ARTICLE

Artificial Intelligence Applied to Assess Perceptions of the Quality of E-Commerce Logistics: Case Study of Rio de Janeiro

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ABSTRACT

The COVID-19 pandemic imposed many market changes, driven partially by new consumer needs. In the electronic commerce field, changes occurred in parallel to an upsurge in demand, directly impacting logistics service quality. Within that context, this paper seeks a way of assessing the quality of e-commerce logistics, based on end-customer perceptions at the close of the purchasing cycle. The objective is thus to develop a mathematical model based on the artificial intelligence precepts that can interpret qualitative expressions captured through a questionnaire. Such values form partial indexes and the E-Commerce Logistics Quality Index (IQLE). After processing 180 records, it was noted that three of the seven analyzed attributes scored below 5.0, denoting some concern, but also opening up opportunities for improvement and the development of marketing solutions.

KEYWORDS

Logistics, E-commerce, Artificial Intelligence, IQLE

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Inteligência Artificial Aplicada para Avaliação da Percepção da Qualidade da Logística do *E-Commerce*: O Caso do Rio de Janeiro

RESUMO

É fato que com a pandemia da COVID-19 ocorreram muitas mudanças de mercado, em parte, impulsionadas pelas novas necessidades dos consumidores. No âmbito do comércio eletrônico, as mudanças aconteceram em paralelo com o aumento rápido de demanda, impactando diretamente na qualidade do serviço logístico prestado. É nesse contexto que este artigo busca desenvolver uma forma de avaliar a qualidade da logística do *e-commerce,* baseando-se na percepção do cliente final ao final do ciclo do pedido. Para tanto, objetiva-se desenvolver um modelo matemático, baseando-se nos preceitos da inteligência artificial, que possa interpretar expressões qualitativas, capturadas por intermédio de questionário, transformando-as em valores quantitativos, passíveis de análise no mundo real. Tais valores formam índices parciais e o IQLE (Índice da Qualidade da Logística do *E-commerce*). Após o processamento de 180 registros, observou-se que dos sete atributos analisados, três deles redundaram em nota abaixo de 5,0, denotando certa preocupação, mas oportunidade de melhora e desenvolvimento de soluções mercadológicas.

PALAVRAS-CHAVE

Logística, E-commerce, Inteligência Artificial, IQLE

1. INTRODUCTION

There is no denying the importance of technology for most people in their daily lives. During the COVID-19 pandemic, its importance became clear for shortening distances in human relationships, and, above all, for obtaining goods through electronic commerce, better known as e-commerce.

At the start of the purchasing cycle, after the customer places an order, logistics comes into play, providing operational support for the activities needed to convey the goods to their destination: the end-customer.

It should be noted here that these activities are underpinned by planning, operations, and control of the entire cycle, streamlining flows of data and goods, and extending beyond aspects linked to mere physical movements. Consequently, in order to keep service levels up to contracted quality, a systemic overview is needed, that encompasses inventory management and compliance with requirements established for storing, handling, and packing goods, all focused on customer satisfaction.

A satisfied customer implies better possibilities of repeat purchases, building up customer loyalty. Along these lines, it is cheaper to build up loyalty than to attract new buyers. Furthermore, building loyalty may also underpin inflows of new purchasers, through word-of-mouth recommendations.

After goods are delivered to buyers, many after-sales actions are required in the e-commerce field, particularly should any adverse events occur, that might undermine trust in commercial relationships.

In this context, the importance of a systemic overview of the entire process is needed, because any unsuitable action may have negative effects on pre-established service levels. It is thus understood that the ripple effect of these impacts will affect the recipients of e-commerce services.

In order to monitor the many activities involved in complex logistics, it is understood that each of them must be controlled, as well as checking impacts on end-customers, comparing their perceptions with specified quality standards at the end of the purchasing process.

This is the aspect addressed by this paper, due to the possibility of contributing to the uptake of end-customer impressions of e-commerce logistics service quality at the end of the order cycle. The question arises here: is it possible to measure these customer perceptions accurately, establishing a database steering subsequent decisions?

To do so, attempts were made to develop a mathematical model based on artificial intelligence precepts that could interpret qualitative expressions learned from questionnaires completed by end-customers, transforming them into quantitative values that can be analyzed in the real world.

This is where the relevance of this paper lies, identifying effects that are certainly related to underlying cause(s). This is a crossroads between cause and effect, with this connection underpinned by the need for control, justifying measurement systems: "*if you can't measure it, you can't manage it, you can't define what you don't understand, there's no success that's not managed.*" (Deming, 1990)

It is also a fact that customer perceptions may indicate quality standards for planning, designing and operating purposes (Rodrigues, 2006), converging on a management mindset that places the customer as the main focus of organizations. Customers are understood through the use of more accurate tools, as pursuing their satisfaction is not an option, but rather a matter of survival for any enterprise. Their satisfaction is the result of foreseeing their needs and exceeding their expectations, both implicit and explicit, and should be a corporate *raison d'être*. (Cordeiro et al., 2005)

2. METHODOLOGY

According to Prodanov and Freitas (2013), the research conducted for this paper may be divided into four aspects: nature, objectives, technical procedures, and approach to the problem.

In terms of its nature, this research is rated as applied, as it strives to generate knowledge for developing a mathematical model that will provide input for drawing up e-commerce logistics ratings, with practical applications for solving problems, with a case study examining the City of Rio de Janeiro.

In terms of the main objective of this paper, it is firmly linked to a case study for testing and validating a mathematical model. The research is classified as exploratory, providing a diagnosis of e-commerce logistics through collecting data from a survey of end-customers. Along these lines, it is also viewed as explanatory research, as it is designed to underpin the development of a monitoring system, linking causes and effects through registering, analyzing, and classifying researched data.

The technical procedures used in this study are related to the modeling process and data collection for its validation. The following aspects are noteworthy:

- Data were collected through a survey with direct questions completed electronically over the internet by end-customers. The method used was a survey, with questions on customer characterization, followed by specific questions with replies based on Likert scales. To do so, a sample was defined through statistical procedures;
- Next, the collected data were run through quantitative analysis, divided into four parts: respondent characteristics; average order profile; end-customer perceptions of logistic services; and end-customer perceptions of services after closing the deal;
- The mathematical model processing data collected during the survey used a hypothetical-deductive approach to identify other information relevant to the e-commerce logistics analysis, such as the E-Commerce Logistics Quality Index (IQLE) developed by the Getulio Vargas Foundation (FGV), and its partial ratings. This is considered as the model validation phase;
- This is an *ex-post-facto* survey, meaning after the fact (receipt of the purchased goods), as the collected data reflect end-customer experiences under certain everyday conditions, for explaining and understanding this experience in terms of a logistics quality profile.

With regard to the approach to the problem, this research project is characterized as qualitative + quantitative, meaning: it is qualitative, because there is a dynamic link between Logistics activities in the real world and the subject (the end-customer), forming an unbreakable connection between subjectivity and objectivity; it is quantitative, through translating customer perceptions by means of the mathematical model, giving rise to numerical data and information used to classify these perceptions and analyze them.

Consequently, it is understood that the following steps should be followed in order to reach this objective:

1. As an exploratory survey, the following aspects must be characterized:
    a. Attributes are related to the mean profile of the orders, perceptions of logistics services, and after-sales services once the purchased goods are received;
    b. Under these attributes, qualitative data are recorded representing subjective aspects of user perceptions.

2. For modeling the data collection and processing system:
    a. Preparation of a data collection questionnaire, requesting qualitative replies for each attribute;
    b. Characterization of attributes as entry variables (Fuzzy variable format), defining the pertinent functions associated with each linguistic label (qualitative reply) mapped out within a specific discourse universe;
    c. Modeling the attributes according to Fuzzy Integer precepts;
    d. Characterization of the output variables constituting the IQLE, based on Fuzzy Integers;
    e. Data processing and analysis, converted into information.

3. THEORETICAL FRAMEWORK

3.1. Remarks on E-commerce Logistics

Usually shortened to e-commerce, electronic commerce is a type of trade using electronic devices and the internet as a channel for accessing virtual stores.

Dating back to the 1970s with Michael Aldrich, the popularity of e-commerce was strongly leveraged in 1995 with the arrival of Amazon, soon becoming a core sector of the world economy as globalization spread. Consisting of inter-organizational data systems, this type of trade allows buyers and sellers to exchange goods and data, related mainly to buying, selling, ordering and paying transactions, in addition to after-sale services after the receipt of purchased goods. (Pereira & Pereira, 2020)

As societies shut down during the COVID-19 pandemic, e-commerce became a vital tool for the survival of the retail sector, due to plummeting demands at brick-and-mortar stores, with some of them shutting down. This process triggered an upsurge in access to portals that were already in place, forcing entrepreneurs to adapt rapidly to this new context.

In order to offer a better idea of this sudden change, an article published in the *e-commercebrasil* portal estimated that the pandemic shoehorned five years of digitization into just a couple of months in Brazil, as Brazilian online buyers soared from 35% to 57%. This expansion may be affecting the post-pandemic world, with 55% of consumers in Brazil stating that they intend to continue buying over the internet. (*E-Commercebrasil,* 2021)

Fueled by the need to keep the economy turning over, e-commerce became the main tool for buyers to access consumer goods. In its wake, some subsystem upgrades were needed, prompted by greater market awareness of demands for good quality products and services, in parallel to keener competitive edge in all niches. Noteworthy among them are aspects related to electronic security for internet communications, storing data in the cloud, marketing structures for end-customers and, above all, for logistics operations.

Earlier studies have indicated a concern with logistics activities, which influence e-commerce quality as perceived by end-customers. Particularly noteworthy among the approaches adopted during the pandemic are those adopted by Guimaraes Junior et al. (2020) using SERVPERF modeling to process data from 249 consumers; the study by Rachmawati et al. (2020) using descriptive research with 546 users of the Shopee platform to analyze the impacts of logistic service quality on customer satisfaction and loyalty, using the structural equations modeling method provided by the LISREL software; Vasić et al. (2021) affirm in their study that customer satisfaction in the e-commerce sector depends directly on eight aspects of logistics services. They used a model based on Confirmatory Factor Analysis (CFA) and Partial Least Squares method (PLS) to process the data collected from 425 e-commerce customers.

In order to explore how important this issue is over time, even prior to the pandemic, studies explored the need to upgrade e-commerce logistics quality. Although recent, the study by Gajewska et al. (2020) did not include the influences of the pandemic, instead focusing on e-commerce service quality criteria, particularly within a specific ranking of importance assessed through the Servqual method. Using an empirical approach, Hua and Jing (2015) sought explanations for the main logistics factors affecting customer satisfaction with e-commerce. Lin et al. (2016) address quality factors influencing customer satisfaction from three standpoints: the logistics provider, the retailer, and the customer; Davidavičienė and Meidutė (2011) noted service efficiency as a key quality measurement factor for consumer satisfaction, encompassing logistics quality assessment criteria and considering specific aspects of consumer behavior. Finally, Yang et al. (2006), analyze and assess e-commerce services in general in order to propose a quality assessment measurement system in four aspects, one of which is logistics; Ballou (1992, p. 5) adopted the convergence of logistics attributes for customer services, based on the 7 Rights of Logistics: getting the Right Product, in the Right Quantity, in the Right Condition, at the Right Place, at the Right Time, to the Right Customer, at the Right Price.

3.2. Customer Satisfaction Approach

Perceptions of logistics service quality are a noteworthy and also determining factor, to some extent, for assessing e-commerce performance. However, dealing with human "perceptions" requires a subjective approach, attempting to indicate customer expectations and needs, as a springboard for building up loyalty-based market relationships.

Consumer satisfaction is closely linked to opinions on services rendered. This means that the higher the chances that expectations and needs are met, the higher the perceived quality.

As mentioned in Fonseca and Borges (2002) Anderson et al. (1994) stress that user satisfaction is affected by three preceding factors: perceived quality (current system performance assessment); price (perceived value); and expectations. In this paper, logistics quality must be reflected through customer perceptions after the service is rendered.

More pragmatically, some studies attempt to approach the customer satisfaction view in terms of perceived quality; it is thus worth listing some of them here:

- De Albuquerque (2019) offers an analysis of attributes related to customer satisfaction, focusing on the link between customer satisfaction and product or service performance. He mentions that some product/service attributes boost customer satisfaction significantly, in counterpart to others that make little difference;
- De Farias and De Oliveira (2020) analyzed quality assessment models, underscoring the 5 Gaps designed to help managers understand the origin of service quality problems, reflecting

differences between the expected service and the received service; the Servqual is located in the gaps left by the previous model, assessing service quality through differences between expectations and performance in five dimensions; and the Kano system that ranks product/service attributes by satisfaction or dissatisfaction with the performance level;
- Soares and De Oliveira (2019) strive to rank carwash service attributes in order to estimate the trustworthiness of functional/dysfunctional questions, together with satisfaction/dissatisfaction coefficients, while measuring customer satisfaction levels by the Kano System;
- Dias (2018) addresses the Kano model by proposing a practical application identifying major quality attributes, indicating the requirements that could potentiate customer satisfaction.

It is understood that perceived qualities are associated with the attributes representing them. Among those most widely studied are the related triad of quality x logistics x e-commerce, listed in Table 1 below.

In brief, based on the attributes listed in Table 1, the following descriptions may be reached for each attribute:

Trustworthiness: customer analysis of what was contracted and what was effectively rendered;

- Speed: fast delivery, minimizing time variations;
- Empathy: service provider stance when servicing the customer with care, in an individualized manner;
- Flexibility: able to adapt processes to customer needs;
- Accessibility: ease in accessing information during and after the transaction;
- Availability: records of constant customer care from the company;
- Tangibility: presentation of the company with material physical evidence of rendering the service.

Table 1

Equivalent Trapezes and Levels of Importance of Attributes

Attributes	A	B	C	D	E	F	G
Trustworthiness	x	x	X	x	x	x	x
Speed					x		x
Empathy	x				x		x
Flexibility	x	x	X	x			x
Accessibility					x		x
Availability					x	x	x
Tangibility	x						x

Sources: A - Tontini and Zanchett (2010); B - Porto et al. (2019); C – Maia et al. (2019); D – Lara et al. (2020); E - Marchesini and Alcantara (2012); F – De Barros (2016); Ballou (1992, p. 5)

3.3. Artificial Intelligence and Fuzzy Theory

Artificial Intelligence is addressed as a set of techniques applicable through computer systems that are related to intelligent human behavior. Noteworthy among these techniques is Fuzzy Logic (Lopes et al., 2014; Bittencourt, 2001) whose starting point was the paper by Zadeh, published in the Information and Control journal in 1962 (Volume 8, page 338 - 353). (Tanaka, 1997)

For a certain discourse universe, in a crisp dataset considering only binary values (0 or 1), the variation is sharp. However, under the same condition, the transition is taken at a subjective border for a certain Fuzzy dataset element, where this element might or might not belong to this dataset. Ross (1995)

The level to which elements belong to a Fuzzy dataset is thus represented by the Pertinence Level for a certain discourse universe X = {x_1, x_2,..., x_n}. The relationship among the discourse universe elements and pertinence levels [0,1] is expressed through pertinence function *A*, which may be discrete or continuous, according to expressions 1 and 2, respectively. In them, $\mu_A(x_i)$ is considered the pertinence level of element i, x_1 is the value of element i in discourse universe X. (Tanaka, 1997)

$$A = \mu_A(x_1)/X_1 + \mu_A(x_2)/X_2 + \ldots + \sum_{i=1}^{n} \mu_A(x_i)/X_i \quad (1)$$

$$A = \int_x \mu_A(x_i)/X_i \quad (2)$$

Fuzzy datasets A and B may be processed through Union $A \cup B$ (3) and Intersection $A \cap B$ (4), resulting in a third Fuzzy C dataset. The pertinence of the Fuzzy C dataset results from the union obtained through the expression (5); for the intersection (6) is used. (Tanaka, 1997)

$$\mu_C(x) = \max(\mu_A(x), \mu_B(x)) = \mu_A(x)\, OU\, \mu_B(x) = \mu_A(x) \vee \mu_B(x) \quad (5)$$

$$\mu_C(x) = \min(\mu_A(x), \mu_B(x)) = \mu_A(x)\, E\, \mu_B(x) = \mu_A(x) \wedge \mu_B(x) \quad (6)$$

A linguistic variable in any Fuzzy dataset must be represented by its linguistic terms, which reflect its pertinence functions. For continuous datasets, this variable may be represented by a Fuzzy Integer, as shown in (2). (Sucena & Andrade, 2021) Shaw and Simões (1999) mention that pertinence functions may be developed on the basis of the analyst´s experience and/or the process under analysis. The authors also stress that a Fuzzy variable must have between 2 and 7 functions, with more functions leading to more accurate findings and heavier computer demands, but with greater interpretation difficulties for analysts.

A Fuzzy number is an algebraic representation of a subsidiary Fuzzy dataset, a mathematical artifice used to represent subjective or vague situations. The formats most commonly used are triangular and trapezoid (Figure 1). (Sucena & Andrade, 2021)

As noted in Sucena and Andrade (2021), two Fuzzy numbers Aa = (a1,a2,a3,a4) and Ab = (b1,b2,b3,b4) may be processed through simple arithmetical operations. Expressions (7) to (12) indicate the most common of them.

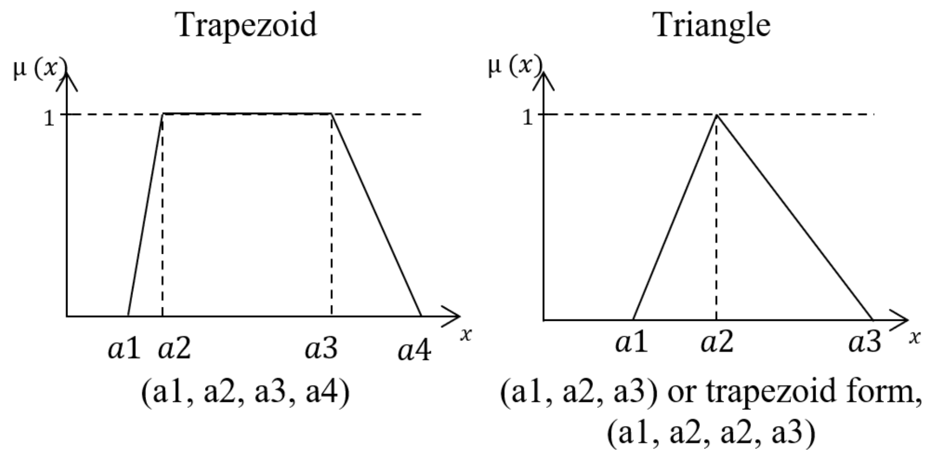

Figure 1. Examples of numbers
Source: (Sucena & Andrade, 2021)

Addition: $Aa \oplus Ab = \{a_1 + b_1, a_2+b_2, a_3+b_3, a_4+b_4\}$ **(7)**

Subtraction: Aa ! Ab = $\{a_1 - b_4, a_2-b_3, a_3 - b_2, a_4 - b_1\}$ **(8)**

Product: $Aa \otimes Ab = \{a_1.b_1, a_2.b_2, a_3.b_3, a_4.b_4\}$ **(9)**

Division: Aa % Ab = $\{a_1/b_4, a_2/b_3, a_3/b_2, a_4/b_1\}$ **(10)**

Product of an *n* scale: $n.Aa = \{n.a_1, n.a_2, n.a_3, n.a_4\}$ **(11)**

Division by an *n* scale: $Aa/n = \{a_1/n, a_2/n, a_3/n, a_4/n\}$ **(12)**

Applications using Fuzzy numbers are versatile, useful for analyzing problems involving perceptions, uncertainties and performance and quality assessments. Using Google Academic as a basis, with “Fuzzy numbers” as the search keyword, 264 studies were located. Using the same keyword and adding “Perception” this resulted in 108 studies; with the “Quality” keyword, 185 works were listed.

Consequently, it is valid to stress some of these studies, such as Pinho et al. (1997), associating Fuzzy numbers with Games Theory for uncertain decision processes for analyzing investments; Montevechi and Pinho (1999), addressing uncertainties in production flow-shop operations programming, based on triangular Fuzzy numbers linked to the NEH algorithm; Almeida et al. (2010), exploring how entrepreneurs perceive environmental sustainability actions; Sá et al. (2007) also used triangular numbers to interpret consumer perceptions; Boente et al. (2009), assessed software quality for products developed in a state government foundation; Ibáñez (2018), observed Fuzzy Boundary Value Problems (FBVPs), focused on dataset theory precepts and Fuzzy numbers; and Silva (2020), working with dataset operations using Fuzzy numbers in a government-run middle school.

Another way of dealing with subjective sentences is through the use of Fuzzy Logic, whose inference between the Fuzzy datasets uses an *if-then* form that results in linguistic vector Ã, like $\{\frac{\mu(x)_1}{Label1}+\frac{\mu(x)_2}{Label2}+\frac{\mu(x)_3}{Label3}\}$, exemplified in this case by three pertinence functions with linguistic labels 1 – 3 and their activated pertinence levels. This vector represents a distribution of possibilities of a specific condition, analyzed in a specific Fuzzy dataset. (Oliveira Jr., 1999; Ross, 1995)

Based on the above-mentioned Fuzzy vector, it is then possible to return to the crisp domain (defuzz), underpinning the feasibility of the analyst understanding the extent of the real implications of the inference. Shaw and Simões (1999) stress that there are several methods for returning to the crisp domain, after which the real-world context of the decision may be modified. One of the most common defuzzification methods is the Center-of-Maximum (13) which represents a weighted average of the pertinence levels (μ_i) by the crisp entries X_i, with i being the quantity of linguistic variables, varying from 1 to n (quantity of linguistic variables).

$$Output_i = \frac{\sum_{i=1}^{n} \mu_i \times X_i}{\sum_{i=1}^{n} \mu_i} \quad (13)$$

4. MODELING INPUT AND OUTPUT VARIABLES

The input variables for the mathematical model are obtained from an investigation of the literature in sub items 3.1 and 3.2, which relate pertinent attributes to logistics quality assessment, focused on e-commerce. It should be stressed that the attributes are observed from the end-customers standpoint after purchases have been made through the internet.

The analyzed studies indicate a broad range of attributes, many of them with redundancies, despite different nomenclatures. This is why the Ballou (1992, p. 5) approach was selected, as it includes the logistics mission represented by the 7Rs, which are modeled in this sub item by Fuzzy Theory precepts.

Consequently, the attributes described below are used in this project:

1. Right Product – ability to deliver the order as specified on purchase.
2. Right Quantity – ability to respond to requests for quantities of the ordered item in full, due to either damages to part or all of the item, or through a reduction in the quantity of the item recorded in the order.
3. Right Time – this refers to the order cycle time variability, from placing the order through to effective delivery to the end-customer.
4. Right Condition – this is the ability to deliver the order faultlessly, with no defects or damage during storage and/or transportation.
5. Right Customer – condition of delivering the order to the end-customer as specified during the act of purchase.
6. Right Place – this refers to the condition of delivering the order at the place specified during the act of purchase.
7. Right Price – this reflects the balance between the shipping charged and the amount added to the order, and the delivery time.

In order to generate the IQLE and its partial ratings, a Fuzzy variable was created for each reply to the questionnaire, representing each of the 7Rs. Furthermore, end-customers were asked about the importance of each of the attributes, in terms of their importance.

Five pertinence functions were qualified, identified by labels or linguistic terms as being "very dissatisfied", "dissatisfied", "neutral", "satisfied" and "very satisfied", recorded according to their respective Fuzzy Integers, developed as set forth in expression 2, resulting in Equations 15 to 19 for a certain discourse universe X => [0,10], in which 0 is the worst rating, meaning the "very dissatisfied" label.

$$\mu(x)_{very\ dissatisfied\ (EI)} = \int_{0\to1}^{1\to0} -x+1/X \quad (15)$$

$$\mu(x)_{dissatisfied\ (IN)} = \int_{0\to0}^{2\to1} \frac{x}{2}/X + \int_{2\to1}^{3\to1} 1/X + \int_{3\to1}^{5\to0} \frac{-x+5}{2}/X \quad (16)$$

$$\mu(x)_{neutral\ (NE)} = \int_{4\to0}^{5\to1} x-4/X + \int_{5\to1}^{6\to0} -x+6/X \quad (17)$$

$$\mu(x)_{satisfied\ (SA)} = \int_{5\to0}^{7\to1} \frac{x-5}{2}/X + \int_{7\to1}^{8\to1} 1/X + \int_{8\to1}^{10\to0} \frac{-x+10}{2}/X \quad (18)$$

$$\mu(x)_{very\ satisfied\ (ES)} = \int_{9\to0}^{10\to1} x-9/X \quad (19)$$

The replies to each item in the questionnaire were aggregated in the Fuzzy Integers, using trapezoidal arithmetical operations as shown in expressions 7 to 12, representing a consensus of the respondents, which also encompasses the level of importance of each one of the 7Rs for each end-customer. The outcome is expressed as a Fuzzy Ã vector, as presented in Ross (1995), according to expression 20.

$$\tilde{A} = \left\{ \frac{\mu(x)_{EI}}{EI} + \frac{\mu(x)_{IN}}{IN} + \frac{\mu(x)_{NE}}{NE} + \frac{\mu(x)_{SA}}{SA} + \frac{\mu(x)_{ES}}{ES} \right\} \quad (20)$$

Next, using expression 4, the Fuzzy datasets were united, represented by each pertinence function of "very dissatisfied", "dissatisfied", "neutral", "satisfied" and "very satisfied". Through these results, it is possible to move from the Fuzzy domain into the crisp area, through the application of equation 13. This result constitutes a partial indicator for each one of the 7Rs. When all of them are aggregated, they result in the IQLE, which represents a consensus on end-customer perceptions, also within the discourse universe [0,10].

In brief, the procedure for defining the partial indicators is shown in Figure 2, as well as the IQLE.

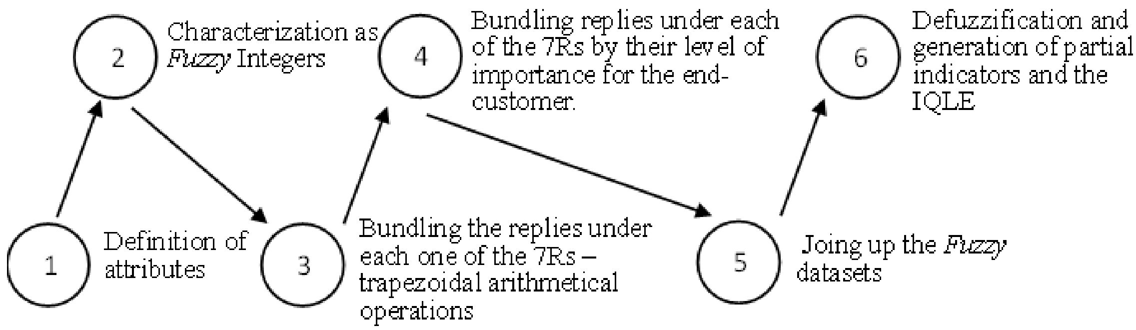

Figure 2. Methodological Procedure Adopted for Modeling
Source: The Authors (2021)

5. APPLICATION OF THE MODEL

5.1. Data Collection

The extensive, direct observation survey conducted to obtain quality on perceived data uses a questionnaire accessed via the internet, with multiple-choice, closed, and opinion questions. Each respondent was characterized through questions identifying their profiles, but with no identification by name or any other information. Questions focused on purchases and other questions specific to logistics. All the questions generated metrics associated with e-commerce logistics quality attributes.

For the City of Rio de Janeiro, 180 replies were collected for the composition of the IQLE, from October 4 – 20, 2021. The respondents were characterized in four questions: age bracket, education level, gender, and the city where they received most of their internet purchases.

The general profile of their orders was also established through the questionnaire, examining order frequency, mean product quantity, main (most frequent) delivery company, and mean shipping cost.

In order to rate e-commerce logistics quality, each of the 7Rs was used, representing attributes reflecting their mission. The same number of questions was also used to explore the importance of each one of the seven attributes for end-customers.

5.2. Data Processing

As noted in the methodological procedure Illustrated in Figure 2, Step 1 defined the attributes (subitem 3.1); and in Step 2 they were modeled as Fuzzy Integers, as presented in item 4. Aggregating the end-customer replies (Step 3) was handled through trapezoidal arithmetical operations, resulting in the registration of the equivalent trapezes. These trapezes are linked to attribute levels of importance (Step 4) from the customer standpoint. Table 2 presents the results of the last two steps.

Step 5 of the methodological procedure is rooted in the need to bring the Fuzzy datasets together, represented by a Fuzzy vector (expression 20) for each attribute. The results are presented in Table 3.

Table 2
Equivalent Trapezes and Levels of Importance of the Attributes

Attributes	Equivalent Trapezes	Levels of importance (normalized)
Right Product	(5.78, 7.35, 7.96, 9.28)	0.80
Right Quantity	(5.82, 7.36, 7.92, 9.18)	0.72
Right Time	(5.27, 7.83, 7.42, 8.78)	1.00
Right Condition	(4.31, 5.35, 5.64, 7.37)	0.61
Right Customer	(5.47, 7.01, 7.58, 8.90)	0.55
Right Place	(5.62, 7.21, 7.82, 9.17)	0.50
Right Price	(3.90, 5.35, 5.84, 7.20)	0.62

Source: the authors (2021)

Table 3
Fuzzy Vectors for each Attribute

Attributes	Fuzzy vectors
Right Product	$\{\frac{0}{EI}+\frac{0}{IN}+\frac{0}{NE}+\frac{0,56}{SA}+\frac{0}{ES}\}$
Right Quantity	$\{\frac{0}{EI}+\frac{0}{IN}+\frac{0,55}{NE}+\frac{0,22}{SA}+\frac{0}{ES}\}$
Right Time	$\{\frac{0}{EI}+\frac{0}{IN}+\frac{0}{NE}+\frac{1,00}{SA}+\frac{0}{ES}\}$
Right Condition	$\{\frac{0}{EI}+\frac{0,84}{IN}+\frac{0}{NE}+\frac{0}{SA}+\frac{0}{ES}\}$
Right Customer	$\{\frac{0}{EI}+\frac{0,52}{IN}+\frac{0}{NE}+\frac{0}{SA}+\frac{0}{ES}\}$
Right Place	$\{\frac{0}{EI}+\frac{0,62}{IN}+\frac{0}{NE}+\frac{0}{SA}+\frac{0}{ES}\}$
Right Price	$\{\frac{0}{EI}+\frac{0,78}{IN}+\frac{0}{NE}+\frac{0}{SA}+\frac{0}{ES}\}$

Source: the authors (2021)

5.3. Findings and Analysis

Designed to collect mathematical data for testing and validating the model, the survey begins by characterizing respondent profiles, expressed through gender, age bracket and education. The findings are presented in Figure 3.

Next, the order profile was explored. It was noted that just over a third (36.7%) of them purchased at least once a month, with a mean of 1 product ordered each month (51%) and free shipping (40.6%). In addition to the five main shipping companies mentioned by the respondents, these three attributes are shown in Figure 4.

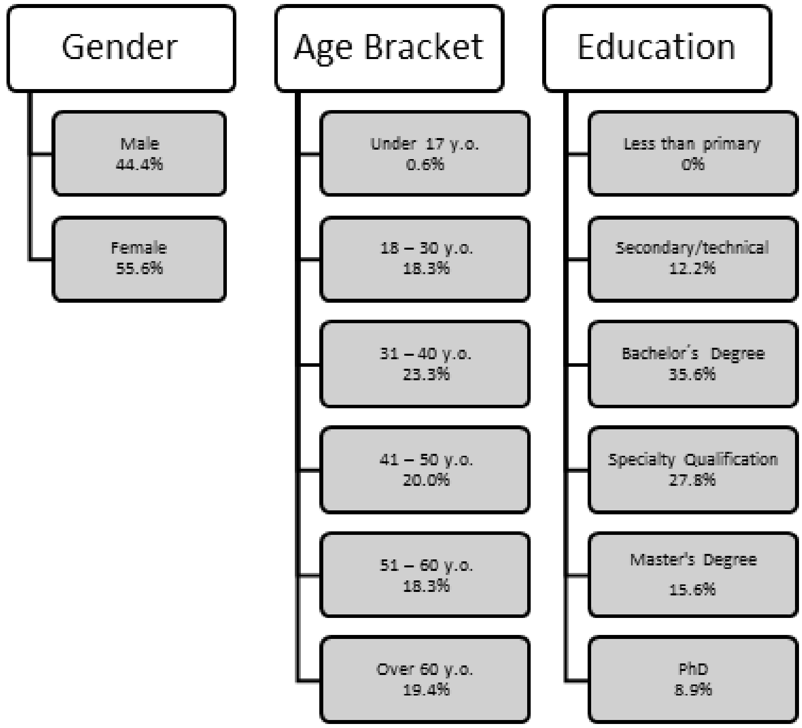

Figure 3. Respondent Profiles
Source: the authors (2021)

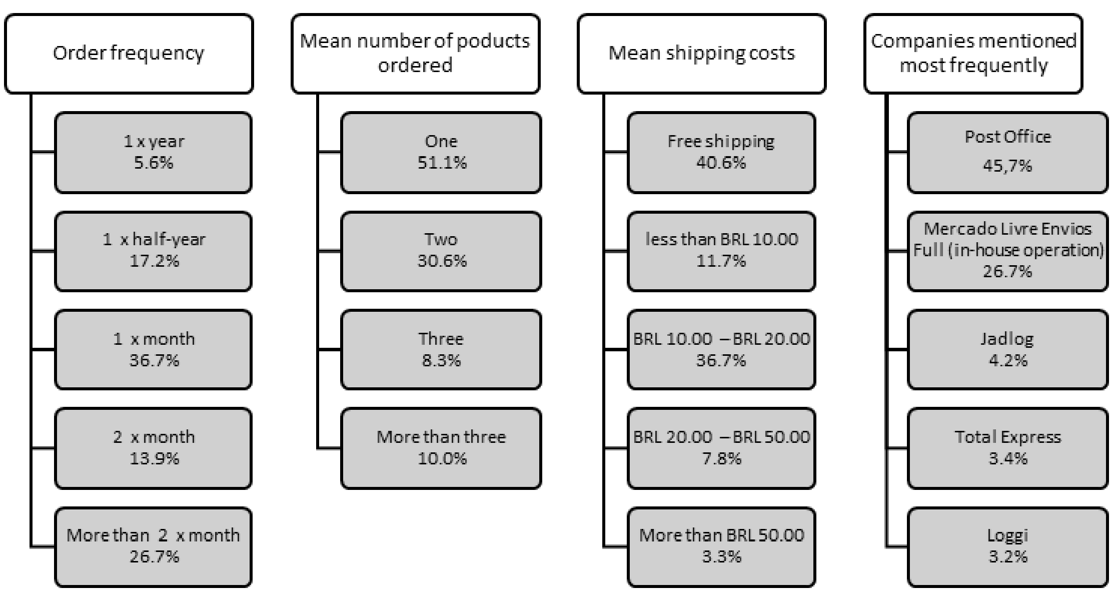

Figure 4. Order profile
Source: the authors (2021)

As shown in Figure 2 Step 6 (methodological procedure) pursues the objective of this project, recording the need to interpret end-customers perceptions through developing a mathematical model. Partial ratings were defined, based on the 7Rs, which represent the quality of logistics providing operational support for e-commerce, and leading to the IQLE value (Figure 5). The outcomes of these ratings are listed in Table 4.

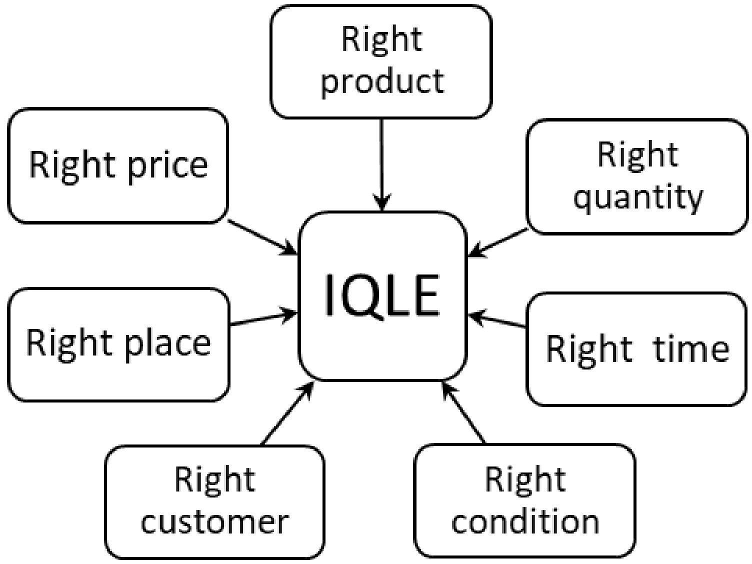

Figure 5. Partial Ratings and IQLE
Source: the authors (2021)

Table 4
Results for Partial Ratings and IQLE

Attributes	Partial Ratings
Right product	6.12
Right quantity	5.45
Right time	7.09
Right condition	3.31
Right customer	3.96
Right place	3.76
Right price	3.44
IQLE	**4.80**

Source: the authors (2021)

The survey also asked about the main delivery company used for most of the orders placed by each respondent. It was noted that competition is heating up on the e-commerce logistics market, due to new arrivals, with current contenders upgrading their services. This has undermined the prevalence of the Brazilian Post Office (*Correios*) which is nevertheless a major player with 55% of deliveries, followed by the local E-Bay subsidiary delivery service (*Mercado Livre Envios Full*) at 32%. This aspect is forcing players to engage in ongoing analysis and constant modifications and innovations in their business procedures.

With a market share over 80% held by just two shippers, the survey collected replies from customers on the seven attributes, in order to define the logistics services profile from the end-customers standpoint. The data presented in Table 4 show that four of the seven attributes analyzed are scored at less than 50% on the scale, indicating that there is still significant headroom for improvement in e-commerce services in Rio de Janeiro, in the view of the end-customer.

In addition to the quality of wares acquired through electronic channels, which is not dependent on logistic services, it is a fact that storage and packaging for shipping may affect the "Right Condition" attribute, which scored 3.13.

In storage facilities, the selection of the floorplan for optimizing space and protecting goods may interfere in the handling and integrity of these loads. For example, for perishable goods, attention must be paid to use-by date, lighting, temperature, moisture, and other aspects. The use of Warehouse Management System (WMS) platforms may offer substantial upgrades in cargo protection.

While packaging is designed to protect products and ensure their integrity, there are other aspects that may intervene, as seen by customers, as this is where they first come into contact with the logistics outcomes. This also reflects indications of care and trust in people shipping the product, and may constitute a comparative advantage in terms of the competition. This can also buttress brands through upgrading their visual identity.

The score for the "Right Customer" attribute was also unsatisfactory at 3.96. It is not uncommon for problems to arise at the start of the order cycle, when keying in delivery address information and recipient data, which may be different from the person actually making the purchase.

For example, one of the fields in the destination address is the ZIP code (CEP) which may also affect the "Right place" attribute. This information may have negative effects on cycle times, in addition to stepping up losses through deliveries to the wrong recipients (at the wrong addresses). In order to minimize this problem, there are computerized platforms that compare a ZIP code to the address keyed in by an end-customer, or even simple solutions that allow automatic completion (and not alteration) of the street data, when keying the ZIP code at the top of the form.

Also scoring around 3 points is the "Right price" attribute, at 3.44. Defining shipping prices at competitive levels is challenging for the logistic system. To do so, several factors are taken into consideration, including the ZIP codes of the sender and the recipient, as well as the cargo characteristics (cubic measurement – load mass x packaging volume, perishability), the added value of the wares, and others.

Along these lines, it is a fact that fractional freight, for example, is one of the factors that increases the price. A possible strategy is known as fulfillment, which encompasses the complete cycle through centralizing inventories from several product suppliers, with shorter separation and preparation (picking) times for orders within the cycle, as well as quicker packaging. This strategy may be adopted by the marketplace, which handles the inventory management and delivers goods to end-customers, which affects the ease of managing the inventory, with better adjustments between demands and capacities.

In this evolving process, it is appropriate to mention e-fulfilment, which includes marketplace integration strategies with back-office actions linked to marketing, sales and finance, as well as the entire logistics process. In this area, information technologies play a leading role, connecting up links in logistics chains and the many different actors involved, with better synchronized flows of goods and data.

The "Right Time" is the attribute with the highest score (7.09) mentioned by end-customers. It appears that companies are meeting their delivery deadlines in terms of variability, with better processes for managing flows of information and goods. They begin with the preparation, transmission, and processing of an order, encompassing inventory management, synchronized operations with suppliers, separating and packing the goods and hand-over to shippers for final delivery, with many variables related to physical and informational aspects that intervene in this issue, but are not visible to customers.

The attribute with the second-highest score from end-customers (6.12) is the “Right Product”. This scores compliance with the items selected for purchase. Very close to 50% on the measurement scale is the “Right Quantity” attribute, at 5.45 points. Which includes questions related to the overall quantities ordered.

The 7Rs rating focuses on the logistics mission; however, for e-commerce, this may underpin excellence in services rendered, with enhanced possibilities of boosting customer loyalty, which in turn contributes to upgrading the entire business.

It is noted that even considering specific scores in simulations using the proposed mathematical model (which represents customer perceptions) it is still feasible to invest in related aspects, such as service reliability, as well as delivery oversight processes and easy access to complaint channels with fast customer service, should any unexpected contingencies arise.

Attempting to embody the aspects listed in the data collection questionnaire, a final question was thus included, in order to allow end-customers to reflect and express their overall views in a qualitative manner (Figure 6).

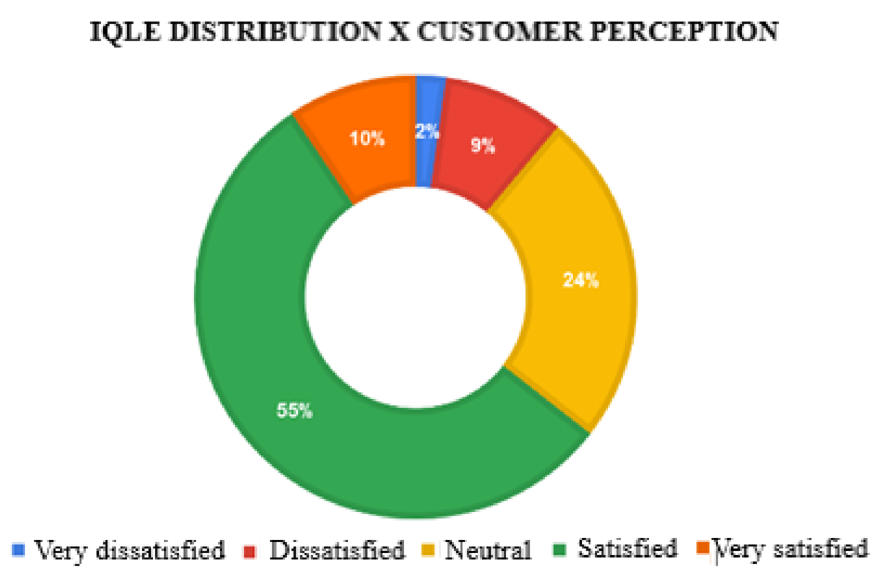

Figure 6. IQLE Qualification
Source: the authors (2021)

6. CONCLUSIONS

Initially, it was concluded that the main objective proposed for this project could be attained through the proposed methodology by generating a mathematical model addressing the possibility of capturing end-customers perceptions of logistics providing operating support for e-commerce.

A case study of Rio de Janeiro produced substantial data for testing and validating this mathematical model, which was considered to be valid and suitable for use in other future data collection projects, in any city. Consequently, it is possible to generate historical datasets that underpin strategic, tactical, and operating decisions, based on future forecasts.

Regarding the analysis of the findings, the possibilities of cross-referencing these data are not exhausted, using different filters, screens, and rankings, as well as the characteristics of the respondents and their orders. This fact indicates versatility, allowing the expansion of other attributes related to generating the IQLE.

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AUTHOR'S CONTRIBUTION

MS: Planning and methodological development. **MC:** General coordination.

CONFLICTS OF INTEREST

The authors hereby declare that there are no conflicts of interest.