray, 2004), looking for suppliers able to offer the lowest prices for high quality goods and services worldwide (Stock and Lambert, 2001).

Globalization is nowadays directly correlated with turning purchasing into a strategic decision-making process with the highest potential impact in terms of long term profitability (Quintens et al., 2006). Accordingly, the transportation of goods is an essential element in supply chains (SC) (Crespo de Carvalho et al., 2010) supporting all international movement and management of goods.

Stank and Goldsby (2000) mention that companies which merge transportation and logistics planning with purchasing and production are more likely to create consolidation opportunities across the SC. And Papageorgiou (2009) states that in an extremely competitive environment, improved decision-making is a demand for an efficient supply chain management (SCM), having tremendous impact in the company's path to success or failure.

In today's business environment, and according to Tayur et al. (1999), there is no doubt about the importance of quantitative models and computer tools to improve the decision-making process.

Christopher (2011) mentions that the purpose of conducting a cost analysis is to identify the different variables resulting from choosing between different scenarios. And that the cost delta of these different scenarios is the end result of the analysis, providing relevant information that supports the decision making-process.

For example, the total landed cost (TLC) analysis concept, usually associated with large international shipments (Trent e Roberts, 2010) normally represents most of the total international shipping cost, and can often showcase potential cost reductions (Pumpe and Vallée, 2015). Still, Coyle et al. (2011) suggest that it is possible to adopt a simplified approach to these cost modelling calculations although they may portray result as approximates, it's simplicity and ease of use is an advantage.

In this paper, an analysis of the international purchasing and transportation process cost was conducted to support the decision-making process at Blocks Technology. To achieve this, an analytical model was created to compute different scenarios that represent significant cost reductions in the SC.

This study only considers inbound purchasing and transportation occurring between Portugal and China as they represent 82% of all goods used for production. They are ultimately the biggest challenge the startup faces in terms of planning, management and decision-making.

To conclude, the model showcased throughout this paper is an analysis of purchasing and inbound transportation processes central to Blocks Technology's business, aiming to encounter the main goal behind a logistics cost analysis of obtaining trustworthy data that allows managers to make better resource allocation choices (Christopher, 2011).

The focus of this study is the development of a tool that allows the startup to identify all variables and opportunities to reduce cost in its international purchasing and transportation process and consequently increase profitability.

2. Case Study

This paper starts with a short presentation of Blocks Technology supply chain, followed by the current purchasing process along with its portfolio and suppliers. In the end of this section is characterized the problem of this study.

2.1. Blocks Technology Supply Chain

Specializing in developing and manufacturing 3D printers, the startup Blocks Technology faces a constant challenge to efficiently manage its international supply chain due to limited resources and lack of know-how. In the process of implementing a new production process in new specialized facilities this challenge becomes ever so important.

Up to the point where this study was conducted the startup managed its production without any defined production schedules fulfilling customer orders without any strategic plan for purchasing.

This study is based however on defining a standard for international purchasing and transportation to support the implementation of the improvements that are to be made to the startups production process.

The supply chain is divided into five distinct levels: suppliers, the startup's headquarters, the new production facilities, wholesalers/distributors and a proprietary online store and end consumers.

Reducing operational costs is a need for the startup. This study aims to provide a clear analytical tool to assist in the decision making process while complimenting the production innovations to be undertaken.

2.2. Current Purchasing Process

Based on a ad hoc system, purchasing is currently conducted when a need for goods arises in production. This often leads to an increase on production costs as well as a constant variation of the total landed unit costs. The urgency in the production process is a contributing factor to the increase in these costs as it ultimately determines the transportation method that is chosen to ship the goods.

Recognizing the inefficiency in this process the startup recognizes that the new production plan to be implemented will be crucial to improve their performance and are committed to work on a quantitative tool to systemically analyse their purchasing and transportation process. They understand this will be key to reduce costs and increase profitability, knowing it to be possible to reduce final goods costs (landed costs1) by 20% to 30%, based on past experience. They recognize that efficient purchase management is elemental.

To summarize, the current purchase method is limited and not able to effectively support the decision making process. Blocks is now seeking for a model that provides them with accurate clear information to assist in this process since they recognize it leads to maximizing profit and cost reduction.

2.3. Portfolio and Suppliers

At the moment Blocks Technology commercializes three 3D printers out of which only two will be featured in this study. Approximately 100 raw goods and components were identified, ones that integrate only one of the products mentioned above and others that are shared throughout their product line.

To develop this study the aggregation of raw goods was conducted grouping them by SKU (commercial product) – Blocks One MK II (MK II) and Blocks Zero (ZERO) – and by parts groups by individual suppliers. The orders are placed to the suppliers in quantities of each SKU as they have information on which parts integrate which SKU.

The startup operates a global network having approximately ten direct national and international suppliers. Although small in number, a disperse network such as this intrinsically makes the purchasing process more complex. This study will only approach inbound purchasing and transportation from Chinese suppliers as they represent 82% of the goods purchased for production and it pose the biggest challenge for the overall management, planning decision making process of the startup.

2.4. Characterization of the problem

Having a set a clear goal for growth and consequentially an increase in production volumes while reducing operational costs, the startup is committed to improve its internal processes, recognizing the relevance of international purchase management and transportation as a key factor to reduce costs and sustainably increase their profitability whilst maintaining a healthy cash flow.

This study aims to produce an analytical model to support the systemic decision making process of purchasing and transportation of production goods through the analysis of different scenarios that accurately represent cost reduction upstream of the supply chain.

Through the implementation of this model Blocks is effectively able to reduce the total cost per SKU produced, ultimately leading to increasing profitability and sustainable growth.

3. Model development and Tool presentation

This section portrays the development of a model, based on an Excel spreadsheet, created with the purpose of systemically analysing the international purchasing and transportation process of goods.

[1] *Landed costs* – custo total dos bens; inclui custo de produção (ou preço) e custo de transporte

Firstly, the methodology adopted to develop the model is presented. Hereinafter, the assumptions undertaken to provide a basis for its development are showcased. And lastly, the computer tool and underlying model construction process are explained.

It is important to note that any and all good's costs portrayed in this paper do not represent real purchasing figures due to a non-disclosure agreement.

3.1. Introduction

The model is showcased in this section as an instrument through which different cost scenarios for the international purchasing and transportation of goods can be analysed. It enables a simple approach to analyse the end unit cost variation in different purchasing and transportation scenarios, considering the impact of the quantity of purchased goods and their transport throughout the process.

The model requires user interaction to adequately function, the following must be input:

- Quantity of each SKU (i) for which to buy production materials, q_i;
- Current Euro to US dollar exchange rates;
- Cargo characteristics (urgente or non-urgent).

This case study, as requested by the company, focuses only on the transportation of goods inbound from China and is limited to air and sea freight.

To sum up, the main goal behind the development of this case study is to provide to the purchase managers and decision-makers at Blocks Technology, a tool to base their international purchasing on analytical grounds that cover all cost scenarios relevant to that process. The tool provides a comparative basis on which the end user can evaluate possible costs inherent to the process at hand.

3.2. Methodology

According to Sekaran (2003), "having identified the variables in a problem situation and developed the theoretical framework, the next step is to design the research in a way that the requisite data can be gathered and analyzed to arrive at a solution."

As no technique referenced in literature can be directly applied to approach the problem at hand, a research methodology specifically developed to apply to this case study is explained in this section. There was a partial approach through a TLC cost modelling, mainly because international shipping and relevant elements of the company's product structure costs, such as, cost of acquisition (unit price), freight cost (sea or air), customs clearance costs and a final to-door delivery costs are involved.

Figure 1 represents all stages of the development of the research methodology however not in chronological order.

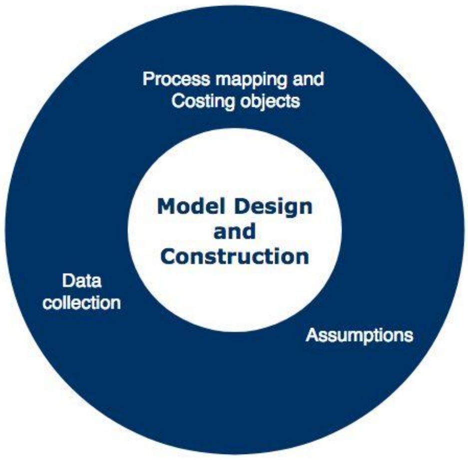

Figure 1 – Research Methodology adopted in the development of the model

Since the beginning of the first stage of mapping out the study process, constraints to the modelling process were identified and the assumptions undertaken are showcased in the next section.

Blocks Zero (ZERO) and *Blocks One MK II* (MK II) were the two products identified as study objects as they are partially produced through goods imported from China.

The data collection process was symbiotically developed with the conception and construction of the model allowing for the creation of an integrated process of structuring and shaping the study tool to the available data.

3.3. Assumptions

Due to the embryo nature of the startup's database, the data portrayed in the model are based on average costs for goods and transportation. Its structure is limited to Chinese suppliers, transport companies for which quotes were requested and to the data on which the assumptions are based on, that go along with the extent of the rigor desired.

The unavailability of detailed data implies the assumption of the following.

- The model considers purchasing from three distinct suppliers, however it considers only one cargo shipment to be delivered in Lisbon not contemplating cargo consolidation fees at the origin.
- Weight (in kilograms) and volume (in cubic meters) represent the consolidated cargo from all the three suppliers and are accounted for in totals to calculate transportations costs.
- Sea and air freight are both contemplated in the model characterizing the two types of urgency the cargo can have – urgent and non urgent.
- The model allows for the analysis of the purchase and transportation of materials required for exact quantities of finished products (commercialized SKU's) not allowing the user to analyse the purchase and transportation of individual parts.
- A minimum amount (50 units of each SKU) and a maximum amount (2500 units in total) is required to perform an analysis.
- Weight and cargo volumes also have a minimum (150 kilograms and 0.25 m3) and maximum (1500 Kg and 18.75 m3) to allow for data structuring.
- The cost structure relating to goods and quantity discounts offered by the suppliers is based on a linear variation percentage (equation 1) within four intervals (Table 1) set forth by the startup based on previous orders and quotes.

$$Discount\ percentage\ (x) = \left(\frac{\%\ Discount_{max} - \%\ Discount_{min}}{Quantity_{max} - Quantity_{min}}\right) \times x, \quad x \in interval \tag{1}$$

Tablel 1 – Materials quantity discount percentage rates

Order Quantity	Discount Percentage
<100	0%
100	6%
200	12%
500	20%
1000	25%

- The cost structure related to the transportations of goods is based on 51 quotes requested to three transport companies that usually provide transport services for the startup when an import from China takes place. They include freight cost, customs clearance and delivery to their headquarters. These quotes are showcased in Tables 2 and 3.

Table 2 – Air freight quotes

Weight KG/ Operator	Transport Operator 1	Transport Operator 2	Transport Operator 3
150	450.00 €	477.77 €	453.60 €
200	687.00 €	646.82 €	612.00 €
500	1 325.00 €	1 235.94 €	1 116.00 €
1500	3 545.00 €	3 419.82 €	3 260.00 €

Tabela 3 – Sea freight quotes

Volume m3 / Operator	Transport Operator 1	Transport Operator 2	Transport Operator 3
0.25	360.00 €	315.00 €	257.83 €
0.27	400.00 €	385.00 €	283.97 €
0.67	430.00 €	395.00 €	316.89 €
2	545.00 €	480.00 €	428.15 €
2.7	650.00 €	570.00 €	488.21 €
4.5	826.00 €	825.00 €	645.35 €
6.5	1 085.00 €	960.00 €	820.70 €
8	1 255.00 €	1 085.00 €	943.50 €
10	1 482.00 €	1 338.00 €	1 105.50 €
12	1 665.00 €	1 538.00 €	1 261.10 €
15	2 032.00 €	1 942.00 €	1 505.00 €
18.75	2 480.00 €	2 263.00 €	1 796.00 €
Dedicated Shipping Container	1 580.00 €	1 379.91 €	1 127.00 €

In order to create a cost structure that covers every weight and volume value, a linear variation of the transport cost within each interval was defined by the quotes according to equation 2.

$$Custo_{transporte}\ (x) = \left(\frac{Custo_{transp_{max}} - Custo_{transp_{min}}}{Medida_{max} - Medida_{min}}\right) x, \quad x \in intervalo \qquad (2)$$

- This model does not include the total cost of ownership as demonstrated and considered in a Total Cost of Ownership (TCO) costing model approach.

Moreover, it is important to convey that the data supplied to the cost structure, noting the assumptions portrayed, are adequate to conduct an analysis of the average cost of this process and to the extent of rigor and purpose the startup aims to obtain.

3.4. Model construction

The main activities concerning the modeling developed for this case study were the purchasing of goods from suppliers and their respective transportation from China to the company's headquarters in Lisbon. The shape each cost assumes and what components are subject to cost variation due to varying quantities was identified. These variations were then modelled.

The goods purchasing cost structure was shaped firstly moving on to the transportation cost structure. The calculation structure of the model was developed lastly.

Materials Cost Modeling

The goods cost structure was modelled according to the unit cost of goods per SKU and minimum and maximum number of SKU's per order. A linear variation percentage of the cost of acquisition of the goods was drawn, within four intervals (equation 1) as mentioned previously in section 3.3. of the assumptions, as base data.

Transport Cost Modeling

The transportation cost structure was modelled based on three quotes requested from transportation companies (Tables 2 and 3). Equation 2 was then applied to cover all weight and volume values the designated cargo may have, as showcased and argued in section 3.3.

Being aware of the volatility in prices of the transportation market, an average of all requested quotes was calculated. The average cost of transportation was obtained for air freight, as showcased in Table 4, and for maritime grouping and dedicated sea container as showcased in Table 5, having calculated all weight and volume intervals using equation 3.

$$Avg\ Transp.Cost = \frac{(C_{T1} + C_{T2} + C_{T3})}{3} \qquad (3)$$

Where: C_{T1}, C_{T2}, C_{T3} are the transport operators 1, 2 and 3 costs.

Table 4 – Average air freight quotes

Weight Kg	Average Cost
150	460.46 €
200	648.61 €
500	1 225.65 €
1500	3 408.27 €

Table 5 – Average maritime grouping and dedicated sea container quotes

Volume m3	Average Cost
0.25	310.94 €
0.27	356.32 €
0.67	380.63 €
2	484.38 €
2.7	569.40 €
4.5	765.45 €
6.5	955.23 €
8	1 094.50 €
10	1 308.50 €
12	1 488.03 €
15	1 826.33 €
18.75	2 179.67 €
Dedicated Shipping Container	1 362.30 €

Model calculations structure

A calculation database was developed in order to accommodate the computing process necessary to showcase the results when an entry is submitted by the user.

Firstly, general data that characterizes the cargo that the user wishes to analyse is processed: total weight and volume, percentage of weight and volume of each SKU in regards to the cargo, goods cost. These are calculated according to equations (5) to (10):

$$MaterialsCost_i = q_i \times C_{q_i} \quad (5)$$

$$Total\ Cost_{materials} = \sum_i MaterialsCost_i \quad (6)$$

$$Order\ Weight = \sum_i q_i \times Wunit_i \quad (7)$$

$$Order\ Volume = \sum_i q_i \times Vunit_i \quad (8)$$

$$\%\ Weight_i = \frac{Weight_i}{Order\ Weight} \quad (9)$$

$$\%\ Volume_i = \frac{Volume_i}{Order\ Volume} \quad (10)$$

Where:

- $i = MK\ II, ZERO$
- q_i equals total amount of SKU's i in the user input
- C_{q_i} equals the total cost of goods for the SKU i in regards to a quantity q_i
- $Wunit_i$ equals the weight (in kilograms) of q_i SKU's i
- $Vunit_i$ equals volume (in cubic meters) of q_i SKU's i
- $Weight_i = q_i \times Wunit_i$
- $Volume_i = q_i \times Vunit_i$

The $Total\ Cost_{transport}$ is obtained using the function *vlookup* in the software (Excel) used to develop the model. It searches the $Order\ Weight$ and $Order\ Volume$ in the cost structure, feeding back the transport cost applied to the corresponding cargo. The function *min* is used to feed back the minimum transport cost scenario.

The unit transport cost is calculated and allocated to each SKU using equations 11 and 12. Reducing unit cost per SKU is the key goal throughout this process.

$$TranspCost_i = Total\ Cost_{transport} \times m, \quad (11)$$

where $m = \begin{cases} \%\ Weight_i, if\ air\ mode \\ \%\ Volume_i, if\ water\ mode \end{cases}$

$$Total\ unit\ cost_i = \frac{MaterialsCost_i + TranspCost_i}{q_i} \quad (12)$$

Finally, a Dashboard interface presented to the user is built on these values, integrating total scenarios costs and relevant cost functions to analyse along with decision making.

It is highly important to note that there are values in need of conversion into the designated currency (Euro) and it is vital that the user inputs current exchange rates prior to conducting an analysis. For the purpose of calculating the exchange rate equation 13 is used.

$$Cost(EUR) = Cost(USD) \times USD\ Rate \quad (13)$$

3.5. Tool presentation

Commonly used throughout the companies, Excel was the platform chosen to build the model upon. It not only provides easy access and user-friendly interface, it has all the features required to develop and build this model.

Resorting to tools like functions and macros developed through VBA programming (Visual Basic for Applications) the tool was shaped, serving as a supporting key element to conduct a clear analysis of all possible scenarios regarding the process at hand and its impact on total cost. It is thoroughly adapted to the current needs of the startup.

The Dashboard (Figure 2) conveys an analytical ground on which the user can base himself to conduct a knowledgeable decision on the subject of international purchasing and transportation allowing him to easily visualize the cost effects of the following:

i. When there is a competitive advantage to be gained by allocating more cash flow in the purchase of goods by placing larger orders while reducing the total cost per SKU (this translates in an increase in gross profit margins)
ii. When there is less cash flow available however there is urgency

to purchase goods to fulfill production needs

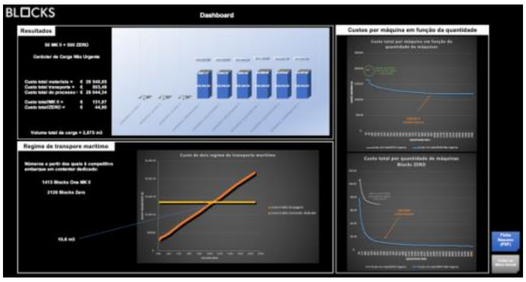

Figure 2 – Dashboard (Excel)

As the user concludes his analysis he is able to export a PDF file summarizing the key aspects previously analyzed.

4. Results

This section will analyse whether the results obtained through the development of the model its supporting the tool bring forth real competitive advantages by improving the decision-making process undergone by the startup when importing goods for production.

4.1. Model Validation

Validation of this model lies on the principle that a decrease in cost per SKU must occur as an increase in order volume is verified, confirming all initial expectations set forth for the development of the model.

A brief purchase history of the startup is showcased and replicated in the model.

Historical Data Validation

Blocks has manufactured around 350 3D printers since its opening. Table 6 showcases the data collected on previous purchases directly linked with the production of the SKU ZERO and the cost it represented for the startup while purchasing and transporting goods from China.

Table 6 – Purchase and transport history for Blocks Zero

Date	Quantity *Blocks Zero*	Materials Cost of acquisition	Transport Mode	Total Transport Cost	Total Process Cost	Total Cost / SKU
Dec 2016	100	5 593.75 €	Maritime Grouping	478.56 €	6 072.31 €	**60.72 €**
Apr 2017	30	2 188.05 €	Maritime Grouping	292.98 €	2 481.03 €	**82.70 €**
Ago 2017	50	2 768.29 €	Maritime Grouping	315.90 €	3 084.19 €	**61.68 €**

The cost reduction pattern associated with the increase in order volumes is clearly reflected through the analysis of the order history showcased in Table 6. This is one of the fundamental premises for validation of the results obtained through the model.

All three scenarios identified in Table 6 were replicated and inserted in the tool developed in this study aiming to identified the factors responsible for the creation of the reduction pattern.

Table 7 showcases the results obtained through the replication of the three scenarios.

Table 7 – Replication of Blocks Zero's order history in the tool

Quantity *Blocks Zero*	Materials Cost of acquisition	Transport Mode	Total Transport Cost	Total Process Cost	Total Cost / SKU	Relative Error
100	5 173.02 €	Grupagem maritima	302.90 €	5 475.92 €	**54.76 €**	**9.8%**
30	1 999.83 €	Grupagem maritima	252.10 €	2 251.93 €	**75.06 €**	**9.2%**
50	2 751.61 €	Grupagem maritima	257.83 €	3 009.44 €	**60.19 €**	**2.4%**

Variations can be observed on the cost per SKU, these however are mostly linked to variations in FOREX rates at the time of purchase. The values portrayed in Table 7 do not differ more than 9.8% from the original values showcased in Table 6, for this reason this model and its assumptions are considered to be validated.

General Results Validation

This section aims to validate the initial expectations set in the beginning of the development of the model by the startup and the results obtained through it. These are:

- ✓ Obtaining an understanding on the impact of order quantity in the cost process;
- ✓ Evaluating what order quantities are more competitive and profitable for each SKU;
- ✓ Accessing when transportation in a dedicated maritime container becomes more competitive.

The graph showcased on Figure 3 portrays a sketch of the total cost function per quantity of SKU ZERO materials purchased and transported.

Figura 3 – Total Cost per SKU ZERO (Excel)

A stabilization point is easily identifiable while analyzing the cost function per Blocks Zero in relation to the transportation of non-urgent cargo (arrow in Figure 3). This tipping point represents the stage where it is most profitable to purchase larger quantities of this SKU if there is cash flow availability and willingness to invest to benefit from the cost reduction. The same can be verified in the cost function related to the SKU Blocks One MK II.

Another question raised by the startup is a conclusive analysis on sea freight – transportation through maritime grouping or a through a dedicated shipping container. Figure 4 showcases the answer to this question, portraying a graph built based on average maritime shipping costs in relation to cargo volume. It is easily identified the point in which transportation through a dedicated shipping container becomes more competitive, starting at a volume of 10.6m3.

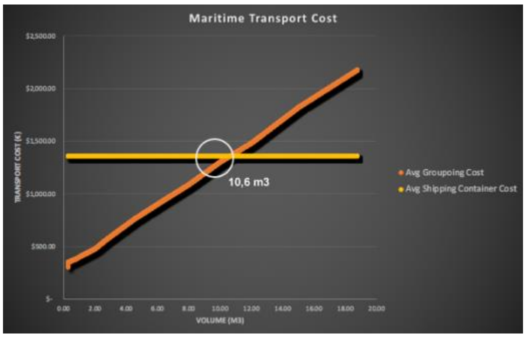

Figure 4 – Maritime Transport Cost for grouping and shipping container (Excel tool)

4.2. Process cost analysis for a year

In this section the expected cost for the process of purchasing and transportation from Chinese suppliers for the year of 2019 is estimated through a consultation of the startup's production schedule for the upcoming year where it is predicted to have two distinct purchase moments:

350 MK II + 175 ZERO

650 MK II + 325 ZERO

An analysis of both purchase moments was conducted revealing an increase in profitability in the moment where a larger order quantity is purchased, resulting in a significant cost reduction when compared to the moment where a lesser order quantity is purchased. The FOREX rate used was the daily rate at the date on which this study was performed. A non-urgent transport was considered as a planned approach to purchasing does not require urgent transportation.

It is a matter of a fact that if the company conducts only on purchase moment throughout 2019, consolidating all cargo on one single order, an increase in profitability can be expected. This was verified through the analysis of the purchase and transportation process of the goods required for the production of 1000 units of one SKU and 500 units of another.

Nevertheless, the ability to perform larger quantity purchases is more often than not limited by the company's cashflow and financial agility.

It is possible to conclude that the startup can potentially reduce the total cost per SKU in next year's purchases when comparing them to the past.

5. Conclusions

The cost reduction hypothesis in the process under study were verified. The reduction represents a cost decrease in the purchasing and transportation of production goods that ultimately leads to an increase in profit margins and long-term profitability for the company.

The theoretical potential of the model to access and identify competitive advantages in purchase scenarios taking into consideration the company's cash flow standpoint were also verified.

Ultimately this study concludes that there is a correlation between the cost variation of a unit's final unit cost and the volume of the purchase, clearly identifying a cost benefit in placing larger orders as long as both the company's cash flow allows it and the decision makers are willing to invest to produce an increase in unit gross profit margins.

Once implemented, this model aims to support the startup's purchasing and transportation process, however it should also consider external factors not contemplated in the model to decide effectively and efficiently.

The future directions for this work involve: allowing for continuous updates in the transport cost structure to meet market variations; hyperlinking this tool to other tools to compliment the potential of the model developed, such as but not limited to, production planning and forecasting tools.

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