FLUMINENSE EDUCATION, SCIENCE AND TECHNOLOGY FEDERAL INSTITUTE

SYSTEMS APPLIED TO ENGINEERING AND MANAGEMENT MASTER'S DEGREE PROGRAM

PAULO ROSSI CROCE

LAST-MILE ANALYSIS IN DIFFERENT E-COMMERCE DELIVERY METHODS

CAMPOS DOS GOYTACAZES, RJ

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Dissertation submitted as a requirement for preparing the dissertation to obtain the **Master's degree** in the Postgraduate Program in Systems Applied to Engineering and Management, Area of Concentration in Computer Systems.

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ABSTRACT

The world's habits are shifting from traditional shopping with physical retails to a virtually store, consequently, the logistics are also changing drastically. Additionally, shopping online became practical from the client's perspective, which reduces the need for a physical store and overall costs for the companies. As a consequence of online shopping growing demand, the logistics requires environmental attention since express deliveries are expected to provide a better experience for the consumer. In this context, the present dissertation has the objective of assessing the challenges of the last-mile delivery in two stages: first, through a survey to explore the possibility of different approaches for the last-mile delivery; and a discrete event simulation model to compute the mileage of the vehicles used to carry parcels to the consumers of e-commerce. The people interviewed was highly receptive to try new ways of e-commerce delivery, encouraging the integration of drones, crowdshipping and lockers while coexisting with the traditional delivery process. The simulation based on the survey, literature and field data resulted on a lower mileage distance traveled on drone's and parcel locker's delivery while the crowdshipping increased, but the route would be already on the driver's plans, making it an efficient travel. Parcel Locker has a great potential in large cities that have structured mass transportation, while drones may not be as effective as it seems due its flight limitations by local legislation. By combining crowdsourcing with parcel lockers alongside traditional delivery, the mileage can be reduced and be more environmentally efficient way, indicating a positive outcome that should inspire the practical appliance of this delivery method. Every scenario considered in this study lowers or proposes a more efficient usage of the fleet's mileage, achieving less energy consumption (both electric and fuel) and, consequently, less greenhouse effect gas emissions.

KEYWORDS: CO2 discharge, DES, electronic commerce, last mile, shipment

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1 INTRODUCTION

1.1 Contextualization

The electronic commerce or e-commerce is growing at a fast pace and at a same time, develops the logistics, increasing the demands and creating new challenges to the supply chain (XU; HUANG, 2017). As the competitive environment grows, the companies must have a special care for their logistics (LU; LIU, 2015; WU; LIN, 2018; ZHANG *et al.*, 2019). Also, due the pandemics caused by COVID-19; the e-commerce orders had a tremendous growth in a short period of time threating even more the logistics system (IBM, 2020).

In this context, as the e-commerce intensified, the customers grew more exigent regarding the demand and quality of delivery services, requiring same-day, next-hour or next-day delivery without thinking about the environmental impact of their choices, since the difference between a fast and slow delivery does not changes the final price significantly. In order to innovate, the companies tried to gather the distribution system to new transportation solutions integrated with the internet (SACHAN; KUMAR; KUSHWAHA, 2020).

The last step of the order placement is called last-mile and it is long known to be the costliest part of the logistics system, due to the expanding market and the inclusion of the stream of packages to be delivered and maybe returned (CORTES; SUZUKI, 2020; SOROOSH; WILDING, 2016). Also, the rapid increase of the delivery fomented by fast deliveries caused gigantic challenges in the organization and distribution of online orders, such as the traffic on the cities gets worse and CO_2 emissions increases, making the last-mile environmentally less sustainable (LIU, 2014). According from the International Energy Agency (IEA) (2020) one quarter of the global CO_2 emissions from fuel combustion were originated from transport organizations in 2018, reaching a historical peak of 8.4 $GtCO_2$.

Normally, the consumers only worry about the delivery time and the retailers adjust the final value of the products making it more attractive, which reflex in a system that have higher greenhouse gases (GHG) emissions. With this theme in mind, this research evaluates the problems caused by a high demand of the fleet through a more wellbalanced setup, since the majority of the orders may not require urgency. This anxious-like behavior for fast deliveries may be changed according to Ignat and Chankov (2020).

Studies about emerging methods like delivery drones (KITJACHAROENCHAI, 2020; MOSHREF-JAVADI; HEMMATI; WINKENBACH, 2020a), reception boxes (RISHER; HARRISON; LEMAY, 2020; ZHOU *et al.*, 2020) and crowdsourcing logistics (LI *et al.*, 2020; SEGHEZZI *et al.*, 2020a; SEGHEZZI; MANGIARACINA, 2021) demonstrate an optimistic and promising overview to include these modes in the logistics system.

1.2 Objectives

1.2.1 GENERAL OBJECTIVES

The objective of this research is to investigate new methods of goods distribution on e-commerce B2C and how it may affect the fuel consumption of vehicles used on last-mile deliveries inside a virtual ambient.

1.2.2 SPECIFIC OBJECTIVES

The specific objectives of this research are:

(I). Investigate the acceptance of a population of using new modalities of delivery on e-commerce;
(II). Identify the profile of the electronic consumer from the COVID-19 pandemic;
(III). Quantify the mileage of vehicles used on different modalities acquired by e-commerce;
(IV). Analyze the usage possibilities of mixed transportation modes with less energy consumption and, consequently, more environmentally sustainable.

1.3 Justifications

As Ignat and Chankov (2020) stated, when customers order something online, they may choose between deliveries modes, but they are only based on economic and time related factors but the environment impacts are not provided by the online retailers and even if it was in fact informed, they would probably select the most economically viable option. The customer opinion may change if they are briefed with the impacts of his choice, encouraging this research to explore environmentally and economically sustainable ways to handle the last-mile.

The Sars-CoV-2, a viral disease caused by the often-called COVID-19 or new coronavirus, is a pandemic virus that infected millions of people worldwide. The epidemic outbreak led to around half million causalities until the first half of 2020, that significantly changed the lifestyle of everyone as the need for social distance and lockdown rises (WHO, 2020). Due recommendations of the World Health Organization (2020), people were advised to stay home and most of countries complied in order to lessen the virus spread. Aside from the health crisis, the business was directly hit by this lifestyle, since the need of social distance. Tourism and some entertainment activities that involves agglomeration, such as live shows, since march 2020 cannot function fully (ALI; ALHARBI, 2020). Due the COVID-19 outbreak, there are studies that prove that e-commerce demand grew as a necessity to attend the social distance (HASANAT *et al.*, 2020; KIM, 2020a; NGUYEN *et al.*, 2020). According to IBM's U.S. Retail Index (2020), the pandemic caused a massive migration from ordering at physical stores to online shopping, anticipating five years' worth of ecommerce growth. The report indicates that department stores had a degrowth of 60% and the e-commerce had a growth of nearly 60% in 2020. In this context, the Figure 1 shows that the pandemic aided the consumers to better classify which products are "essential", for instance, clothing had a decline while home improvement had an accelerated growth.

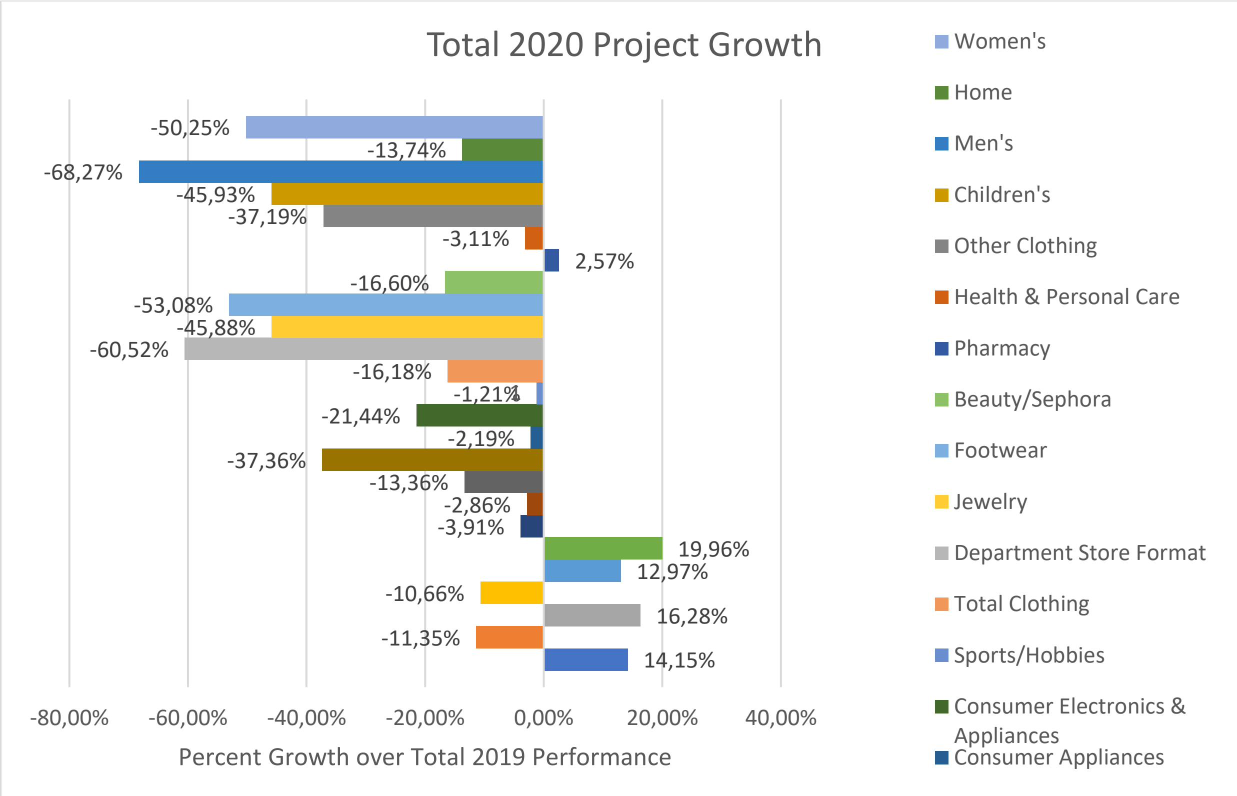

Figure 1 - Cegories Growths and Declines
Source: IBM (2020)

Combining a possibility of same-day delivery offered at a low additional cost offered by some companies, the logistics behind the order result in disarray.

The last-mile is still the most challenging phase of the delivery process, with a very large of content from research and simulation. To find more efficient ways to address this problem and to discover how the consumer behavior would affect the distribution of a hypothetical organization this research proposes an overview about the last-mile on e-commerce delivery with realistic parameters supported on the literature and other works.

1.4 Method of Research

Defining the research methodology, two areas must be covered: the overall style of the research and the techniques used in this word. In this context, research has two basic styles which are objective and subjective, whereas objective approach is focused on physical characteristics and applicable laws and rules within the world verified by experiments, hypothesis and surveys; and subjective approach targets the social lives of individuals or groups through observation and explanation (SWETNAM, 2007). Swetnam (2007) also explains briefly outlines some possibilities as follows:

(I). Action research (or participative): the problem is studied directly, interventions, changes are proposed and the resulting effects monitored;
(II). Survey: have the objective of data gathering from a group or sample which can be used to propose an intervention or reveal useful information. The data collection can be gathered in several ways, like questionnaires or structed lists. Surveys can be descriptive or explanatory;
(III). Experimental method: with the formulation of a hypothesis based on theory and observation that can be tested and proved/refuted, every research utilizes this method.
(IV). Ethnographic research: qualitative and descriptive style targets to study the behavior and customs of a group in society, usually the procedures are complex;
(V). Case study: the commonest approach and largely used by the academia. The case studies consist in detailed consideration given to the development of a particular person, group, or situation over a period of time.

The methodology present in this study has characteristics from survey, experimental method and ethnographic research.

1.5 Research Delimitations

The present research approaches the sustainable problems of logistics regarding the delivery of products commercialized between companies and final consumers that uses e-commerce B2C as channel. In order to be more sustainable, the freight must deliver more parcels with less overall distance, mitigating the GHG emissions.

The aspects approached from the survey are about the acceptance of consumers to choose a more sustainable method of delivery. It contained only closed questions for the data gathering.

Regarding the simulation was executed on Python 3.7 and the code was made specifically for this research by the author. The output variable is the mileage traveled by the vehicles, since it is directly proportional to CO_2 emissions.

The methodology has a geographical delimitation, it considers the opinion and location of the southeastern region of Brazil, in a medium-sized city and a metropolis.

2 LITERATURE REVIEW

2.1 Theorical Framework

In this section the theorical framework is presented, detailing the concepts about the main theme. It was defined some perception related to computer simulation, showing pros and cons about the use of these tools, examples of simulation software, concept of the python programming language and logistics.

2.1.1 SURVEY

The survey research has been promoted as a way to deliver relevant information to practically any goal. This research method is used for collecting data from a predetermined group of respondents to assess insights and information about a topic of interest. It may serve as multipurposed research as well, being extremally important on nowadays, making possible the understanding the benefits of social research (BRUIN, 2021; FERRIS, 1982).

2.1.2 COMPUTER SIMULATION

According to Makinia and Zaborowska (2020) the computer simulation consists in the use of mathematical models alongside a computer to mimic a vast number of functioning real-life processes. To conduct an experiment from a model, from variables it is possible to better understand its functioning and take a better strategy for the operation.

From computer simulation techniques, as Freitag and Kotzab (2020) stated, it is possible to study with details the behavior of system by models that imitates partially or totally what happens in the real world.

Among different approach found in the literature to classify the systems of computer simulation and modeling, Kelton, Sadowski and Zupick (2014) summarize the most common usages:

(I). Static and Dynamic Systems: static, the time variable doesn’t represent a key role, on dynamic it is the opposite;

(II). Deterministic and Random (or Stochastic) Systems: on the first system, the possible variables states can be described and predeterminate, on the second one, it is the opposite, when the input variables are random;

(III). Continuous and Discrete Systems: on the first system, the system state can change continuously over time, on the second system, the change occurs in specifics states and separated from this event occurrence.

Zeigler *et al.* (2018) classify the computer simulation in three basic categories, Monte Carlo method, Continuous and Discrete Event Simulation (DES):

(I). Monte Carlo Method: from random number generator, it simulates physics or mathematical models, which don't explicitly consider the time as a variable;

(II). Continuous Simulation: used for system modeling when the state changes over time, through differential equations to calculate the changes of the state variables;

(III). Discreet Event Simulation: used for system modeling when the state changes in specific moments in time, from event occurrence. The DES events are numerically analyzed with computer proceedings to solve mathematical models.

2.1.2.1 Advantages and Limitations of Simulation

The simulation usage can represent lots of advantages, as well limitations, even if it is a great evaluation tool. A list of pros and cons can be seen on Table 1 (MAKINIA; ZABOROWSKA, 2020):

Table 1 – Pros and Cons of computer simulation

Pros	Cons
After the creation of the computational model, it can be used several times;	The construction of computational models requires special training;
Generally, it is easier to apply simulation than analytical methods;	It is possible to encounter difficulties in the interpretation of the results;
Simulation models do not require a large number of simplifications; thus, it is possible analyze virtually any conceivable measure;	The modeling and experimentation of simulation consume many resources, mainly time;

Pros	Cons
Hypotheses about why or how certain phenomena happens can be tested for confirmation;	Each simulation model is unique, so it is not possible to use it in different situations and obtain gains of scale;
It is possible to reproduce phenomena slowly or accelerated for better study;	The simulation does not generate good results if the model was elaborated carefully;
It is possible to understand the performance and the interaction between the variables and the other elements of the system;	Despite the use of software, simulation is not a optimizing technique;
The analysis methodology used by the simulation allows the evaluation of a system, even if the data of input are in the form of diagrams or drafts;	Simulation can be used inappropriately when other, simpler solutions would solve the problem in less time;
Bottlenecks can be identified in production systems;	When the simulation model is large, it becomes too complex;
The simulation contrasts the actual form of operation of a system with the preliminary idea of its operation;	Need to use large quantity of values for the model construction and testing;
It is possible to predict the behavior of new systems before they are built.	Powerful software equipment and hardware needed for running and validating the model.

Source: Adapted from Makinia and Zaborowska (2020)

2.1.2.2 Simulation Software

The available simulation software are used on several areas, like meteorologic previsions, military training, vehicle training and others appliances that studies specific behaviors and reactions of a system. These software can be Commercial-OFF-The Shelf (COTS) or Free and Open-Source Software (FOSS).

As an example of a COTS, largely used and recognized worldwide is Arena, from Rockwell Automation. From dynamic analysis and the interaction between the system elements, it is possible to determinate bottlenecks, improve operation conditions, visualize the queue size, resources occupation and verify the system behavior. With an integrated graphics ambient, resources statistics anrevisar3alysis, process modeling and result analysis, every creation process in Arena is made through blocks, representing the company's processes (ROCKWELL AUTOMATION, 2020).

On the other hand, there are 44 FOSS, as Dagkakis and Heavy (2016) reported, they also cite: OMNeT++C, NS-3C, SimPy, JaamSim, JAPROSIM, DESMO-J, Facsimile, SharpSim, PowerDEVS and Ururau.

2.1.2.3 Design of Experiments with Simulation Models

The statistic technique or process of experiments is applied with the objective of determining how the system behavior can be influenced by variable values. Some recurrent terms are defined as follows (MAKINIA; ZABOROWSKA, 2020):

(I). Answer variable: results from an experiment, expressed by some previously defined variables. Makes it possible for the user to observe a system behavior;
(II). Factor: user controller variables that affect the answer variable;
(III). Level: possible values of a factor. Each factor level has an alternative;
(IV). Replication: number of repetitions of the experiment;
(V). Project: action strategy used which results in the experiment numbers, replications and how effective was the replications.

2.1.3 PYTHON

Python is a high-level interpreted programming language with suggestive syntax. Oliphant (2007) summarizes this programming language features:

(I). Open-source license that permits selling, usage and distribution of Python-based application without needing extra permissions;
(II). Multiplatform, which minimizes portability problem;
(III). Python's syntax influences the programmer to write a procedural or fully object-oriented code;
(IV). The interpreter allows real-time code development and experimentation, avoiding time-consuming testing tasks;
(V). It is possible to integrate Python into an existing application;

(VI). Large library modules;

(VII). Large community

A significant feature in Python for scientists and engineers is its syntax, which makes the code easy to understand with blocks defined by indentation, exception handling and easy-to-read looping constructs. The Figure 2 shows an example of a code in Python.

```
1  from math import sin, pi
2  def sinc(x):
3  '''Compute the sinc function:
4      sin(pi*x)/(pi*x)'''
5  try:
6      val = (x*pi)
7      return sin(val)/val
8  except ZeroDivisionError:
9      return 1.0
10 output = [sinc(x) for x in input]
```

Figure 2 - Example of Python Syntax
Source: Author (2020)

It is possible to completely understand this code with little explanation. The modules can be either ".py" archives or libraries. The code on Figure 2 demonstrate exception handling on the lines 5 and 8 (try/except) which allows a separate handling when division fails.

There are some applications of Python in Simulation and Last-Mile Delivery. The Table 2 lists some applications.

Table 2 - Python Applications in DES and Last-Mile Delivery

Title	Application	Citation
salabim: discrete event simulation and animation in Python	Open-source discrete event simulation Python Library	(BRABHAM, 2008)
supplychainpy: A library for supply chain, operations and manufacturing, analysis, modelling and simulation.	Open-source supply chain analysis and simulation Python Library	(FASUSI, 2017)
Transforming last-mile logistics: Opportunities for more sustainable deliveries	Uses Python to construct scripts for data handling from Google Maps	(BATES *et al.*, 2018)
Simulation–optimisation framework for City Logistics: an application on multimodal last-mile delivery	Uses Python for simulation with Monte-Carlo method	(PERBOLI *et al.*, 2018)

Source: Author (2020)

2.1.4 MONTE CARLO

The Monte Carlo method was first used by scientists when developing nuclear weapons in Los Alamos. This method designs by a class of statistic methods based on random samples, commonly used in physics and math problems when it is difficult to solve with other methods. From a long time, the Monte Carlo Methods may solve any problem with probabilistic interpretation (KALOS; WHITLOCK, 2008). According to Hammersley and Handscomb (1964) the name Monte Carlo was originated during the Manhattan project on the World War II while developing atomic bomb in a renowned resort town from Monaco, known for its casinos.

The Monte Carlo Simulation provides a risk analysis from built models with the possible results by changing the range of values (probability distribution) for factors with a level of uncertainty, calculating repeatedly using a different group of random values each time from the probability function. The Monte Carlo Simulation may involve thousands or ten thousand of recalculations before its completion depending upon the number of uncertainties, producing distributions of possible results. Variables can assume different probabilities of different outcomes occurring by the use of probability. To describe uncertainty in variable of a risk analysis is much more realistic to use probability distributions (RUBINSTEIN; KROESE, 2007).

Common probability distributions used may include (THOMOPOULOS, 2013):

- Normal: also known as “bell curve”, the mean or the expected value and the standard deviation are defined in order to describe the variation about the mean. The intermediate values near the mean have a higher chance to occur. It has symmetric characteristics and can describe many natural phenomena. As an example, energy prices and inflation can be cited;
- Lognormal: positively skewed values, asymmetric in contrast with normal distribution. Represents values that do not occur, but have positive potential indefinitely. Stock prices, oil reserves and property values can be cited as examples;
- Uniform: every value has the same chance of occurrence, the maximum and minimum are the only parameters required. New products, Manufacturing costs

2.1.5 E-COMMERCE

Wendler *et al.* (2008) define the electronic commerce (or e-commerce) as a cluster of processes and technologies in order to execute transactions through electronic ways. This service provides the possibility to buy and sell products, services or information. This approach changed the way to do business, having a considerable part on the globalization process. In other words, the e-commerce is the exchange of business information, conducted by business transactions between different people or organization. This involves buying and selling online, but since everything is on a virtual level, the orders must arrive physically to its destiny to complete the transaction, this means that a delivery process have to happen.

Kotler and Armstrong (2018) stated that the e-commerce gathers a variety of types of online transactions, like purchases made by suppliers by electronica data interchange (EDI) and baking transaction. The author also states that the e-commerce evolved through the globe at a fast pace, complementing the sales process and skipping intermediary stages in the supply chain, assisting the globalization of the economy through business and partnership, bringing countries close and transforming the behavior among the market and providing business opportunities.

Regarding the models of e-commerce, Wendler *et al.* (2008) affirms that is classified depending of the relationship between trade participants: companies, customers, employees and government. In this context, the Table 3 defines each model of e-commerce with its initials, description and definition of process.

Table 3 - Models of e-commerce

Initials	**Description**	**Definition of the process**
B2B	Business to Business	Companies sell to each other
B2C	Business to Consumer	Sale of goods and services to end consumers
C2B	Consumer to Business	Consumer requests a product or service from the seller
C2C	Consumer to Consumer	Consumers sell to each other
B2B2C	Business to Business to Consumer	It is executed using B2B model that supports the company’s operations on the model of B2C
C2B2C	Consumer to Business to Consumer	Connects consumers using on-line company as an intermediary (marketplace)
B2E	Business to Employee	Web site that gives products or information to employees.

Source: Wendler *et al.* (2008)

2.1.5.1 Delivery

A common delivery process can be explained in three main steps after a fulfilment process in the retailer’ distribution center. The carrier picks up the packages, then the goods are taken to the truck and loaded; The packages arrive at the sort center closest to the customer’s address and the truck is unloaded, the order is now loaded into an urban cargo vehicles and directed to its final destination; The last step, called Last Mile, the urban vehicles delivers to the customer’s address, concluding the order (ZHOU *et al.*, 2020).

Nowadays, Brazilian courier services delivers goods to customer’s doorstep, require theirs signatures and go for the next one. This is the most worldwide consolidated “last mile” type for delivery. With massive orders numbers comes low efficiency due to traffic, the limited possible delivers that can be done in one day of service, waste of time waiting for the customers, and other factors. In order to increase the efficiency, there are a search for new solutions to deal with the challenges prevenient from the last mile, for instance: reception boxes, delivery drones and crowdsourcing (SEGHEZZI *et al.*, 2020a).

2.1.5.2 Last-Mile

The carrier picks up the packages, then the goods are taken to the truck and unloaded; The packages arrive at the sort center closest to the customer’s address and the truck is unloaded, the order is now loaded into an urban cargo vehicles and directed to its final destination; The last step, called Last Mile, the urban vehicles delivers to the customer’s address, concluding the order (GEVAERS; VOORDE; VANELSLANDER, 2011).

The last-mile are intensely studied and the literature shows some prominent challenges in distribution, as Archetti and Bertazzi stated (2020):

(I). Online orders: lots of clients requires fast delivery, the orders must be processed immediately after placing, hasting the whole delivery process in a short time span of order processing, transportation and the last-mile delivery. This scenario is usually the most challenging, which will be addressed in the following sections;

(II). Short delivery times: as customers grow more exigent, extremely short delivery time are require to fulfill the client’s expectation, like services known as same-day delivery and next-day delivery for instance. Hence, additional resources, low-cost delivery and strategies are needed to manage this task efficiently, always with the limited time available pressure. In this problem lies the heart of this research;

(III). Presence of release dates: in general lines, the release date is the moment when the products are ready to be delivered. Considering that every product listed online are available at the time of the order, the distribution starts, solving the routing problem. The information on the release dates is primordial for the distribution management, being another key factor for the last-mile;

(IV). Overlap of customers' time Windows: for most the deliveries takes place, it is necessary that the costumer accept the delivery in person, which is known as attend home delivery. One of the main problems with this modality is that the available time of the clients may vary, being overlapping. Most of them prefers the deliveries in the evening, concentrating on specifics periods of the day, henceforth making extra hard to manage the distribution;

(V). Failed home deliveries: according to Duin *et al.* (2016), around 25%, resulting in additional distance travelled, gas emission and greater costs. The primary motive for an incomplete delivery is the customer not being present at home in order to receive the ordered package.

(VI). Cargo Theft: according with Cowen (2014), this is a global serious problem, but each country or region has its specificity. It may disturb the supply chain and cause financial loss for the buyer or retailer. The cargo thefts in Brazil generates great losses for the entire supply chain, which increases the costs with security. Justus *et al.* (2018) affirm that companies spend money in order to assure the package delivery. So, summing the loss of stolen goods to the security fees gathers a high delivery cost, which the customers pay in their final product. The disturbance begins when the theft happens: the delivery is delayed, and even if the customer is notified of the theft, it may cause the feeling of a bad customer experience.

(VII). New Delivery strategies and technologies: While the previous topics presents the difficulties of the last-mile, the last two topics have a more optimistic view. Since most of online orders are light weight and have small volume, unusual means of transportation can be used, like drones. Since the drones have reduced capacity, they can only deliver small parcels. Normally they have limited flight range and capacity due its batteries. As advantage, drones don't' are affected by traffic jams and roads, which means that they have the potential to be the best mean of transportation on big cities and rural areas. Another issue with this modality is about the distribution, deciding whether this order will be delivered by drone or not and synchronize the routes with the trucks. As seen on studies it is very difficult to optimize these parameters. While it's not technically new, the next two modalities are still in testing phase in Brazil. The reception box, is a click-and-collect system, where the seller informs when the parcel is ready to be collected on smart lockers, which will only be unlocked by the costumer (or the responsible for delivery if something happens). Another strategy is to use a crowdsourced service, where the delivery is made by standby ordinary drivers (not professional drivers) registered on the app and delivered to its destination, offering their time and resources to provide the transportation service. There are pros and cons about this method which will be discussed in later topics.

With all these challenges, the online retailers may restrict deliveries in high-risk areas or suggest a pick-up point to complete the delivery, adopting these alternatives, it is proven to mitigate cargo theft on the last mile (DUARTE *et al.*, 2019).

2.1.5.3 Reception Boxes

There are four kinds of reception boxes (RBs), another method to handle the last-mile (IWAN; KIJEWSKA; LEMKE, 2016a; WANG *et al.*, 2014):

1. Independent reception box located on the customer's propriety;
2. Delivery Box equipped with a docking mechanism, retrieved only after the goods inside are collected;
3. Collection Point, which can be locker point or service point. Locker point or unattended point is an installed shared reception box located on public area. The parcels are delivered and stored at the unattended point, then the customer can may pay, collect and return goods. Service point or attended is built in shop-in-shop concept, located near residential location (local store, railway stations, hospitals, etc.) where customers can pay, collect, and return goods.
4. Shared password-protected reception box, installed near customers for shared usage. The courier stores the package in the boxes, the customers may pick up their order anytime through password provided to them.

With the reception boxes, the couriers don’t waste time waiting for the customers, improving the efficiency of the deliveries. In the other hand the implementation of reception boxes is expensive, Tiwapat *et al.* (2018) compared the traditional attended home delivery to the reception boxes modalities and found that from the perspective form the customers they were interest about the opening hours, which can allow them to pick their goods up at any time they want. Regarding the courier services provider, they were interested in failed first-time delivery and its cost. If the first-time delivery fails, it affects the delivery cost directly. Hence, if the modalities can reduce the failed first-time delivery, it could minimize the costs of the service providers.

2.1.5.4 Drone Delivery

In order to contribute positively to environmental outcomes regarding deliveries, there are many innovative initiatives and projects being developed. One of them are the Delivery Drones, automatically or remotely piloted aerial vehicles. In Europe, they are still on trial phase and deliver only urgent goods, such as medical supplies. The first drone launched, specifically for delivery, is called “parcelcoper” and reached 12 km of distance traveled. Deutsche Post DHL, a German multinational package delivery and supply chain management company, was responsible for this delivery, the first drone weighted less than 5 kg, had a carrying capacity up to 1.2 kg and could travel at an altitude of 50 m at 64.8 km/h (DHL, 2014). However, these features, such as load capacity, power solutions and delivery distances were further improved through research (EDENHOFER, 2018).

Drones are powered by batteries, which have to be replenished when depleted, limited their flight range. They also can carry one package at a time with restricted weight (HONG; KUBY; MURRAY, 2018). Customers concerns about the reliability of the drone delivery service for expensive items, thus, the promotion activities for the drone delivery will be necessary for its implementation (KIM, 2020b). On the other hand, they can deliver parcels with a low cost, high speed, no road restriction with a minimum CO2 emission. As the drones’ technology improves, the logistics’ system will have even more competitive advantages over traditional logistics (PENG; SUN; MENG, 2021).

2.1.5.5 Crowdsourcing Logistics

Brabhan (2008) best defines the term Crowdsourcing as “the process of posting a problem online, having a vast number of individuals offering solutions and awarding the winning ideas with some form of a bounty”. The concept of crowdsourcing was proposed by Howe (2006) based from class of business model that offers temporary asset ownership benefits to the users at a reduced cost.

Big companies are adapting this approach with ridesharing services to perform same-day deliveries that the customers demand, this is known as “Crowdsourced Logistics” (CLS). In this business model, the shipper solicits transportation services through mobile or desktop online service directly to an independent contractor that owns a vehicle asset, which integrates the retailer and the driver that will deliver the goods to its destination, through a good use of communication technologies (BEIRIGO; SCHULTE; NEGENBORN, 2018; GUO *et al.*, 2019).

The crowdsourcing logistics can build customer networks and local communities, which can make a better use of the existing capacity and feedback in order to improve the services, reduce costs of acquisition and maintenance of vehicles and even minimize the negative environmental impact, with an opportunity to serve the customer and creating the image of an environmentally friendly company (HUANG *et al.*, 2020). The obstacles of implementing the CLS include the responsibility of private issues, which can have additional costs; customers may not agree to share their addresses with the so-called strangers; Additional costs for insurance may be needed; software development, its implementation, maintenance, training for contributors and GPS devices have to be considered in the overall costs (JIANG; REN, 2020).

2.2 Bibliometrics

With the need for a solid framework, the Scopus base was used, since launched on November 2004 by the Elsevier publisher, it is the major multidisciplinary abstract and literature citation database in the world. It is highly used and proved to be an expended view of the science, offering tools for search and monitor the interested research (ELSEVIER, 2017).

The Table 4 shows the keywords and the respective thesaurus used for this research.

Table 4 - Keywords and Thesaurus

Keyword	Thesaurus
logistics	delivery organization; delivery plans
e-commerce	electronic commerce; online commerce; online browsing
shipping	transportation; shipment; transit; freight

Source: author (2020)

With this information, it was possible to arrange a strategy search to find results on Scopus database, as Table 5 shows.

Table 5 - Search Strategy

Search strategy	logistics OR “delivery organization” OR “delivery plans” AND "e-commerce" OR "electronic commerce" OR "online commerce" OR “online browsing” AND transp* OR shipping OR shipment OR transit OR freight

Source: Author (2020)

The Figure 3 shows the chronological of the e-commerce logistics with its 572 results the publish numbers started to continuously grow between 2015 and 2019.

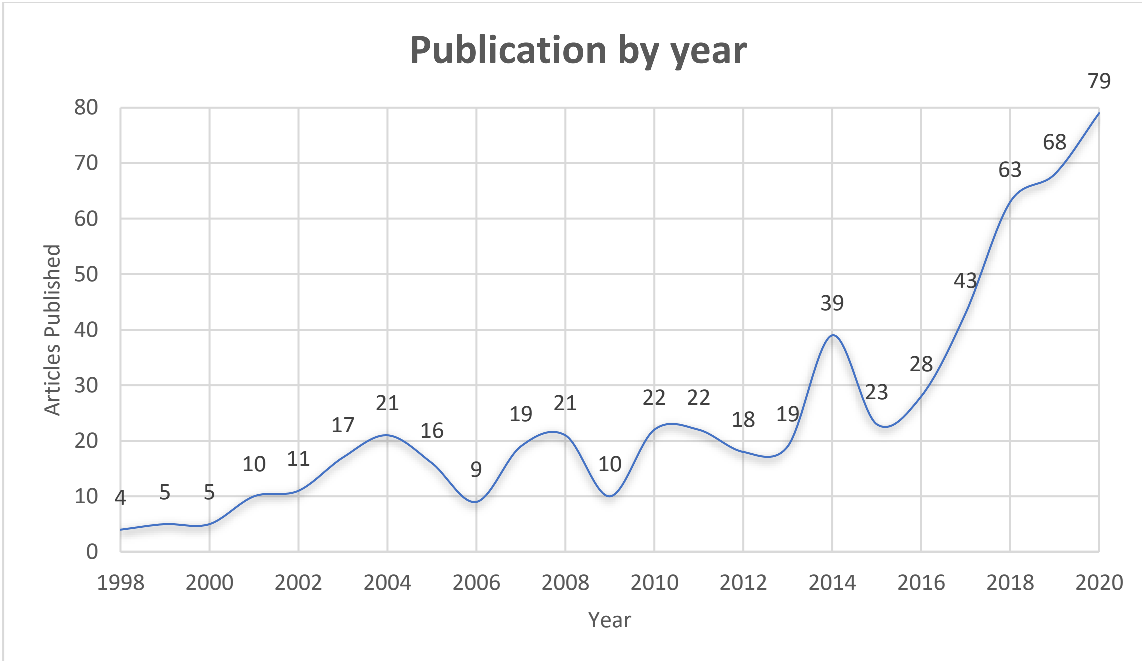

Figure 3 - Articles Published
Source: Author (2021)

The first five journals with most publish are ACM International Conference Proceeding Series, Proceedings of The International Conference on Industrial Engineering and Operations Management, Transportation Research Procedia, Transportation Research Part E-Logistics and Transportation Review and Advanced Materials Research as the Figure 4 shows.

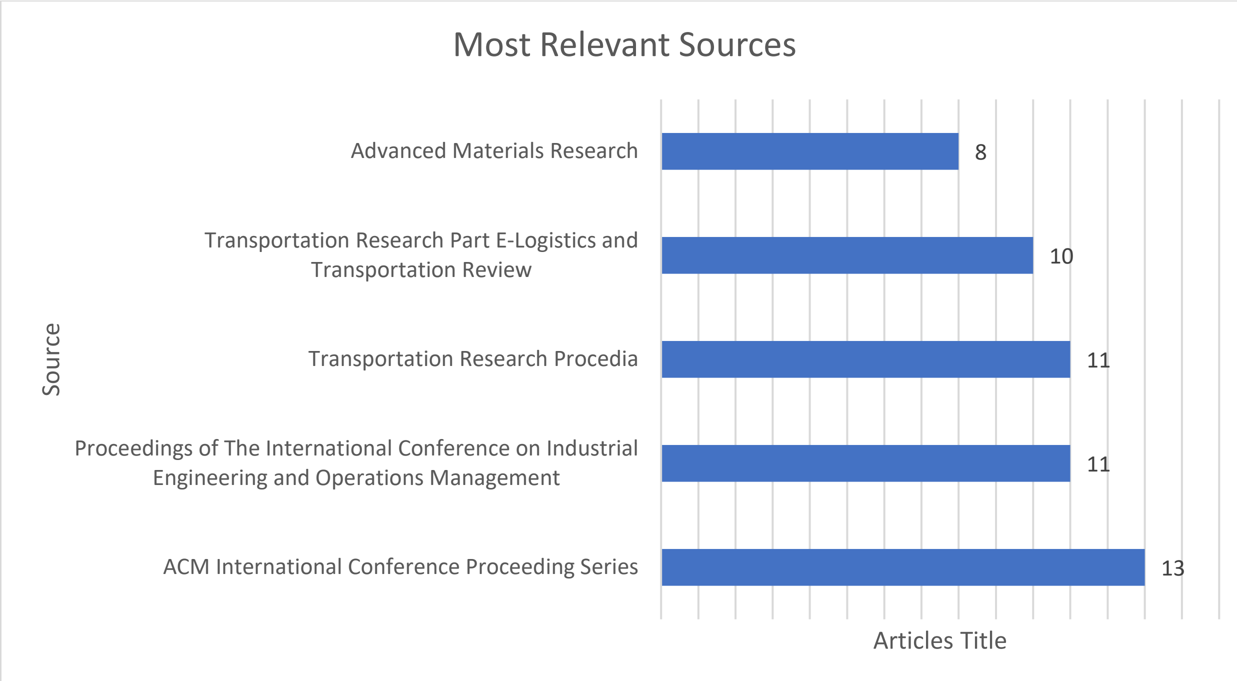

Figure 4 - Most Revelant Sources
Source: author (2020)

2.3 State of Art

This section aims to show the relevant work towards this research. The Table 6 shows the selected work within the Scopus search done as described on the Bibliometrics section.

Table 6 - Selected articles for state of the art

Citation	Title	Journal	Methodology
(TOKAR; WILLIAMS; FUGATE, 2020)	I Heart Logistics — Just Don't Ask Me to Pay For It: Online Shopper Behavior in Response to a Delivery Carrier Upgrade and Subsequent Shipping Charge Increase	Journal of Business Logistics	Survey
(KANG *et al.*, 2020)	Characterizing the generation and spatial patterns of carbon emissions from urban express delivery service in China	Environmental Impact Assessment Review	GIS based simulation
(SIMONI *et al.*, 2019)	Potential last-mile impacts of crowdshipping services: a simulation-based evaluation	Transportation	Simulation

Citation	Title	Journal	Methodology
(HIDAYATNO; DESTYANTO; FADHIL, 2019)	Model Conceptualization on E-Commerce Growth Impact to Emissions Generated from Urban Logistics Transportation: A Case Study of Jakarta	Energy Procedia	Model Conceptualization
(MARUJO *et al.*, 2018)	Assessing the sustainability of mobile depots: The case of urban freight distribution in Rio de Janeiro	Transportation Research Part D: Transport and Environment	Data collection
(IGNAT; CHANKOV, 2020)	Do e-commerce customers change their preferred last-mile delivery based on its sustainability impact?	The International Journal of Logistics Management	Survey
(SHE; OUYANG, 2021)	Efficiency of UAV-based last-mile delivery under congestion in low-altitude air	Transportation Research Part C: Emerging Technologies	Simulation
(ZHEN *et al.*, 2021)	Crowdsourcing mode evaluation for parcel delivery service platforms	International Journal of Production Economics	Six Mathematical Models
(ORENSTEIN; RAVIV; SADAN, 2019)	Flexible parcel delivery to automated parcel lockers: models, solution methods and analysis	EURO Journal on Transportation and Logistics	Logistic Model
(GONZÁLEZ-VARONA *et al.*, 2020)	Reusing Newspaper Kiosks for Last-Mile Delivery in Urban Areas	Sustainability	GIS based Simulation
(CASTILLO *et al.*, 2021)	Hybrid last mile delivery fleets with crowdsourcing: A systems view of managing the cost-service trade-off	Journal of Business Logistics	Systematic Review

Source: author (2020)

Tokar *et al.* (2020) experimented the e-costumer behavior related to the fees of shipping when an online retailer changes the preferred carrier and increases the shipping value. Their experiment presents 12 scenarios to the participants with questions to measure the perception of fairness, sentiment and intended response. In every scenario the participant would make a purchase from the store that they already regularly bought on the past, but when it is close to the checkout page, they notice that the shipping cost increased from the last time they purchased, based on real life carriers’ services. They concluded in their experiment that consumers expect faster deliveries but are not willing to pay more for them.

Kang *et al.* (2020) elaborated a spatially based dynamic model to measure the carbon emissions impact from the express delivery sector in urban areas in China. They discovered that the carbon emissions from the transportation varied from 20 tons to 4000 tons in 2017, 18% of these emissions were due the extra packaging materials.

Simoni *et al.* (2019) analyzes through simulation the impacts of different scenarios using crowdsourced delivery services, considering macroscopic features of traffic, simulating congestion in the city center of Rome, Italy. They simulated the emissions as well, and discovered that crowdsourced deliveries by car presents more emission impacts than corresponding delivers using public transit, but with a good management, through off-peak deliveries and adequate parking options can reduce the crowdshipping externalities significantly.

Hidayatno *et al.* (2019, p. 4) proposed a model that explains the total CO2 emissions generated from urban deliveries from e-commerce growth in Jakarta, Indonesia. Their study focuses on economic and environment aspects of urban logistics with an illustrated model conceptualization based on existing literature and casual loop diagram.

Marujo *et al.* (2020) studied the possibility to better accommodate the distribution of freight in densely populated areas, proposing a new method to discover how it would impact the service, quantify the footprint and deliveries costs of the strategy. It was found that the CO_2 emissions can be drastically lower using cargo tricycles and mobile depots in the last mile delivery with costs advantages over the traditional setups.

Ignat and Chankov (2020) conducted a state-preference survey to show how the social and environmental impacts of last mile deliveries influence the e-commerce shoppers. The costumers, when showed the environmental of the last-mile deliveries, generally makes more likely to choose a slower delivery, contributing with lower CO_2 emissions.

She and Ouyang (2021) designed two scenarios using conventional ground-based distribution facility and a new concept of airborne fulfillment center. They sought to mitigate a possible low altitude air congestion, caused by drones due its requirement of simultaneous use of a bigger fleet to fulfill the requirements of commercial scale operations. The created model, described the operation of a large fleet of drones operating on the last-mile delivery, providing useful insights to accomplish an efficient and sustainable last-mile delivery.

Zhen *et al.* (2021) studied variations of crowdshipping by applying six mathematical models, analyzing the service time for each task, cancellation ratio and distribution. The authors contributed by providing a quantitative methodology to match creation between drivers that are willing to make small detours and parcel delivery tasks. Also, they discovered a beneficial strategy which the driver takes two tasks.

Orenstein *et al.* (2019) elaborated a logistic model for parcel locker's deliver, whereas the client specifies one or more locations of choice to receive their order. The lockers' location (also known as service points) can be near the recipient's home address, office, metro station and other strategic places around the city. Depending of the consumer's flexibility, a delivery task may cost less and be delivered more rapidly. The authors make use of the concepts of the petal method, savings heuristic and tabu search to appraise this model to the traditional nonflexible one. Continuing the parcel locker's context, González-Varona *et al.* (2020) proposes a model that works with an existing newspaper journal kiosks network utilizing them as parcel lockers. They mapped the network of a city in Spain and compared two scenarios: the traditional delivery and their model. Through a simulation, the traveled distance and emissions were estimated.

Castillo *et al.* (2021), by adopting sociotechnical system perspective examined how a hybrid fleet, composed by crowdsourced assets and privately owned delivery vehicle, would affect the service and costs in last mile delivery. The authors made use discrete event techniques with delivery data from a major US retail pharmacy on a multimethod simulation combined with agent-based modeling in GIS space. The findings of this paper highlight the crowdsourcing services, showing that per-task compensation from crowdsourced drivers can have a positive effect on delivery costs and order fulfillment times as well. Also, the authors found that the crowdsourced drivers can be rewarded too much or too little. With a great payment, the company may face an inefficient capital resource management, with low payment the acceptance rates from the drivers falls, increasing the need of emergency deliveries, costing even more. Thus, there is a media compensation amount that the company can offer to provide a balance between service and cost.

2.4 Conclusions of Literature Review

From the main articles analyzed, it was concluded that studies to address the challenges of the last-mile logistics are continuously growing, with new approaches and strategies.

Although there are several studies evaluating new methods of sustainable delivery, not a single research about a simulation combining several ways of last-mile delivery was found. Which encourages this study, with the research focused on simulation and new deliveries strategy reunited publications between 2017 and 2020. It was observed that every study tackles the problem with at least one of the three delivery methods: Drones, Reception Box or Crowdsourcing, which affirms that are scientists interested about the development of a more sustainable last-mile delivery.

Henceforth, it was concluded that the last-mile delivery has a vast research gap and have the academia attention to fill these voids, with experiments, simulations and theories in order to create a better logistics system with less CO_2 emissions, consequently improving the quality of life.

3 MATERIAL AND METHOD

In this section the material and methods used in this dissertation will be presented. As Figure 5 shows, this study had two phases, the first one a Survey which explores the approval of new deliveries methods by local residents. The second phase simulates the possible scenarios with these methods.

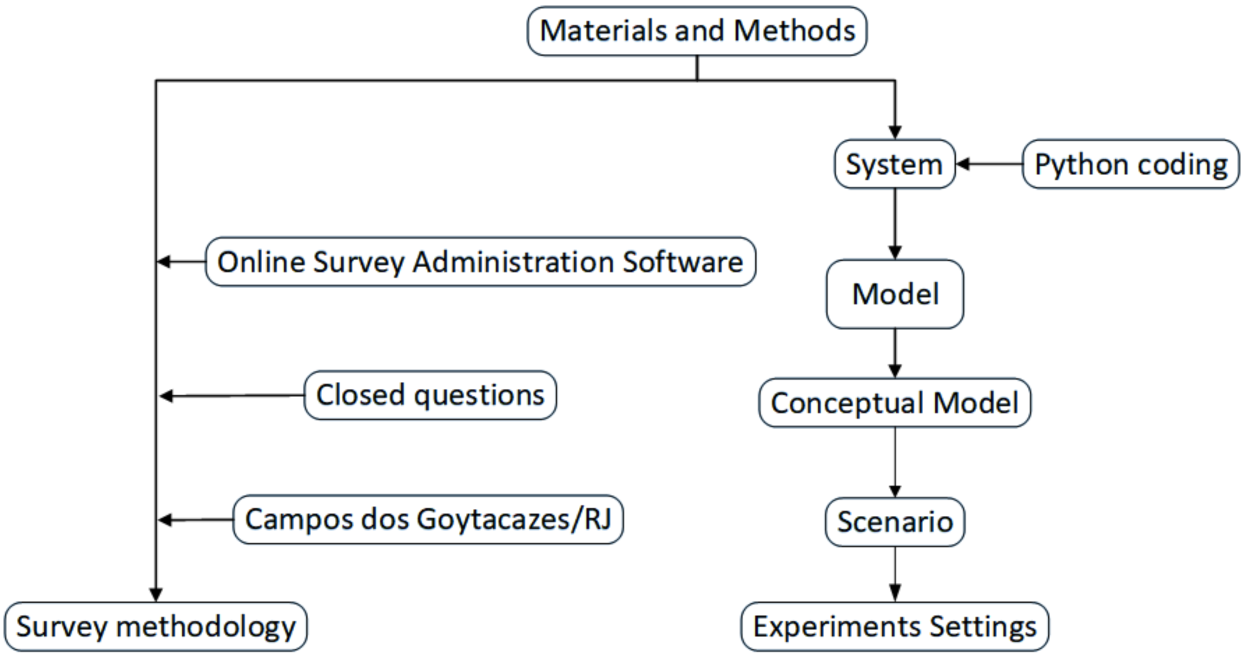

Figure 5 - General Visualization of Materials and Methods
Source: Author(2020)

3.1 Survey

The appliance of the survey aimed to investigate the changes about the means of acquiring products during the pandemics outbreak and also explores new ways to deliver goods that are little explored in Brazil. The data collection was made to gather information about this subject though an online survey applied for residents of Campos dos Goytacazes, located on Rio de Janeiro state, on the northern Fluminense mesoregion, to quantify the willingness of the population to try new deliveries methods. The five-points likert scale was used on questions regarding the customer's opinion, a higher score means a stronger concordance with the affirmative (LIKERT, 1932). Only closed questions were considered, divided in sections that flows according with the previous answer. There are four paths depending on the answer in order to analyze each customer profile. The Figure 6 illustrates the flowchart of questions and each section. It was used two questions regarding demographic information based on IBGE's census (2017) to identify the sample: age range and educational level. The age group on question I considered were under 13 years old, 14 to 17 years old, 18 to 24 years old, 25 to 39 years old, 40 to 59 years old. The education under consideration was the Incomplete Primary Education (IPE), Complete Primary Education (CPE), Incomplete High School (IHS), Complete High School (CHS), Incomplete Higher Education (IHE), and Complete Higher Education (CHE). The question 3 asks if the interviewee bought online before, at this point depending of the progressing the questionnaire may progress differently. If the answer is "Yes" the respondents will proceed to question 4a, otherwise they will be directed to question 4b, which asks if the interviewee would agree to buy online someday.

The question 4a intends to search if the participants of the survey have made use of the e-commerce by means of three options as solely before the pandemics, exclusively after the pandemics or if the respondent have been buying online regardless the coronavirus novel. For those who placed orders before, they were questioned if they would agree to buy online again. The following questions were measured with the five-points likert scale and were about which kind of products they bought (question 5a, 5b or 6c) and by which means (questions 6a, 6b or 7c), then they were asked about their satisfaction level with the current delivery method utilized by the courier on question 7a, 7b or 8c.

The questions 8a, 8b and 9c were based on the concept of reception boxes explained by Wang *et. al* (2014), in the same way, the questions 9a, 9b and 10c were based on Slabinac (2015) explanation about drone delivery and lastly the questions 10a, 10b and 11c were based on Wang *et al.* (2016) work, which defines the Crowdsourcing logistics, in order to quantify the acceptance of the citizens toward these three modalities.

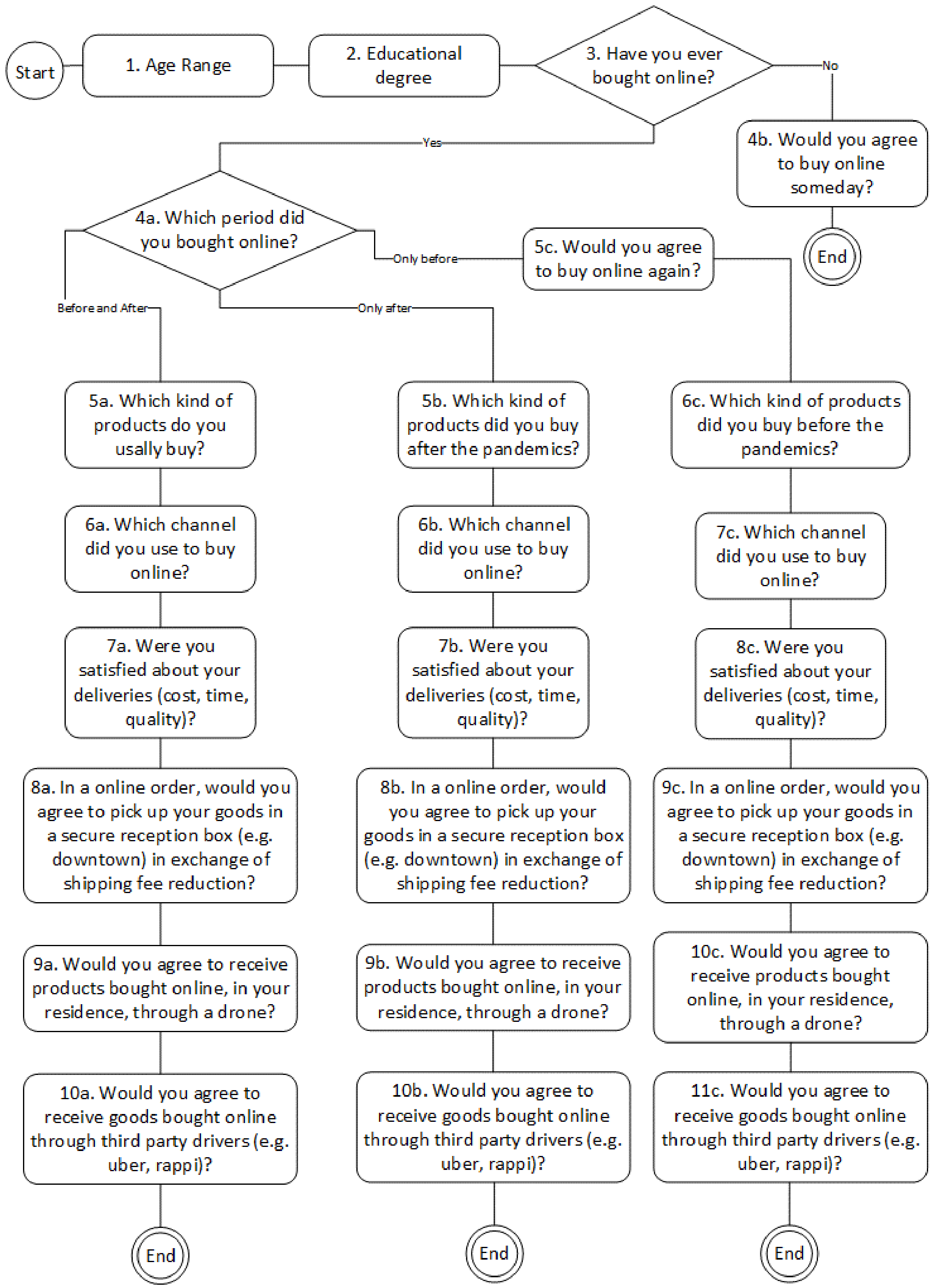

Figure 6 - Questions and paths
Source: Author (2020)

The theorical framework included related articles about e-commerce and innovative ways to attend the high delivery demand caused by the pandemic virus outbreak. The questionnaire was applied between June and July of 2020 to residents of Campos dos Goytacazes. This municipality is located on Rio de Janeiro state, on the northern Fluminense mesoregion. According with the 2010 census, the city has a 463,731 population and a demographic density of 115.16 person per km². The estimative of 2019 populace by the Brazilian Institute of Geography and Statistics (IBGE) is 507,548. The medium monthly income of formal workers in 2017 is 2.5 minimum wages, which is only the 19,6% of overall population (IBGE, 2017).

From the population number, informed by IBGE, the ideal sample was determined by the equation of sample calculation for finite population (GIL, 2008), as seen on Equation (1. The minimum sample calculated corresponds to 384 respondents.

$$n = \frac{z^2.p.q.N}{e^2(N-1)+z^2.p.q} \tag{1}$$

In which:

n: sample size;

z: confidence level scored;

p: probability of success event (50%);

q: probability of failure (50%);

N: population size;

e: maximum error used (5%).

3.2 Simulation

The computational simulation may be utilized for both simple and complex circumstances, making the data and variable management easier than real life experience (LI; HE, 2021). The simulation is normally applied for decision making due the possibility of combining the complexity of real-life system to a virtually controlled environment, which its effects can be analyzed (GUO *et al.*, 2019) Through simulation, it is possible to determine virtual scenarios and collect enough data for a satisfactory analysis. Some of the many benefits of this approach are its viability, scalability and flexibility (ARNOLD *et al.*, 2018). Due the challenge of virtualization of the model, it was decided to develop a study based on the mileage traveled, since this variable is directly associated with the overall costs and gas emissions, which can be seen in lots of logistics studies (ALVES *et al.*, 2019; GUO *et al.*, 2019; MOSHREF-JAVADI; HEMMATI; WINKENBACH, 2020b; SEGHEZZI *et al.*, 2020b; SIMONI *et al.*, 2019).

To create a simulation model applied to a hypothetical system, Banks *et al.* (2013) methodology was adopted, consisting in the following steps: problem formulation; objective definition and general project plans; concept plan construction; data gathering; validation; experimentation; execution and analysis; runs; documentation and reports. The verification and validation of the model followed the steps provided by Sargent (2013).

Firstly, in order to obtain a function that best describes the number of daily orders, 100 e-commerce websites were consulted to gather the delivery arrival estimative. The Appendix A has the detailed information collected Through Monte Carlo method; new orders were generated daily. Then the first run of each scenario ran 20 times in order to obtain mean and standard deviation, aiming to achieve a confidence index of 5%, as seen on Equation (2 (BANKS, 2013):

$$n = \frac{100 \times z \times S}{(r \times \overline{x})^2} \quad (2)$$

Where:

n = number of replications;

z = standard score;

S = standard deviation of mileage variable;

r = confidence index;

x̄ = mean of mileage variable.

If the confidence semi-interval is lower than 5% of the variable mileage mean the Equation (3) is applied to adjust the number replications needed.

$$n^{*} = n \times \left(\frac{h}{\bar{x} \times 0.05}\right)^{2} \quad (3)$$

Where:

n^{*} = new number of replications;

n = number of replications;

h = confidence semi-interval;

x̄ = mean of mileage variable.

3.2.1 System

The last mile on e-commerce delivery market is one of urban freight transport branches. The study from Kum *et al.* (2018) define it as a group of processes and activities that are needed for delivery, ranging from the last transit mark to the final drop point of the delivery chain. Each city has its own expectation and preferences, the e-customer (the one that buys products online) chooses from an online retailer and a company is responsible to deliver the goods (mostly represented by courier, express and parcel companies). Some service provider will deliver fast and cheaper than others, and most of the time ignores the problems faced by the shipping such as congestion and pollution (KIBA-JANIAK *et al.*, 2021). To solve these issues, this study provides a sustainable alternative of last-mile logistics, based on the traditional delivery. The Figure 7 illustrates a typical traditional delivery system.

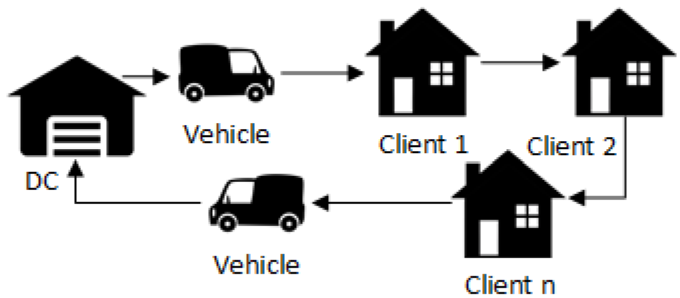

Figure 7 - Typical layout for last-mile delivery
Source: Adapted from Bandeira et al. (2019)

The delivery consists of vehicle dislocations from the Distribution Center (DC) to the first client, then the driver proceeds to the next client and repeats until the last consumer of the schedule is attended. At last, the vehicle returns to the DC at the end of the cycle. This system configuration was designed based on experiments made by Bandeira *et al.* (2019), in their study they evaluated the delivery's sustainability with electric vehicles on the last-mile with a similar set up.

Furthermore, the following systems consist on the traditional delivery occurring simultaneously to each alternative. The daily orders are processed and distributed on DC to each vehicle before leaving to the route. Each modality has its uniqueness, varying the delivery method, max distance allowed and how many clients can be attended. In this study three possibilities are explored alongside traditional delivery, being further detailed as follows.

The first alternative of this study is delivery by drone, often called Unmanned Aerial Vehicle (UAV). In this circumstance, the Brazilian authority responsible for regulating and overseeing civil aviation, activities, aeronautics and aerodromes infrastructure is the National Civil Aviation Agency (ANAC). According to the Brazilian Regulation of Special Civil Aviation number 64/2017, the maximum distance of a parcel deliver UAV is 2.5

kilometers, which is unfortunate considering the promising technologies of this modality (ANAC, 2017).

In this system, similar to most of studies, only one parcel is delivered per drone each time (BRAR *et al.*, 2015; TROUDI *et al.*, 2018). The UAV takes off from the DC, travels to the client's home, leave the parcel and return (SHEN *et al.*, 2021). Simultaneously, the fleet of ground vehicles (which can be a car, a van or a truck) are delivering the parcels door-to-door and returning to the DC. The Figure 8 illustrates the model using drones. It is important to note that the Figure 2 has the same elements as Figure 1, the difference is the addition of drones at lower part of the image.

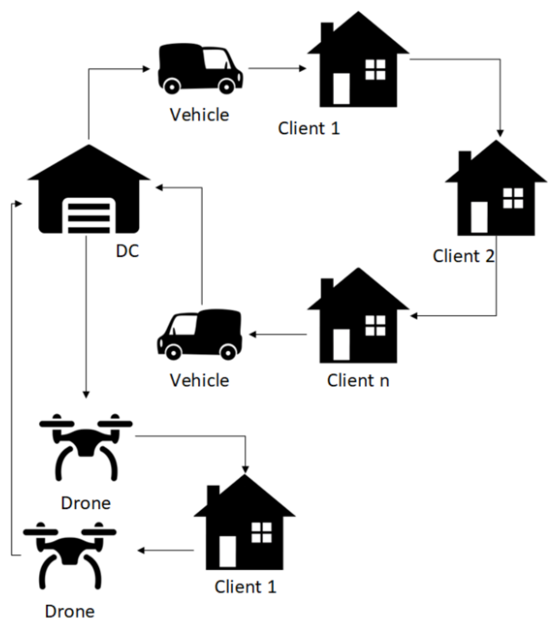

Figure 8 - Drone Delivery Layout
Source: Author (2021)

Another emerging logistics modality called crowd logistics (crowdshipping for short) is gaining notoriety steadily (CARBONE; ROUQUET; ROUSSAT, 2017; DEVARI; NIKOLAEV; HE, 2017; MARTÍN-SANTAMARÍA *et al.*, 2021). The main feature of this practice is the possibility of ordinary citizens to participate in the delivery of goods. Additionally, implementing crowdshipping may contribute with sustainability, since it would reduce the network of logistics, which results on lower traffic levels and logistics costs (GUO *et al.*, 2019).

The crowdshipping method of this study consist in each user taking the task provided by the courier and taking off from DC by their own car. Then deliver one or two parcels to clients, optimizing the time considering the driver's route, and does not return to DC (SEGHEZZI; MANGIARACINA, 2021). The Figure 3 shows how the model layout looks like. Similar to Figure 8, this model also has the same cycle as Figure 7, but now adds a crowdshipping vehicle route on the lower part of the image.

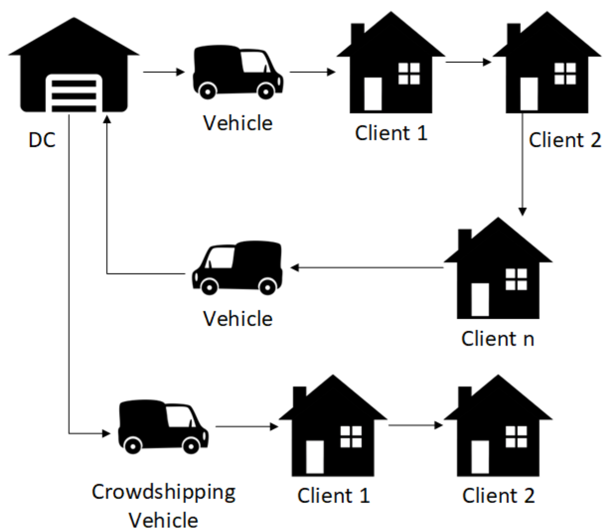

Figure 9 - Crowdshipping Layout
Source: Author (2021)

The last system of this study is the Parcel Locker, also known as smart locker. It is a very discussed solution for innovative last-mile delivery (MANGIARACINA *et al.*, 2019). The main advantage of this method is its practicality in customer's point of view, being able of choosing their preferred location and time to collect their goods. In addition, the locker's location can be strategically placed, avoiding delivery problems and decreasing the number of absent recipients (IWAN; KIJEWSKA; LEMKE, 2016b).

A single vehicle leaves from DC and travels through the stations leaving the parcels in the lockers (RABE *et al.*, 2021). The Figure 10 shows the model of parcel locker delivery. As seen before, the traditional delivery remains the same as Figure 7, Figure 8 and Figure 9 on the upper part of the image while adding the parcel locker vehicle's route on the lower part.

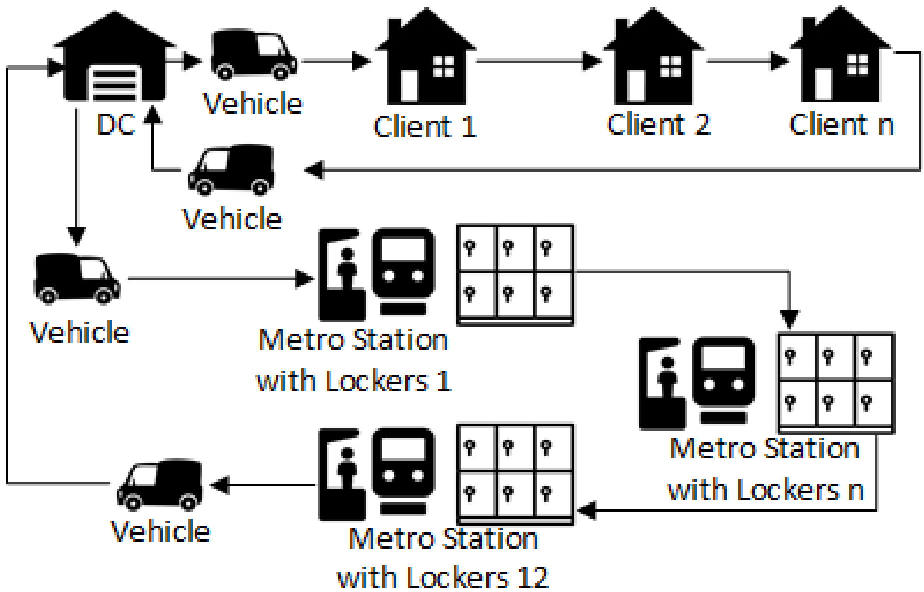

Figure 10 - Parcel Locker Delivery Layout
Source: Author (2021)

3.2.2 Model

The present simulation model arranged in this work was developed based on a study made by Marujo *et al.* (2018). These authors assessed the use of motorized cargo tricycles alongside conventional ground vehicles. Also, they proposed a method to evaluate the environmental benefits of this strategy of distribution by estimating the reduction of emissions. Their study was applied in the city of Rio de Janeiro, Brazil, collaborating with the average distance from DC and the first customer, distance between two clients, average number of stops per day and the total distance traveled. The experiment was based on this set of data.

Thus, the designed simulation model features the parcels distribution on the last mile of business-to-consumer e-commerce, in a mega city environment of the city Rio de Janeiro, Brazil, composed by a distribution center and multiples clients (BANDEIRA *et al.*, 2019). The survey was applied to a smaller city, during the early stages of COVID-19 pandemic, the collect data were very suitable to this study, since the purchase pattern reflects along the whole state. For this study, it was considered 8 hours for a day's work, approximately divided in 6 hours for deliveries, 1 hour to prepare and load the vehicle and another hour to return to the distribution after the last delivery (ARNOLD *et al.*, 2018). Subsequently, the output variables are: total mileage traveled (in kilometers), fleet size (units of vehicles) and orders delivered. It is important to make clear that a lower mileage means a lower greenhouse gas emission.

3.2.3 Conceptual Model

The conceptual model construction was defined by gathering the necessary data from the literature and data gathering from online stores though Ebit (2020) report. Since it is very difficult to compare the delivery limit from a wide range of products, 10 categories of websites were considered: Health /Cosmetics/Perfumery; Fashion and accessories; Home and decoration, Home Appliances; Phones/Cellphones; Sports and Entertainment; Books/Subscriptions/Handout; Computing; Electronics and; Drinks and Food. The Full List can be seen on Appendix B - Delivery Limit from Different Websites. In this way, a model that represents the system's behavior and trustworthy results can be formulated. Then, the system is described through a conceptional model using the necessary elements of computational model. The language used in the conceptual model was IDEF-SIM, which consists in a symbol system that uses IDEF0, EDEF3 and flowcharts inside a logic of simulation (MONTEVECHI *et al.*, 2010). The model is illustrated on Figure 11.

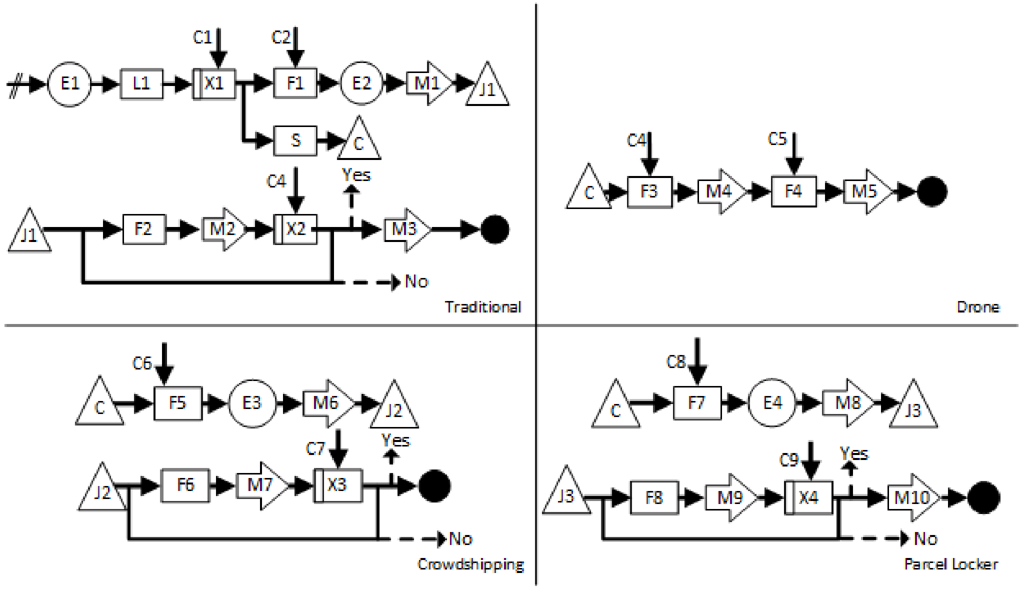

Figure 11 - Conceptual Model

On the upper left, the element E1 is responsible for the creation of entities of the system, which in this case are the orders that are being delivered to clients. Then, the element L1 represents the local (DC) where the products are stored and the vehicles are boarded. In addition, X1 is a decider that processes the loading of orders on DC, dividing how many parcels are being delivered by traditional and by another alternative. Additionally, the variable consolidation level means the occupational level of a delivery vehicle, which means how many parcels are delivered to the clients in a day. In this context, C1 is the consolidation control that distributes the percentage of orders that are loaded to each modality. Moreover, the S element refers to a scenario: depending of which delivery modality is being computed the element C will connect to another figure. Afterwards, the F1 element illustrates the process of loading orders onto vehicles in DC. Next, the element C2 represents the consolidation level, which means how much parcel every vehicle will carry. Then, E2 creates an entity of consolidated orders. The following M1 means the movement of the orders from DC to the first client. Moreover, the J1 is an element of connection of the figure. Jumping to the next part, the F2 is a function that executes the process of delivery to the consumer. Then, M2 is the movement of the orders between clients. Another decider is labeled X2, verifying if all the orders of the vehicle have already been delivered. If there aren't any parcels to be delivered, the process proceeds, on the contrary, the F2 is executed again executing the flow. Finally, M3 is the movement of return to the DC.

Now referring the upper right corner, the scenario with drone delivery is represented. At first, the F3 function represents the process of loading the drone and C4 is the consolidation level, in this case can only be one parcel. Then, the M4 is the movement from DC to the client. Additionally, the F4 illustrates the function of delivery while C5 computes the delivery. At last, the M5 is the movement of return of the drone to the DC.

Focusing on the lower left corner, it shows the delivery by crowdshipping. The first element is the F5, which is a function to load the crowdsourced vehicle followed by C6, the consolidation control of the parcels. Then, E3 creates an entity of consolidated orders from crowdsourced vehicles. M6 represents the movement from DC to the client. The last element in this line, J2, is another connector that links the flow of the pictures. Following to the line below, the F6 function represents the delivery to the client, followed by M7 that is the movement to the next client and X3, which is a decider that verifies if there are any order left to be delivered. If the condition is true, the model will return to the F6 function, otherwise, the model will end.

The last branch is about parcel locker delivery, located on the lower right part of the Figure 11. The first element of this branch is the F7, the function that loads the vehicle on DC, followed by C8, that is the consolidation control of the orders and E4 that creates the entity responsible for consolidated orders for parcel locker delivery. Then, M8 is the movement from the DC to the first parcel locker location. The last element on this line is J3, another connector that links the flow with the lane below. Jumping to the lower row, F8 is the function of unload the vehicle to a locker. Thus, M9 represents the movement between the locker’s locations. At last, X4 is a decider that verifies if there are any orders left to be delivered. If there are any parcels left the process returns to F8, otherwise, the vehicle will be directed to the DC on M10 and the simulation ends.

The explained configuration data that was utilized on the model and are summarized listed on Table 7 as follows.

Element	Name	Description	Settings
E1	Entity Orders	Daily Orders	NORM (98,4)
E2	Entity Consolidated Orders	Consolidated Orders	9 orders
E3	Entity Consolidated Crowdshipping Orders	Consolidated Orders	Max 2 order
E4	Entity Consolidated Parcel Locker Orders	Consolidated Orders	As much as needed
L1	Distribution Center	Location	-
F1	Loading Function	Execution of Loading Cargo	Max 9 parcels by car
F2	Unloading Function	Execution of Unloading Cargo	Delivery resources
F3	Loading Function	Execution of loading a cargo to a drone	1
F4	Deliver Function	Deliver parcel from drone	1
F5	Loading Function	Execution of loading a cargo to a crowdsourcing vehicle	Max 2 order
F6	Unloading Function	Execution of Unloading Cargo from crowdsourcing vehicle	Max 2 order
F7	Loading Function	Execution of loading a cargo to vehicle (parcel locker)	As much as needed
F8	Unloading Function	Execution of Unloading Cargo from vehicle (parcel locker)	Delivery resources
M1	Movement	The Vehicle leaves the DC to the first client	23 km
M2	Movement	The Vehicle moves from one client to another	2.21 km
M3	Movement	The Vehicle returns to DC	23 km
M4	Movement	The Drone moves to clients	2.5 km
M5	Movement	The Drone returns to DC	2.5 km
M6	Movement	The Vehicle goes to client	23 km
M7	Movement	The Vehicle goes to client (if applicable)	2.5 km
M8	Movement	The Vehicle goes to the first locker station	23 km
M9	Movement	The Vehicle goes to the next locker station	1.5 km
M10	Movement	The Vehicle Returns to DCn	2.5 km
C1	Consolidation Control	Defines how much of parcels will go to each modality	Scenario defined
C2	Consolidation Control	Distributes how many orders were finished	Monte Carlo distributed
C3	Consolidation Control	Computes how many orders were delivered	-
C4	Consolidation Control	Computes how many orders will be delivered by drones	Scenario defined
C5	Consolidation Control	Computes how many orders were delivered by drones	-
C6	Consolidation Control	Computes how many orders will be delivered by crowdshipping	Scenario defined
C7	Consolidation Control	Computes how many orders were delivered by crowdshipping	-

C8	Consolidation Control	Computes how many orders will be delivered by parcel locker	Scenario defined
C9	Consolidation Control	Computes how many orders were delivered by parcel locker	-
J1	Jump	Connects with another segment	-
J2	Jump	Connects with another segment	-
J3	Jump	Connects with another segment	-
C	Connection	Connects with a scenario	-
S	Scenario	Has its unique settings	
X1	Decider	Divides the orders between traditional delivery and scenario modality	Type: two ways
X2	Decider	Verifies if there are parcels to be delivered	Type: two ways
X3	Decider	Verifies if there are parcels to be delivered by crowdshipping	Type: two ways
X4	Decider	Verifies if there are parcels to be delivered by parcel locker	Type: two ways

Source: Author (2021)

3.2.4 Experiments settings

The simulation software used for the model construction in this research was coded using Python 3.7, which is freely usable and distributable, even for commercial purposes. There are some libraries for DES and supply chain, such as salabim and supplychainpy, but they were not fully functional, since they are on early versions. So, the author opted to create an algorithm specifically for the model.

Thus, the conceptional model was coded on a web application Jupyter, an opensource software and services for interactive computing for many programming languages. The simulation time length was 90 days and a 100 days period of warmup, which the output variables were not tabulated. For this matter, the simulation was executed on Intel Core i7 2.40 GHz, with 16 Gb of RAM and running Ubuntu Server 20.04 LTS. Each scenario took approximately 30 minutes to be executed and had its number of replications. In addition, the complete code can be seen on Github on the following link: https://github.com/paulorossicroce/dissertation.

3.2.5 Scenario

The full simulation consists of 14 scenarios, including the base scenario T0, developed by a fractioned factorial experiment. The Table 7 presents a summary of the scenarios.

Table 7 - Scenarios Settings

ID	Modality	Orders	CL	DC	L	km	Reference
T0	Traditional	NORM(96,4)	9	23	2.21	(DC*2) + L * (N-1)	(MARUJO *et al.*, 2018)
D1	Drone	5%	1	2.5	-	DC * 2	(BRAR *et al.*, 2015); (ANAC, 2017); (SHE; OUYANG, 2021)
D2		50%					
C1	Crowdshipping	5%	2	23	2.21	DC + (L*N)	(MARUJO *et al.*, 2018); (SEGHEZZI; MANGIARACINA, 2021)
C2		10%					
C3		15%					
C4		20%					
P1	Parcel Locker	10%	n	23	1.5	2*DC + (L*12)	(MARUJO *et al.*, 2018); (RABE *et al.*, 2021); (GOOGLE MAPS, 2021)
P2		20%					
P3		30%					
P4		40%					
P5		50%					
A1	Traditional	70%	n	23	2.21	Σkm	All above
	Crowdshipping	10%					
	Parcel Locker	20%		23	1.5		
A2	Traditional	30%	n	23	2.21	Σkm	All above
	Crowdshipping	20%					
	Parcel Locker	50%		23	1.5		

Source: Author (2021)

Where:

CL = Consolidation level;

DC = Distance between DC and client;

L = Distance between deliveries;

n = Total of orders;

N = number of clients;

Σkm = Sum of all modalities' mileage.

Each line of the Table 2 represents a scenario and its setting. While the T0 has a normal function to determine how many parcels are going to be delivered, the other scenarios have a percentage of the orders to be shipped. This means that daily, a percentage depending of the scenario will be selected for the modality and the rest is going to be delivered by traditional means simultaneously. Following, CL means how much parcels the vehicle carries for the delivery. Then, DC is the distance from the distribution center to the first client and L is the length of the route between the stops for deliveries. Regarding drones delivers, since this modality handles a single client, it is not considered on the mileage's equation. Lastly, the column km stands for how the mileage is calculated for each scenario.

With this information in mind, on a traditional delivery mode, 9 parcels are delivered by each car. This configuration maximizes the daily delivery made by drivers considering traffic, distance and the employee's 8 hours of work without overtime. Additionally, the distance between the DC and the first client is 23 km and the distance between clients is 2.21 km. With the sum of every dislocation, the total mileage of a day is calculated (MARUJO *et al.*, 2018).

Regarding drone delivery, only one parcel will be delivered at a time (BRAR *et al.*, 2015; SHEN *et al.*, 2021). In this alternative, the drone leaves the DC and goes directly to the client, traveling 2.5 km and returns to the DC, summing another 2.5 km (ANAC, 2017).

The following modality, the crowdshipping vehicles leaves the DC with a maximum of 2 parcels, aiming to optimize their travel. Then, the drivers deliver the parcel to the client and does not return to the DC, finishing their task. At last, the total mileage is calculated by simply summing the distance between DC and client, which is 23 km, and if there is an additional client, the distance traveled must be considered as well (SEGHEZZI; MANGIARACINA, 2021).

In the last alternative of this study, the lockers are hypothetically placed on 12 metro stations on the South Zone of Rio de Janeiro. Their locations were consulted on

Google Maps (2021), with an average distance of 1.5 km between each station. A single vehicle carries all orders designed to be delivered, leaves the DC to the first locker, counting 23 km. Then the driver unloads the parcels and goes to the next locker, repeating until the last stop. Finally, the vehicle returns to the DC (RABE *et al.*, 2021).

4 RESULTS

In this section, the results are divided in two segments: survey and simulation. Firstly, the survey was applied to confirm the willingness of a population to adopt new modalities of delivery. Then the simulation explores these modalities in order to reduce the CO_2 emissions. The full results are detailed in the following topics.

4.1 Results from Survey

The results of the survey indicated that the majority age range between 25 and 39 years. Younger people tend to buy more online since they are connected to the internet most of the time (BEDNAROWSKA; JEDRUSZEK, 2012). The Table 8 shows the percentage of each age range and education according to IBGE (2010). The data showed determines the prevalence of customers with higher level of education, which represents most of customers have already finished university or are finishing it. These results were expected, since the e-commerce and internet usage are related to the Brazilian education. According to Information Resources Management Association (2018), people with higher education tend to buy more online.

Table 8 - Age range and Education

Age Range		Education	
0 to 13 years old	0.5%	Incomplete Primary Education	5.7%
14 to 17 years old	3.2%	Complete Primary Education	2.5%
18 to 24 years old	19.2%	Incomplete High School	4%
25 to 39 years old	37.4%	Complete High School	8.7%
40 to 59 years old	28.2%	Incomplete Higher Education	14.7%
60 years old or more	11.5%	Complete Higher Education	64.3%

Source: Author, 2020

From the answers shown on Figure 12, 93.03% of surveyed people buys online, those who didn’t were asked if they are willing to order something online in the future. The predominant opinion was positive towards experimenting the e-commerce. The customers that only placed an online order before the pandemic outbreak were asked if they agree to order online again someday, they are represented by the blue arrow. The most of the ones that only bought online before may try to buy online again, represented by the orange arrow. It is possible to identify four profiles from the customers: the ones that purchased online only before the beginning of the pandemic novel; the ones that ordered only after the outbreak; the assiduous online buyers that always place online orders and; the ones that didn't order online yet.

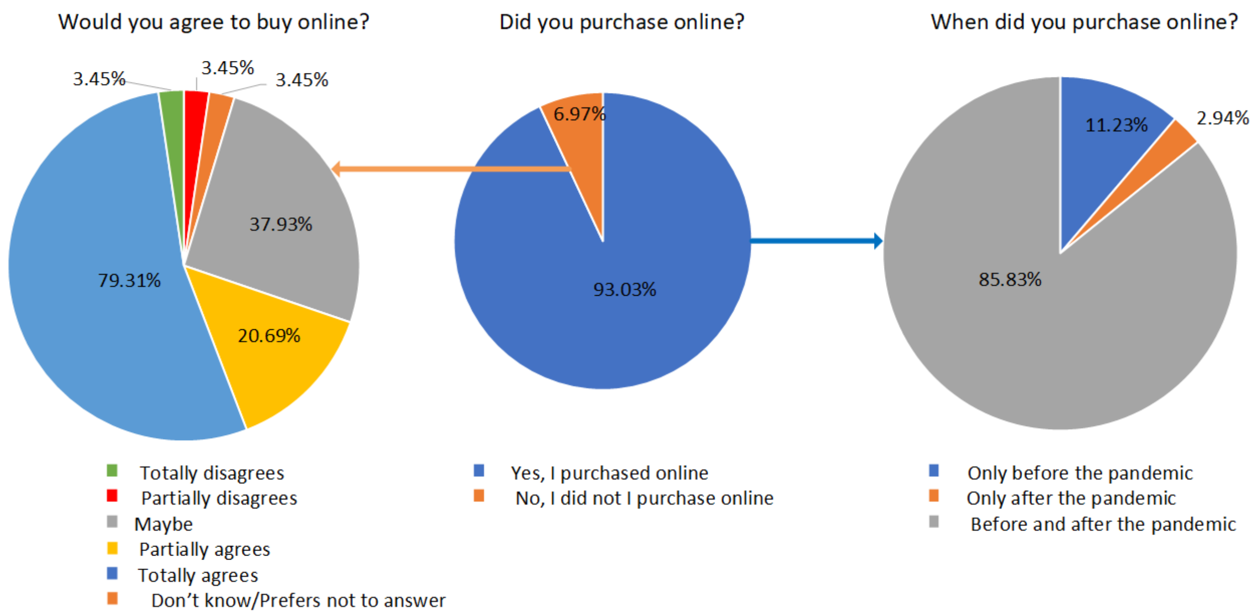

Figure 12 - Online Purchase answers on pie charts
Source: Author (2020)

The Table 9 shows which kind of products the city residents buy online. For those who bought before the pandemics, Fabrics, clothing and footwear were the categories that were ordered the most. New buyers ordered Books, newspapers, magazines and stationery and the assiduous buyers tend to diversify their online shopping, which means a greater variety of products bought.

Table 9 - Categories of Producted purched online

Category	Before	After	Before and after
Gas and lubricants	7.1%	0%	1.9%
Hypermarkets, supermarkets, food products, beverages and tobacco	14.3%	27.3%	26.6%
Fabrics, clothing and footwear	50%	27.3%	56.6%
Furniture and appliances	42.9%	27.3%	68.1%
Pharmaceutical, medical, orthopedic, perfumery and cosmetic	28.6%	27.3%	38.1%
Books, newspapers, magazines and stationery	40.5%	36.4%	49.4%
Office, computer and communication equipment and supplies	33.3%	18.2%	52.8%
Other personal and domestic use items	7.1%	27.3%	53.1%
Vehicles, motorcycles and parts	9.5%	0%	15.9%
Construction material	2.4%	18.2%	4.4%

Source: Author, 2020

The Table 10 shows, from the higher percentage to the lowest, which channels the customers used in order to complete their orders. The store website was the most used channel among the costumers, mobile apps also have a great share of online purchases. Before, during and after pandemic novel the order of channels used was maintained.

Table 10 - Channels of online purchase

Channel	Before	After	Before and after
Website	92.9%	90.9%	96.3%
Apps	16.7%	45.5%	48.4%
Whatsapp	7.1%	9.1%	24.7%
Instagram	4.8%	9.1%	23.8%
Facebook	4.8%	9.1%	8.1%

Source: Author (2020)

The participants were asked if they were satisfied with the current delivery method, their answers are displayed on Table 11, from more satisfied to less satisfied. Most of customers were satisfied with the costs, quality and delivery time, but the assiduous buyers have slightly more diversified opinions on the matter, which can indicate new opportunities to improve the quality of the services provided from the curriers.

Table 11 - Customer's satisfaction with delivery system

Answer	Before	After	Before and after
+2 - Totally satisfied	21.4%	9.1%	26.9%
+1 - Partially satisfied	33.3%	27.3%	44.4%
0 - Neutral	7.1%	9.1%	6.9%

-1 - Partially unsatisfied	14.3%	18.2%	14.7%
-2 - Totally unsatisfied	21.4%	18.2%	6.9%
N -Don't know/Prefers not to answer	2.4%	18.2%	0.3%

Source: Author (2020)

In regard to reception boxes, the Table 12 presents the answers ordered, from most to least positive, about the customer's acceptance about this kind of service, they were asked if they would agree to receive their goods in a strategically located locked box around the city, in return the shipping fees would be decreased. The answers were mostly positive, meaning that it would be a good delivery modality to experiment.

Table 12 - Customer's interest for reception box

Answer	Before	After	Before and after
Totally agrees	38.1%	45.5%	32.2%
Partially agrees	16.7%	18.2%	22.5%
Maybe	16.7%	18.2%	23.8%
Partially disagrees	14.3%	9.1%	5.6%
Totally disagrees	9.5%	0%	15%
Don't know/Prefers not to answer	4.8%	9.1%	0.9%

Source: Author (2020)

According to the results shown on Table 13, the customers are uncertain about this method, but most of them are willing to try.

Table 13 - Custumer's interst for delivery drones

Answer	Before	After	Before and after
Totally agrees	38.1%	36.4%	33.1%
Partially agrees	16.7%	27.3%	17.8%
Maybe	9.5%	9.1%	19.4%
Partially disagrees	7.1%	0%	4.7%
Totally disagrees	14.3%	18.2%	18.1%
Don't know/Prefers not to answer	14.3%	9.1%	6.9%

Source: Author (2020)

The crowdsourcing is a new concept well received by the interviewed sample, companies like Uber and Ifood inserted themselves into their daily lives (YOUNG; FARBER, 2019). The customers now were asked if they agree to receive their goods by a third-party delivery system, in this questionnaire, this concept was the most accepted by the citizens, regardless of their experience of online shopping. The answers can be seen on Table 14, from the most positive to the least positive level of acceptance.

Table 14 - Customer's interest for crowdsourcing

Answer	Before	After	Before and after
Totally agrees	42.9%	45.5%	50.9%
Partially agrees	19%	27.3%	25%
Maybe	14.3%	18.2%	12.2%
Partially disagrees	2.4%	0%	5.9%
Totally disagrees	9.5%	9.1%	4.7%
Don’t know/Prefers not to answer	11.9%	0%	1.2%

Source: Author (2020)

4.2 Results from Simulation

4.2.1 System Validation

Comparing results from the same simulation setting containing constant values between the Rockwell Arena and the Python, the Table 15 shows the parameters and the results obtained.

Table 15 - Results Comparison between Rockwell Arena and Python

Parameters	Vehicles	2	
	Drones	1	
	Reception Boxes	1	
	Crowdsourced Drivers	1	
	Deliveries on Vehicle 1	9	
	Deliveries on Vehicle 2	1	
	Distance between DC and First Costumer	23 km	
	Distance between clients	2.21 km	
		Method	
		Rockwell Arena	Python
Results	Vehicles Mileage Traveled	114.10 km	114.10 km
	Deliveries made	32	32
	Vehicle 1 Mileage	65.9 km	65.89 km
	Vehicle 2 Mileage	48.2 km	48.21 km
	Drone Mileage	30 km	30 km
	Truck (for Reception Box) Mileage	46 km	46 km
	Crowdsource Mileage	23 km	23 km

Source: Author (2020)

Both software returned the same values from the input data, validating the algorithm. The Table 16 applies the parameters of the base scenario and run the algorithm, within a 5-day run, 360 orders, 8 available vehicles with the consolidation level of 100%.

Table 16 - Base Scenario Run

Day	Vehicle	Parcels	Km traveled	Total Fleet Mileage	Total Extra Fleet Mileage	Overall Milage	Packages Delivered
1	1	9	81.54782	598.104	0	598.104	72
	2	9	79.46504				
	3	9	71.23135				
	4	9	67.16423				
	5	9	80.00072				
	6	9	92.5362				
	7	9	60.82489				
	8	9	65.33376				
2	1	9	78.66711	530.2858	0	530.2858	72
	2	9	57.20258				
	3	9	55.00779				
	4	9	72.95432				
	5	9	69.78618				
	6	9	48.81458				
	7	9	77.48492				
	8	9	70.3683				
3	1	9	69.24072	529.1939	0	529.1939	72
	2	9	61.92822				
	3	9	68.251				
	4	9	72.15571				
	5	9	59.9285				
	6	9	75.45334				
	7	9	74.17962				
	8	9	48.05679				
4	1	9	62.04853	421.5324	0	421.5324	72
	2	9	41.36932				
	3	9	52.76041				
	4	9	59.57806				
	5	9	56.97518				
	6	9	47.7622				
	7	9	53.2481				
	8	9	47.79061				

5	1	9	69.99798	532.2853	0	532.2853	72
	2	9	68.74262				
	3	9	57.82637				
	4	9	54.93853				
	5	9	72.58322				
	6	9	63.40647				
	7	9	63.9442				
	8	9	80.84588				

Source: Author (2021)

With a well-organized delivery system, it was possible to deliver every parcel within the 5-day limit without the need of vehicles outside the company fleet. But it is important to note that every vehicle was used, traveling approximately 500 km daily.

4.2.2 Simulation Results

The Figure 13 presents the average mileage for each scenario resulted from their respective replications. Each color is a delivery modality: traditional (blue), drone (orange), crowdshipping (gray) and parcel locker (yellow). Afterwards, the bar height is the total mileage of the scenario, while the number inside the color is the mileage of the modality. In this experiment the T0 is the main reference accounting the overall mileage, being the default delivery method applied countrywide. In a period of 90 days, nearly 64,000 kilometers was driven by the fleet to attend the demand serving as parameter to compare among the other scenarios.

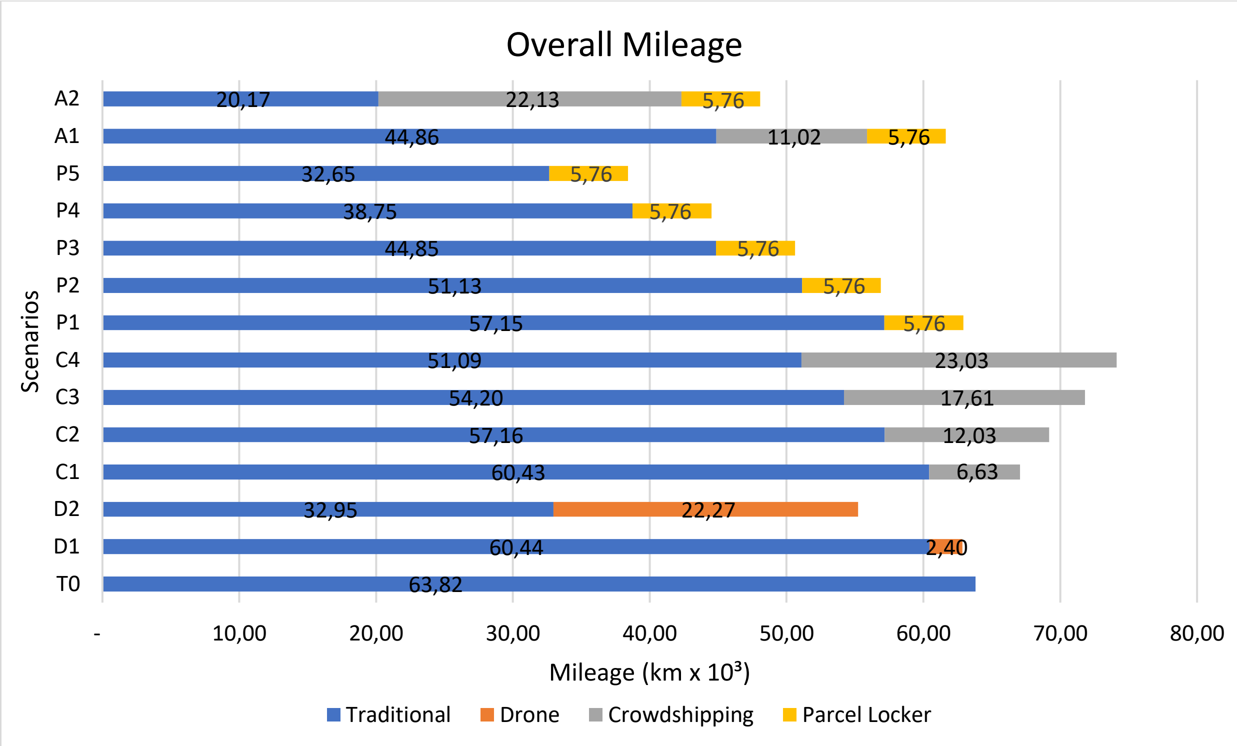

Figure 13 - Total Mileage of the scenarios
Source: Authors (2021)

For this matter, the Table 17was designed to compare the difference between the mileage of the scenarios.

Table 17 - Scenarios Results

Scenario	Traditional	Drone	Crowdshipping	Parcel Locker	Total	Difference From T0
T0	63.82	0	0	0	63.82	-
D1	60.44	2.40	0	0	62.85	-0.97
D2	32.95	22.27	0	0	55.22	-8.60
C1	60.43	0	6.63	0	67.06	+3.25
C2	57.16	0	12.03	0	69.18	+5.37
C3	54.20	0	17.61	0	71.81	+7.99
C4	51.09	0	23.03	0	74.12	+10.31
P1	57.15	0	0	5.76	62.91	-0.90
P2	51.13	0	0	5.76	56.89	-6.93
P3	44.85	0	0	5.76	50.61	-13.21
P4	38.75	0	0	5.76	44.51	-19.31
P5	32.65	0	0	5.76	38.41	-25.41
A1	44.86	0	11.02	5.76	61.64	-2.18
A2	20.17	0	22.13	5.76	48.07	-15.75

Source: Author (2021)

The scenarios with the letter D simulate how delivery drones would affect the mileage of the fleet. Even with a limited operational radius, the drone delivery of D1, which has 5% of the daily demand, managed to lower the driven distance to approximately 60,400 km. Since the batteries from drones are rechargeable, this reduction may be way more sustainable when comparing with vehicles with fossil fuels. The following scenario D2 is a totally hypothetical what if situation whereas 50% of the daily orders are handled by drones. This condition logically halved the mileage from the fleet, characterizing one of the best conditions in this research, if applicable.

On the other hand, referring to ground vehicles, one of the main reasons to adopt the crowdshipping is to take advantage of the trip of the driver that is headed to the same direction as the order's destination. Even though the scenario C1 seems disadvantageous with more than nearly 3,200 km traveled compared to T0 and both modalities are fossil fuel-dependent, consider that the trip was already planned on the driver's schedule. In this way, it can be counted as a more sustainable use of the vehicles. The same applies to C2 with a difference of 5,367.81 km, C3 with 7,989.03 km and C4 with 10,305.84 km, proportionally reducing the fleet mileage and on the other hand rising the overall distance traveled.

While still discussing about ground vehicles, the Parcel Locker scenario has an interesting feature: a single car will always travel the same route and deliver every parcel assigned. Exanimating this alternative, the P1 has a total of 62,914.02 km, which is a little advantageous, with only 10% of the daily orders are being delivered by this modality it was possible to reduce 902.40 km compared to T0. Observing P2 with 20% of the orders, the fleet's traveled distance is fairly reduced to 56,885.58 km, meaning 6,930.88 km less than traditional modality. The following scenarios reduces even more the fleet's mileage, the P3 with 30% of the orders was able to obtain a mileage of 50,610.15 km, saving 13,206.31 km. Then, P4 scenario with 40% of the daily delivery share, was capable to attend to the customers with a 19,408.46 km mark, establishing a feasible management to deliver parcels more efficiently.

In this subject, the P5 is, apparently, the best scenario in this simulation, considering only the mileage number factor, with the lower distance traveled and the same number of deliveries made. This alternative may be the best environmental choice to be made, halving the necessary fleet and accumulating 38,408 km. It means a 25,408.46 km reduction from T0. It even looks more realistic to be applied than D2, on the other hand, it is very important to make clear that Parcel Lockers have limited amount of volume, which means that not every parcel can be delivered by this method alone.

Thinking in a more feasible alternative, combining the traditional, crowdshipping and parcel locker deliveries, the A1 consists with 70% of deliveries for traditional, 10% for crowdshipping and 20% for parcel lockers. This setup mitigates the overall mileage of the fleet, gathering the parameters in order to simulate an attainable distribution of modalities, on the other hand the A2 gathers the best parameters of each approach, considering the efficiency. From cost efficiency point of view, the A2 is very promising, since it would greatly reduce the fleet daily mileage, but ideally the best configuration remains between the A1 and A2 scenarios. In these scenarios lies the great potential of this research, a balance between modalities featuring each feature in order to improve the environmental quality of the services.

More specifically, the A1 Scenario considered the minimal order percentage thinking in the modality's efficiency. Gathered, the three methods reduced 2,181.17 km from the original fleet designed on T0 and the burden of the fleet was lifted by 30% of the orders, reducing costs and developing an environmentally better condition of work.

The following A2 scenario was designed thinking the best configuration possible to reduce the overall mileage, even though it may be not possible to apply in reality. With only 30% of the orders carried by the original fleet, it would mean a 15,749.35 km reduction from the base scenario, promoting a diverse power of choice, whereas the company can take better decisions to deliver its parcels, considering the urgency, parcel weight and the client's locations, making the logistics process more efficient.

5 DISCUSSION

One of the ways to deal with the challenges of the last-mile consists of efficient delivery methods. The situation caused by the pandemics around the world impacted the e-commerce and the goods' delivery models both in big cities and smaller cities. In this context, the survey attempted to further investigate the issue by directly asking a sample of Brazilian consumers what their perception was regarding their willingness to try new delivery methods during the e-commerce high demand due the coronavirus novel. The results of the applied survey showed four consumer profiles categorized by their e-commerce usage. This way, it is possible to observe the people that never used e-commerce to acquire goods, people that used this electronic channel only before the pandemics, others that used it only after the pandemics, and lastly, the assiduous customers that bought online both before and after the beginning of the pandemic outbreak.

Most of people that never experienced an online purchase claimed that was difficult and confusing, complying with Dirgantari *et al.* (2020) research, which determined the level of use and satisfaction of e-commerce customers in the COVID-19 pandemic period with the information system success model (ISSM) approach that was formed through system quality, information quality, and service quality. Their approach formed through system quality, information quality, service quality, which proved to affect the level of usage and ecommerce consumer satisfaction, especially in the current pandemics.

When the respondents were inquired about which categories of products they acquired online, fabrics, clothing and footwear, furniture and appliance were highlighted. On the order hand, Kim (2020a) observed that even new online customers are prompted to shop online and household supplies and entertainment at home are the categories that the customers plan to spend more during the pandemics. Aligned with this research, the author analyzed the impacts of the COVID-19 on business and customers, through an analysis of the consumer behavior and how the pandemics affected consumers and marketplaces, suggesting a growth of the e-commerce, but is unlikely to cease or reduce after the COVID-19 passes.

The citizens in this paper were asked how willing they are towards using the reception boxes for their online orders, deliveries from drones and the crowdsourcing logistics, reinforcing the statement made by Ramanathan *et al.* (2014) that shows the relevance of customer feedback regarding online purchases.

Rai *et al.* (2020) analyzed how the consumers used the collection points and how they traveled to these points through street intercepted surveys. They interviewed 385 consumers in Brussels, Belgium's capital, their results show that 72.2% of consumers use collection points following an unsuccessful delivery attempt at their homes, indicating considerable inefficiencies in the last-mile, 47% of consumers use cars to claim their purchase, while 22.3% take public transport, 21.6% walk and 9.1% cycle. They also concluded that most of consumers visit a collection point within a fifteen-minute distance, generally combining other activities, like grocery shopping and running errands. The authors also found that consumers that prefer collection points are generally younger, similar to this research results, they are more frequent online shopping as well.

One of the challenges for the drone delivery is their flight limitation. Moshref-Javadi *et al.* (2020a) presented a mathematical formulation and a heuristic solution approach for the optimal planning of delivery route in a multi-modal system that uses a drone and a truck. In their system, one or multiple drones travel on the truck, serving as delivery courier person, each drove delivers a single package per dispatch, while the truck follows a multi-stop route. The authors applied theirs Truck and Drone Routing Algorithm to a real-world case of study for e-commerce delivery in the city of São Paulo - SP, Brazil. Their method may be a solution for the drones' limitations, since they can be charged on the truck while moving.

Kim (2020b) analyzed the consumer preference for drone delivery based on a survey applied to potential consumers' preference between the drone delivery service and traditional delivery services (motorcycle or truck). The author found that young people are more likely to opt for the drone delivery service than old people are, the same statement is observed in this study.

Most of answers about the implementation of crowdsourcing were positive in this study, Gatta *et al.* (2019) investigate the crowdsourcing service relying public transportation as a mean to deliver goods to customer. The author's work collaborates with a sustainable view, considering the environmental issues and avoiding possible traffic accidents. The public transportation considered were the metro lines, since it is more frequent used and reliable where this research takes place, which is Rome, Italy. They concluded that the crowdsourcing is a good delivery service in the last mile and suitable for e-commerce, obtaining the most of potential economic and environmental benefits.

In a different approach presented by Dorling *et al.* (2017), two drone delivery models were developed: the first proposes to minimize the delivery time and the second focuses on minimizing the total cost. The authors developed a Simulated Annealing algorithm to evaluate the models, adopting different travel time limits, battery consumption rates, distribution of customer location and budget limits. They concluded that additional strategies are needed to develop the model further, multi depots and recharging the drones may increase the flight duration, which could also be applicable in this study if the ANAC's regulation did not limited the flight for 2.5 kilometers (ANAC, 2017). In this simulation, the approach is more environmentally oriented, even though Dorling *et al.* (2017) also explored the traveled distance by the drone, both studies obtained positive results from the drone delivery approach for delivery. Exploring the battery consumption problem, Cokyasar *et al.* (2021) proposed by a mathematical model that considers an automated battery swapping machine in specific points between clients. Their algorithm proved to converge to optimality in a case of study in Chicago, delivering 874 packages daily. The results contribute positively towards a future use of drone delivery as a cheaper and greener alternative, which is the focus of this paper.

For this matter, Simoni *et al.* (2019) stated that even if crowdsourced delivery by car has higher negative impacts than traditional on door delivery, by limiting the deviation of crowdshippers (drivers that takes the delivery) from the planned trips, with adequate parking locations and off-peak deliveries could reduce crowdshipping externalities. Which is complements the proposition of these scenarios. In the simulation, the crowdsourced driver does note return to the DC and the usage of a family car is assumed, which mitigates the problem with parking.

Complementing, Zhen *et al.* (2021) elaborated mathematical models witch in order to analyze how different modes would affect the crowdshipping service in a case study simulation on Shanghai, China. The “assignment mode” in their study is very similar with the C scenarios, with multiple drivers taking orders and delivering to the client. The costs vary from 7.30 to 261.89 us dollars, considering the tasks are uniformly distributed on the service area. The authors approach regards the optimization of costs, although this study did not consider this variable, indirectly with less distance traveled by the company’s fleet reflects in reduction of costs.

Complemeting, Kiousis *et al.* (2019) simulation used data of DHL in Greece to assess the traffic volume and speed, estimating the environmental impacts with CO_1, NO_x and PM10 (Particulate Matter) for two scenarios, with and without locker. The authors’ base scenario considered 70 delivery stops and a fleet with 5 vehicles, assessing their delivery operation area. In their study, two lockers were proposed to store delivery parcels and the 5 vehicles on the base scenario were replaced by a single one that will deliver the parcels on both lockers and does not consider parcels over 20 kg of weight. Their approach measures a day’s worth of deliveries, considered the mileage traveled from the clients to the lockers and environmental impacts indicators. They concluded that adopting parcel lockers, 82.4% of traffic delays were reduced and 80% of vehicles of the company’s fleet are not necessary. Comparing with this study, the P5 scenario halved the fleet and also uses only one car to deliver to the lockers, on the other hand, it doesn’t replace the traditional delivery since there may be parcels with a high volume or weight that cannot be delivered by lockers, which were not considered in their study. The authors found that with lockers, the unsuccessful deliveries attempts were limited; less distance was traveled for the operator which reduces costs; more flexibility for the clients that can plan their trips to pick up their parcels with other purposes and; smart lockers are mostly located in areas served by public transport. The findings of these authors are the objectives of the scenarios with the parcel locker, but with different approaches. Kiousis *et al.* (2019) tackled the traffic organization and environmental impacts indicators while this study focuses to reduce the distance traveled and a smart use of vehicle in order to achieve a better environmental efficiency.

6 CONCLUSION

This topic gathers the conclusions of the research so far. Further investigation is necessary to achieve the goal of this study.

6.1 Survey

The pandemic forced the consumers to go virtual, increasing even more the demand of the last-mile, that was already growing rapidly on the last years. The results comply with the statement since there weren't a significant part that didn't make a purchase online yet. This research explored if the consumer of a medium-sized city in Brazil were open to experiment new ways of delivery, preparing for a post-pandemic world. The outbreak made people to adapt and make a better use of the technology available, changing the traditional way of working and most of these changes may endure after the coronavirus novel.

It was found that most of citizens have been already buying online before the outbreak, and most of those who haven't experimented yet agreed to try the e-commerce. The majority of consumers are young people, from 18 to 39 years old and have already graduated. Even though the courier provided satisfactory services, the new trends of delivery are slowly being implemented, and the popular opinion was positive towards experimenting these innovations.

With the reception boxes, the costumer may pick up the goods while returning home from work, avoiding being absent during the delivery at home, increasing the efficiency of the logistics. Regarding the drones, smaller packages can be lift and delivered at the customer's door, minimizing the gas emissions from vans and trucks. It prevents human contact, collaborating with the social distancing and performing their work. The crowdsourcing is one of the most promising solutions, since its concept is well accepted by the citizens on food delivery or ridesharing applications. It provides at the same place drivers willing to complete the delivery, the courier's services that needs to satisfy their customer and the receiver.

6.2 Simulation

This study also proposed a simulation to assess the how the emerging modalities of deliveries would be effective environmentally. Combining real-life location and data with simulation, it was possible to compare different scenarios and how it would affect the final mileage of vehicles. In most of scenarios, less mileage was traveled by the fleet and when different modalities are combined it would be possible to reduce the fuel consumption, consequently, it would also lower the CO_2 emissions with a more diversified delivery method.

About drones, the Brazilian's legislation limits the flight to 2.5 km, making it difficult to supply the demand. With a hypothetical 50% of the daily order, the milage by vehicles greatly decreases, characterizing an excellent environmental choice.

However, even though the crowdsourced vehicles seem like poor choice regarding energy consumption, its main's purpose is to take vantage of an existing route of the driver, instead of eliminating the mileage, it would make a more efficient use of the vehicle. Also, crowdsourcing services are well accepted by the Brazilian population which positively affect the consumer's choice.

Another promising idea is the Parcel Locker, considering the busy life of citizens of a metropolitan city. By placing automated lockers in metro stations, a share of online consumers can withdraw their orders in their way home while the delivery vehicle would have a fixed route that carries how many parcels are needed without the necessity of the client being present at the moment of delivery. On the other hand, the logistics may get complicated if the consumer doesn't empty the locker, causing a delivery vehicle to return the parcel to the DC. Also, there is a limited volume restriction due the fact the parcel will be stored in lockers.

Lastly, by combining crowdsourcing with parcel lockers alongside traditional delivery, the mileage can be reduced and be more environmentally efficient way, indicating a positive outcome that should inspire the practical appliance of this method. Every scenario considered in this study lowers or proposes a more efficient usage of the fleet's mileage, achieving less greenhouse effect gas emissions.

6.3 Research Limitations

Due the pandemics, a case study with a real logistics company was compromised, the author opted to create a model that mimics real-life situations based on literature. The survey was limited for the city of Campos dos Goytacazes/RJ and the simulation runs the designed scenarios, which tries to best represent reality.

This work is also limited in the scenarios approached, but new technologies and methods are being developed.

6.4 Productions Originated from this Research

The survey originated an article called “New Horizons for Last Mile Delivery After the Coronavirus Novel”, that was published on July 2nd of 2021, the journal is called “Revista Interação Interdisciplinar”, ISSN: 2526-9550, from “Centro Universitário de Mineiros” (UNIFIMES) an interdisciplinary journal.

The simulation model and results produced an article titled “Last-Mile Delivery Simulation: Drones, Crowdshipping and Parcel Locker Multi-Approach”, aimed to publish in “Journal of Business Logistics”, ISSN: 2158-1592.

6.5 Future Work Suggestions

Future works could estimate how the costs of the use of new services would affect the last-mile delivery, since they have positive results towards an eco-friendlier delivery, also, practical tests could be done to confirm the data from simulation. This research could also be extended as well by assessing drone delivery in an advantageous environment. It could also be interesting to study the battery consumption effects on last-mile delivery.

More research is required to quantify the crowdshipping collaboration towards the reduction of CO_2 emissions, since the drivers might do dedicated delivery trips and the total mileage could be significantly higher.

Currently, some e-commerce companies, and logistics operators have their own research about last-mile delivery using lockers. Thus, the proposed network may serve lots of operators and make use of these strategies. Given the background developed by this research, it can be easily replicated and applied in other cities.

Another approach that could enlighten this research is through metaheuristics. Combined with the proposed model, it would be possible to find an optimal route in different scenarios, contributing even more with less CO_2 emissions.

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APPENDIX A - DELIVERY LIMIT FROM DIFFERENT WEBSITES

Express Delivery Limit (days)	**Regular Delivery Limit (days)**	**Webpage**	**Category**
10	12	ultrafarma	Health/Cosmetics/Perfumary;
5	8	drogasil	
5	8	Onofre	
5	8	Farmadelivery	
7	12	Drogarias Raia	
6	12	Pague Menos	
7	10	Marisa	
7	12	Netshoes	
2	10	lojasrede	
5	7	farmagora	
5	9	vkmodaplussize	Fashion and Accessories;
13	17	gatza	
16	20	zattini	
4	14	zinzane	
7	13	eaquamar	
3	8	C&A	
7	10	fashionbiju	
5	16	mariacerejaacessorios	
10	13	piuka	
5	7	tinna	
7	10	dracenahome	Home and Decoration;
5	10	etna	
10	22	tokstok	
9	12	imaginarium	
10	12	hometeka	
20	23	desmobilia	
8	16	doural	
9	11	bluegardenia	
5	7	donamexerica	
8	12	mimeria	
7	11	cookeletroraro	Home Appliences;
9	17	shoptime	
4	8	colombo	

10	12	brastemp	
9	12	camicado	
9	12	novomundo	
8	11	cookeletroraro	
9	13	aramado	
9	12	magazineluiza	
8	11	efacil	
7	12	havan	Cellphones/Smartphones;
6	10	amazon	
6	17	extra	
7	10	casasbahia	
7	13	magazineluiza	
7	9	pontofrio	
5	10	multisom	
7	9	schumann	
7	17	pontofrio	
9	11	submarino	
7	10	vivo	
10	15	netshoes	Spots and Entertainment;
9	11	n10sports	
2	8	markasports	
9	11	pratiquenet	
6	11	amazon	
9	14	penalty	
10	11	centauro	
8	11	lojasradan	
4	6	lojaodosesportes	
7	10	fantasyplay	
9	14	lojaxalingobrinquedos	
7	11	firstdown	
17	19	livrariacultura	Books/Subscription/Handouts;
7	9	shopfacil	
5	7	submarino	
4	7	travessa	
7	9	bigcerebro	
8	11	nerdstore	
7	9	databinteligencia	
6	15	literarebooks	
9	13	apaginalivrarias	

14	27	livrariacrista	
7	11	Amazon	Computing;
6	18	Shopee	
1	9	pichau	
7	9	fgtec	
7	9	kabum	
7	12	pontofrio	
7	9	submarino	
7	16	shoptime	
6	8	itxgamer	
4	8	miranda	Electronics and;
8	21	gazin	
4	17	hp	
4	9	lojacasaprint	
6	11	thegames	
9	12	wolfgamesloja	
7	15	cissamagazine	
7	12	ibyte	
8	21	gazin	
4	7	crystalinformatica	
7	12	magazineluiza	Food and Drinks.
7	15	americanas	
7	10	emporiodacerveja	
11	13	doceefesta	
7	20	tendaatacado	
6	9	chocofesta	
7	9	submarino	
23	29	bemol	