Blockchain Technology in Innovation Ecosystems for Sustainable Purchases through the Perception of Public Managers

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Abstract: The success of organizational processes is increasingly related to sustainable innovation. The concern with sustainable public purchases has been gaining strength over the years. However, several barriers are found to implementing this practice. At the same time, blockchain advances as technology part of the innovation of industry 4.0 and as a proposal to solve these difficulties. The study aimed to identify the perception of public procurement managers on the use of information systems with characteristic features of this technology, to reduce these barriers and elaborate a proposal for the use of blockchain in open innovation systems. The research developed is qualitative, quantitative and applied, being carried out through the application of a structured questionnaire to purchasing managers using the 92 prefectures of the State of Rio de Janeiro, located in Brazil, with subsequent analysis through descriptive statistics. The results of this work present relevant findings for public procurement through innovation and blockchain technology with the possibility of tracking the entire supply chain, allowing the verification of possible environmental and social damages such as the use of child or slave labor, the use of deforestation wood, counterfeit products, unethical agents, in addition to providing more transparency to the process of acquisition.

Key-Words: sustainable procurement; public sector; blockchain; smart contract; innovation 4.0

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1 Introduction

The activities of public institutions are considered essential to leverage and maintain the reduction of the environmental impact on the economy, participating directly in the balance of the market and operating both as a consumer and as an intermediary agent [1]. Governments' purchasing power is increasingly used as a strategic tool to achieve broader objectives such as promoting innovation, sustainability, social inclusion, and supporting small and medium-sized enterprises [2].As the public sector is concerned with social welfare, it may have a greater propensity to pursue sustainable issues compared to the private sector [3]. After World War I, the use of government contracts was already used as a mechanism to meet the specific needs of people with physical disabilities in the post-war period. In some countries, public works financed by the government have been used as a social policy against unemployment [4]. In South Africa, after Apartheid, public procurement had already been seen as an important lever for social-political actions. Research shows that through public acquisitions it is possible to achieve consistent results in society and that public agencies are encouraged to acquire sustainably [5], while many citizens are concerned about the quality and form of public spending[6].

Insofar as the world population is becoming more aware of the powerful influence of production and consumption on the environment, economy, and society, sustainable development becomes progressively more relevant [7]. The increase in this awareness of environmental depletion has also driven innovation towards sustainability in the technological and consumer domains, resulting, among others, in eco-innovations with positive impacts at various levels in society [8].

The demands of the general population and governments on sustainability in the supply chain motivate investigations of how blockchain technology can solve problems and help achieve sustainable goals [9]. Nowadays, consumers demand sustainability requirements and traditional models of price competition are insufficient [8]. This technology is seen as one of the trends that will influence business and society in the coming years [10] and has the potential to provide benefits to the

government and society in addition to presenting the next step in the development of electronic government, allowing to reduce costs, share reliable processes and improve auditing [11].
The OECD created the Global Blockchain Policy Forum, the main international event that aims to bring together ministers of state, academics, policy makers, and other stakeholders to discuss the main issues and applications of this technology [2]. The State Administration of Taxation (AET) of Beijing in China recently announced the implementation of an application for issuing electronic invoices by the blockchain. The basic benefits of blockchain allow for data integrity and irrefutable transactions, which can result in tracking and transparency that support the reduction of corruption and fraud [10]. The blockchain supports the transparency that has become essential to rebuild trust [12] and can be considered a sustainable measure against corruption.

2 Literature Background

It's been sought first to understand what was produced on the themes, through a systematic review of the literature, following the steps and recommendations suggested [13]: selection of sources, access to databases, adoption of keywords, use of eventual search filters, reading the title, reading the summary, downloading the articles resulting from the search, reading the articles, archiving and searching for the next article as shown in figure 1.Initially, there was a search for databases of multidisciplinary interest. A result of 31 (thirty-one) databases belonging to this area was obtained, out of 272 (two hundred and seventy-two) databases.
After identifying the bases, individual access to each was carried out and proceeded to the next step. Search for keywords: In the search for articles, the following word relationships were used:

- ("blockchain" and "public sector").
- ("blockchain" and "government").
- ("sustainable procurement" and "blockchain").
- ("sustainable procurement" and "public sector").

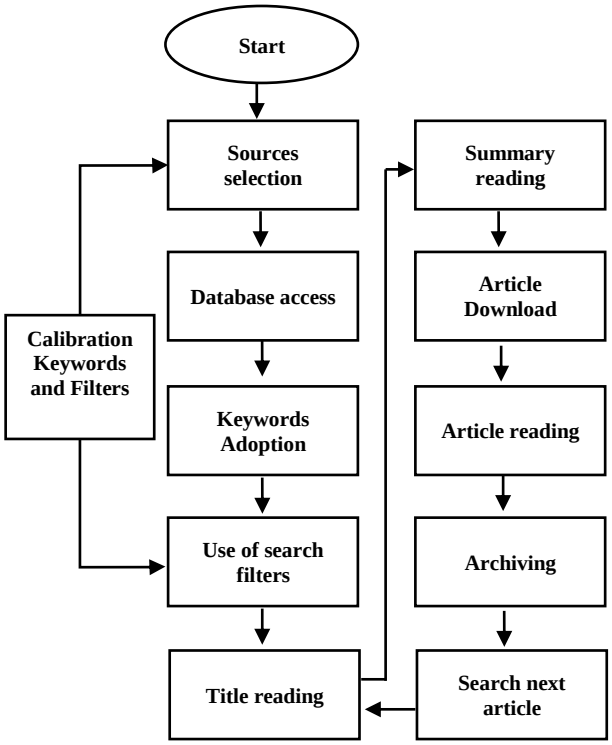

Fig.1: Stages of the search for the theoretical framework
Source: Own work.

To choose the keywords, the initial stage of using the blockchain in public purchases was taken into account. Filters for selection were applied individually to each database. For this, the types of document articles and articles "in press" were considered, the types of sources "journals" between the years 1996 to 2019. Going through the steps suggested in Figure 1, the next steps were followed: Reading the title and abstract, downloading of articles, dynamic reading of articles, archiving, and searching for the next article based on repeating the steps already mentioned. In order to further deepen the key concepts, after identifying frequently cited authors, the "snowball" method was adopted. This method allows, through a sample, to identify other authors of the same population [14].

2.1 Bibliometric Analysis

In the search process, articles were returned in 13 (thirteen) databases, with the largest number being returned in the Scopus database, representing 33.94%, followed by the Web of Science and Compendex databases, both with 18.72%. The three databases together represented 71.38% of the selected documents. The total distribution of results is shown in Figure 2.

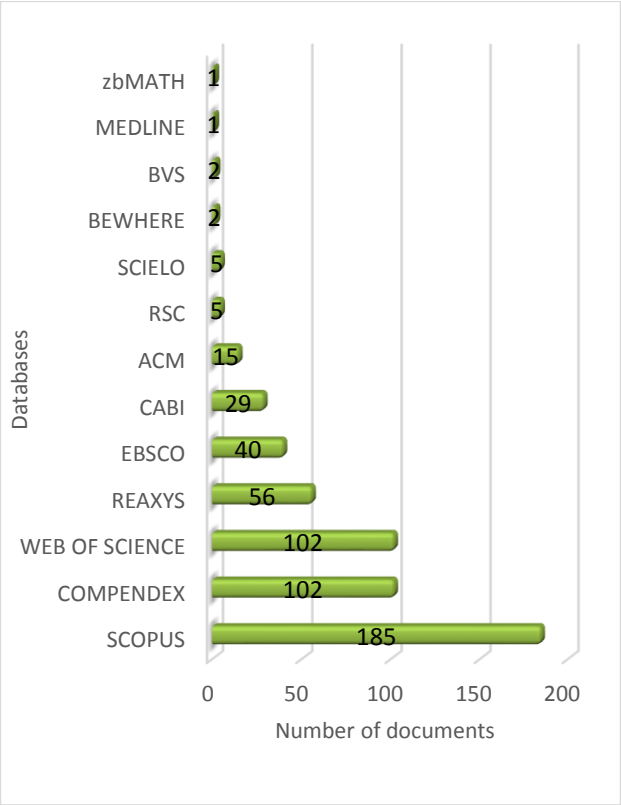

Fig.2: Number of database documents
Source: Own work.

Performing a keyword comparison, the association ("sustainable procurement" and "public sector") returned 67% of the results. While ("blockchain" and "government") got 26%, ("blockchain" and "public sector") 8% and ("sustainable procurement" and "blockchain") got no result. These data are illustrated in numbers in figure 3.

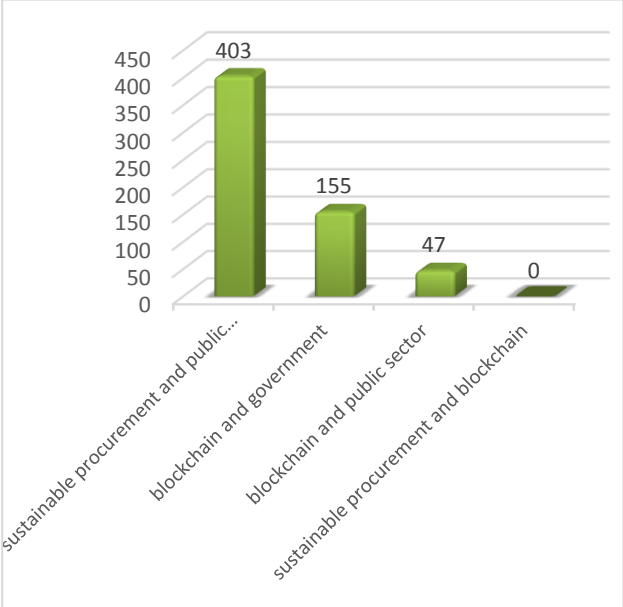

Fig.3: Number of keyword results
Source: Own work.

Of these documents, the journal with the highest number of articles found was IEEE Access, with 8 publications, followed by Computer law & security review with 4 publications. It can also be seen that there was no author with a large number of publications on the topic during the consultation period. But authors Jong Hyuk Park and Pradip Kumar Sharma, both from South Korea, even published 3 (three) articles in this interval considering the search method described above.
Of the articles returned, 102 (27%) were related to blockchain technology. Graph 5 represents the distribution of selected articles over the years. It is seen that the beginning of the publications found, through the filters applied in the searches, took place from the year 2015 and was accentuated in the years 2017 and 2018, reaching a total of 54 published documents. It is also observed that this peak in publications occurred 10 (ten) years after the publication of [15], the initial milestone of the technology. For the year 2019, publications up to the date of access to the databases were considered, however, due to the trend in the graph, the possibility of a growing number of publications in the year is seen.

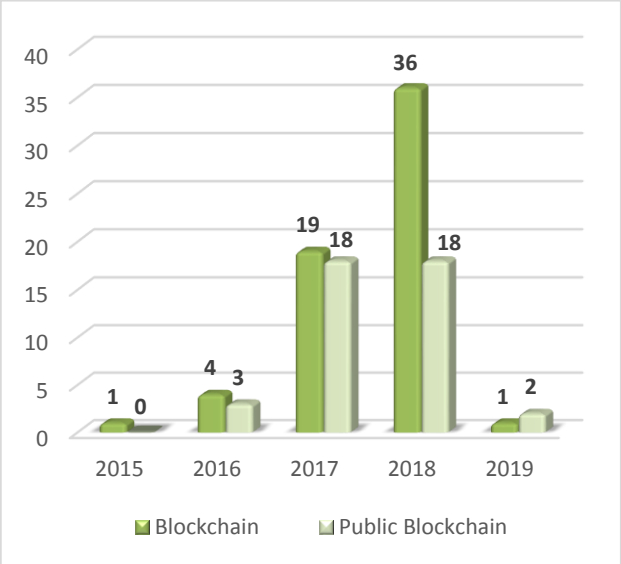

Fig.4: Number of articles on blockchain per year of publication
Source: Own work.

Reading the title and summaries of the documents also made it possible to catalog them according to the area of interest and activity. Figure 5 presents the areas with the greatest relevance on the subject and confirms the position that most academic work has focused mainly on cryptocurrency in general and for Bitcoin in particular [16]. However, it is

observed that research on this topic is comprehensive and diversified.

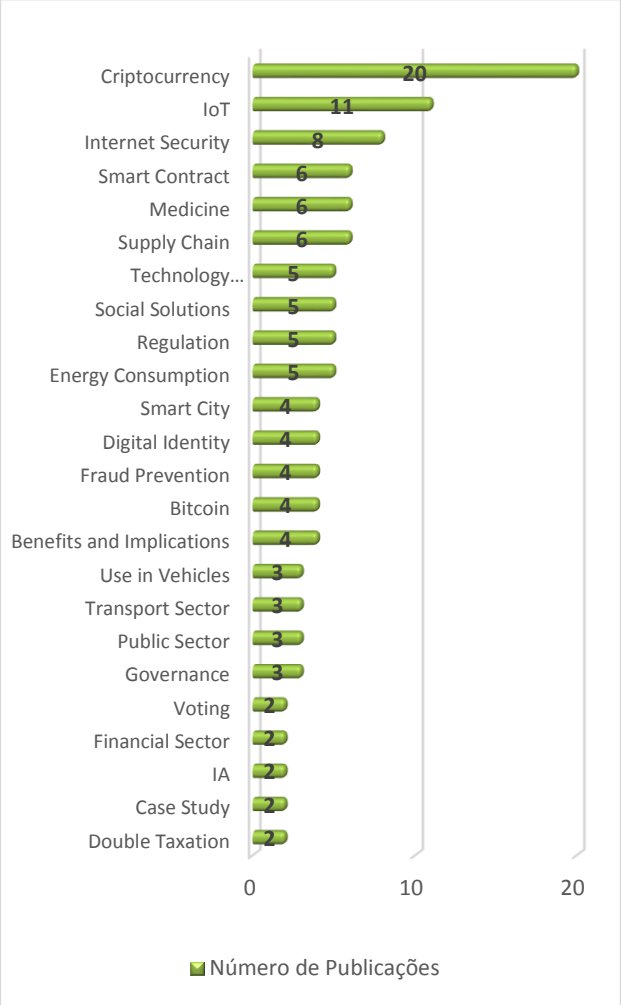

Fig.5: Number of articles on blockchain by subject.
Source: Own work.

It was considered for the theoretical foundation of this work, articles on smart contracts, supply chain, technology advancement, social solutions, smart city, digital identity, fraud prevention, benefits and implications, public sector, voting, case study, and double taxation were considered, totaling 42 articles, given the direct interest of the practical application of blockchain technology in the public sector. This stage concludes with the initial stage of research on blockchain technology in the public sector between 2017 and 2019. However, the scope of the technology's areas of activity can be seen, which allows us to believe in its potential and the growth in the study of this tool. It is also possible to observe the great focus of studies on the blockchain is related to cryptocurrencies.

As for the topic of sustainable purchases, 182 (47%) resulting articles are related to the public sector and 37 (10%) to application in other sectors. It is also possible to observe, according to the list of the most cited periodicals (figure 5), that regarding sustainable purchases, this represents 57% of the total of articles searched. Of these 219 (two hundred and nineteen) articles, 20 articles were published by the Journal of Cleaner Production. The second journal with more publications was the Journal of Construction Engineering and Management representing 4%. Graph 7 shows the classification of journals.

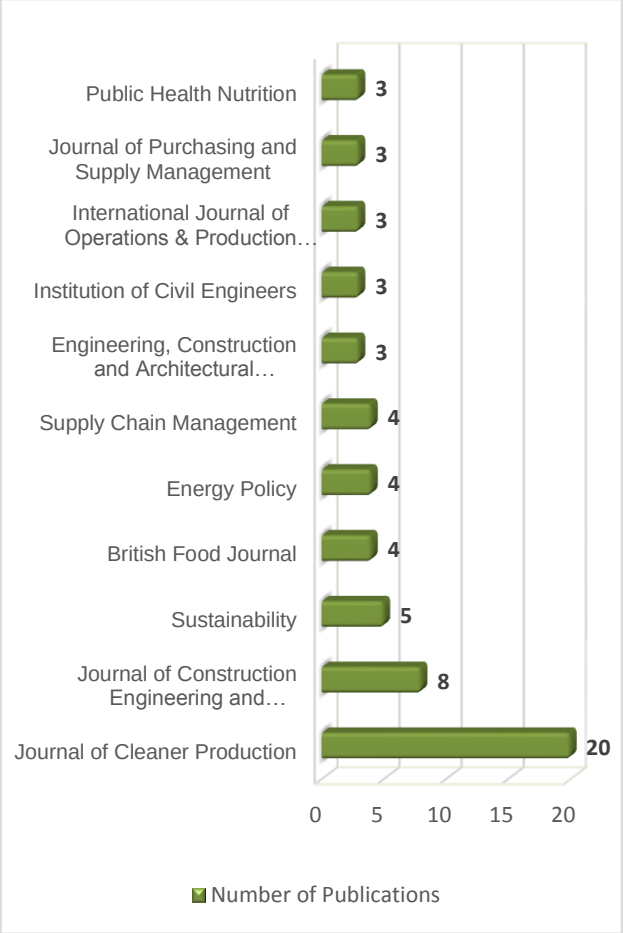

Fig.6: Number of articles found on sustainable acquisitions per journal
Source: Own work.

Regarding the areas of knowledge of sustainable acquisitions, public-private partnerships (PPP), case studies, the search for sustainability in infrastructure and civil construction works with a focus on waste reduction and the use of sustainable materials, in the reduction of energy consumption.

2.2 Sustainable Public Procurement

Public contracts refer to acquisitions made by governmental organizations or the public sector, being a policy with multiple objectives, mainly the guarantee of the quality of services and responsible

consumption [3]. Economically, public procurement is recognized as a means of efficiency and effectiveness of public spending. Broader political objectives, such as innovation, sustainability, social inclusion, and support for small businesses, should also be considered. This purchasing power amounts to more than 1 trillion Euros, 12% of the Gross Domestic Product, in the European Union [2].Developing countries, on the other hand, spend 25 to 30% of GDP on public purchases*[17]*.

The concept of sustainable procurement is associated with the idea of sustainable development cited by the 1987 UN report passing through Rio 92, and the World Summit on Sustainable Development in 2002 in Johannesburg. This interest in sustainability was reflected with the emergence of the 2008 Dow Jones Sustainability Indices and the 2001 indices series FTSEGood*[3]*. It can be understood as the process through which public authorities seek to acquire goods and services with reduced environmental impact throughout the life cycle [1], aiming to meet development objectives through the purchase process, incorporating social, environmental, and economic aspects [2]. It then means achieving a good cost/benefit ratio based on the product's life cycle, generating benefits not only for the organization but also for the society, the environment, and the economy [18].

As an example, governments have formulated sustainable procurement goals, staff training, and product listings on websites as an incentive [5]. Like other countries, they have adopted national action plans for sustainable public procurement [19]. Most countries in the European Economic Area have developed specific National Action Plans on this purchasing model in the last decade. The government procurement entity in Chile has published recommendations for public institutions to follow when making procurement decisions [20]. Thai government initiatives in establishing a national roadmap on sustainable consumption and production 2017–2036 [21], as well as studies carried out in Russia [17], Sweden [22], Bangladesh [23], China [24], and in five Asian countries and Hong Kong [25]. Research on the subject is also seen in the Indian territory [26] as well as in Lithuania [27]. The UK, as well as local governments in Italy, have issued guidelines for sustainable procurement, developing detailed standards that affect all public sector procurement activities [6]. The Indonesian government has established relevant regulations for economic and environmental development through procurement [28]. As for the social pillar of sustainability, purchases can also be considered an umbrella of issues [19] such as application of social policies, a requirement of a minimum percentage of workers with physical disabilities, preference for local employees, ensuring compliance with labor requirements, personnel hiring policies that aimsthe reduction of racial and gender inequality and religious discrimination [4]. Requirement of criteria aimed at reducing gender inequality, security, philanthropy and guaranteeing human rights [26][29], ethics in the execution of the procurement process [20][29], guaranteeing access to public health [6], encouragement for the creation of internship programs by suppliers and preference for hiring social organizations (SO)[30], a guarantee of housing and provision of shelter and social inclusion [31][32], policies for logging as a measure of protection for people who depend on forests [33] and criteria for including immigrant companies as public sector providers [34].

2.3 The Blockchain Technology

Satoshi Nakamoto, outlined a new protocol for a point-to-point system using a cryptocurrency called Bitcoin, called blockchain, originated in 2009 when Nakamoto described cryptocurrency as a model of peer-to-peer transactions [35]. In this model, with each new record, copies of the data are created [9], solving a fundamental problem of transactions on the internet that is trust. The easiest way to understand blockchain is to think of it as a database on the internet to store value, where all participants in the network keep an identical copy [36]. It aims to create a decentralized environment where no intermediary is in control of transactions and data [37].

The objective of the technology is to create a decentralized environment where no intermediary is in control of transactions and data [37][38]. Unlike traditional databases, they do not use the client-server network controlled by a designated central authority.*[39]*.This distributed ledger stores transaction data in “nodes” [35], which are interconnected computers around the world[40]. This decentralization is an important property since the same information is in different nodes and is only confirmed when there is a consensus on the information between the nodes[41]. New transactions are added, but previous information cannot be removed [10], thus maintaining a growing list guaranteeing the integrity of the system, even in the face of dishonesty [9]. Its structure is chained, composed of a header, including a hash (encrypted header), containing its value, the data of the block, and the hash of the block connected to it. The creation of a new block is known as "mining" [10].

Once the effort has been spent to satisfy a job test, the block cannot be changed [15]. All nodes are constantly updated with the information from the most recent transactions, therefore all information is available anywhere, on any node, at any time [36]. Each transaction generated by the nodes of the network is a "block", and the cumulative set of transactions across the entire network is the chain of blocks: "blockchain" [42][43]. Its data structure is linked, each part consisting of a header, including a hash, containing the value of the hash itself, the block data, and the hash of the block linked to it [47][48].

Creating a new block is known as “mining” [10][38] and no block can be created without this step [39]. To attach a new block to the blockchain, “miners” have to go through a cryptographic function and calculate a unique hash that meets certain criteria. Solving this algorithmic challenge is what represents a “proof of work” [35]. Nodes are rewarded at each work test and there is a consensus among all nodes [37][39]. Once the effort has been spent to satisfy the proof of work, the block cannot be changed [15]. All nodes are constantly updated with the latest transaction information, therefore all information is available anywhere, on any node, at any time [36]. This is the crucial step to maintain the integrity of the data registered in the blockchain, protect the transaction and order of blocks [39].

In addition to the core functionality of distributed reason, blockchain technology implementations differ in their technical details and features [16]. Broadly speaking, there are currently two types of blockchains: public and private. The Bitcoin blockchain is an example of a public blockchain. These networks are open to anyone [42]. The idea is that if you have so many people on the network that this unlimited number of computing power spread around the world, theoretically available to the network, is greater than the computing power of an attacker [36]. A private block chain, on the other hand, also registers the exchange of value between the parties in a network, but access to the network is restricted because not everyone can participate [42]. In this model, only authorized users have access to the database, either for reading or writing, but they offer transparency, privacy, and control within the group [43]. In a private blockchain, the parties know each other and there is no anonymity, as in a supply chain network with known entities working to produce and distribute products[9].

The blockchain enabled the creation of smart contracts, computer programs that reside in this technology, executed automatically [44].Designed in 1997 by computer scientist Nick Szabo, the application of smart contracts has gone without a concrete use for more than a decade due to the lack of a reliable source for its application, which has been supplied with blockchain technology [45]. The concept of smart contracts outlined so far will only achieve its goal if it is combined with blockchain networks. This is because you can only be sure of the impartial execution of contractual rules if there is a central agent in control[36].With the blockchain, these computer programs can automatically execute the terms of a contract [10][44], store rules and policies of the terms and actions negotiated between the parties [9]. Integrating these two concepts is to allow, in a distributed manner, automatic workflows, which can be as simple as "sending the product after receiving payment" or even "distributing dividends to shareholders after their declaration", with the possibility of auditing and guaranteeing compliance with the terms of the contract [42].

These contracts give rise to the concept of "decentralized autonomous organizations" (DAOs), the most complex form of a smart contract [45]. They operate autonomously without human intervention, based on programmed rules, and capable of even signing new contracts [36], enabling aspects of traditional corporate governance using software, enabling the benefits of formal corporate structures, and at the same time flexing the scale of informal groups [45].

2.4 Blockchain Technology and Public Procurement

Various barriers hamper sustainability across supply chains. Inefficient transactions, fraud, theft, and mismanagement lead to a lack of trust and therefore a need for better information sharing and traceability [9]. However, the blockchain is a technology that can be used to discourage fraud and increase transparency and efficiency [35][39]. The blockchain's ability to ensure trust, traceability, and authenticity of the information, coupled with smart contracts, means rethinking the management of supply chains [9].

Blockchain together with other technologies can perform traceability with reliable information throughout the supply chain [39][46]. It is suggested to use the blockchain in the supply chain, combined with tags with an intelligent chip (RFID - radio frequency identification) on the products that would inform the origin, ownership, warranty, and other necessary information [40]. With the incorporation of the Internet of Things (IoT) in the blockchain contractual fraud will be easily detected and prevented [39].

Today's supply chains rely heavily on centralized information management systems, sometimes not integrated and independent, and that have their own pitfalls [9]. A system with a centralized database is more likely to attack, corrupt data, and fail [46]. Blockchain follows a decentralized network model, instead of storing all information in a database, as in conventional cloud-based applications, information is distributed and synchronized across all network nodes [10][47]. The proposal of other systems with a direct impact on the supply chain has already been cited in [9][38][39][40][42][46][47][48][49][50].

Technological advances have caused a review of sustainability practices [41]. However, data from interviews with government officials emphasize the difficulty in promoting transparency and traceability in current procurement systems [49]. It is suggested, for example, the inclusion of sustainable procurement criteria in formal planning processes so that it is properly implemented [5]. An integrated, online system could solve this problem, assuming that suppliers would keep their data up to date [49].

In research on the drug supply chain, it is observed that products move through a chain that involves several participants, which makes them complex [47]. The blockchain also makes it easy to track products as they move and change hands in the supply chain [39].

The basic benefits of blockchain are related to improving data integrity and transactions that are irrefutable, which can result in information traceability, transparency, which support the reduction of corruption and fraud [10]. With this technology, frauds can be avoided due to fidelity and transparency, and it is also possible to ward off unethical agents and hold the corrupt responsible for social harm [9]. Impure or counterfeit products waste resources of the population and governments, in addition, it can diminish the general public confidence in the effectiveness of the products [47]. Transparency and trust, data immutability, and having a distributed database shared by society can also influence sustainable supply chains[9].

3 Methodology

This work started with a systematic review of the literature, to provide greater familiarity with the problem, intending to make it more explicit. Subsequently, a structured questionnaire was applied and the data was analyzed using descriptive statistics. The units of analysis were 92 prefectures in the state of Rio de Janeiro, in Brazil, with a sample population of 90 purchasing and bidding managers. The data were obtained from primary sources, by sending the questionnaire. The questionnaires, adequate to the research objectives, allow standardized questions and an analytical approach to exploring the relationships between variables [14]. The statements were based on the literature, seeking to understand the barriers to the use of sustainable public procurement. After obtaining the emails from the responsible departments, shipments took place from September 2019 to January 2020.

The questionnaire statements were elaborated as questions, based on the literature, and in order to seek later the understanding of possible barriers for the use of sustainable public purchases. For this, the variables that corresponded to the barriers related to the application of sustainable public procurement, the respective authors, and the correlation between them, were identified in the bibliographic review, so that the questions were in accordance with the research questions.

In order to get closer to the managers' perception regarding the statements, for ordinal classification of responses and subsequent analysis of the results, the Likert scale was used, composed of 5 multiple-choice items from which the manager can choose one of the five options: (1) totally disagree; (2) disagree in part; (3) neither agree nor disagree; (4) agree in part and; (5) totally agree. Each item received a weight of 1 to 5 which were used for statistical analysis of the results. The Likert scale was developed with the objective of measuring attitude, values, and beliefs about different aspects. With the principle that the attitude follows a linear continuum (positive or negative), this method of creating items is widely used [51]. In these cases, sociometric and psychometric scales are often used, which are generally made up of a set of ordinal items [52].

4 Analysis and Discussion of Results

The questions in the applied questionnaire sought to identify the practices used in public purchases in the organizations surveyed, elucidate the perception of managers about barriers in public purchases and how they could hinder more sustainable purchases. The answers to the completed questionnaires were tabulated in an electronic spreadsheet so that it was possible to carry out their analysis using descriptive statistics.

4.1 Information Sharing

Among the results found, what was most relevant was the difficulty in specifying sustainable

standards and criteria in terms of reference and bidding documents due to the lack of knowledge of the professionals. When examining this lack of knowledge, it was found that 90% of the respondents said they agree or totally agree that there is difficulty in specifying sustainable criteria, as shown in figure 7.

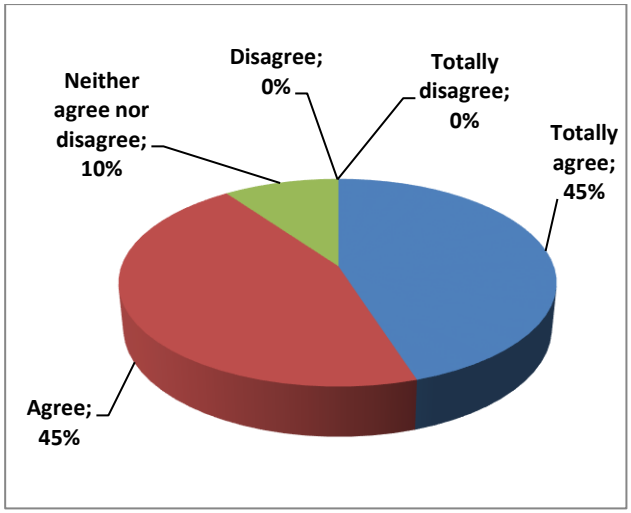

Fig.7: Lack of knowledge on how to specify sustainability standards.
Source: Own work.

This result exposes that disinformation is a barrier to sustainable acquisitions. It is through the technical specifications of the products that the government agencies describe the necessary characteristics for the acquisition, therefore, it requires from the employees knowledge and information in the description of the documents which will be requirements to be fulfilled by the competitors. Their research on the main barriers of this acquisition model [53], that one of the most important issues is related to the lack of knowledge of employees and collaborators about regulatory information and technical knowledge in these practices [17]. The answers show the conception that there is a lack of information on technical specifications that lead to a more sustainable acquisition. As shown in the graph, none of the respondents selected the options disagree or totally disagree for this question, which demonstrates a real feeling that there is a lack of knowledge on how to specify sustainable products and equipment, which somehow becomes a barrier to these acquisitions.
The responses on the difficulty in finding these specifications in documents and websites, totaled a proportion of 81% by the selection of I agree and I totally agree also due to the lack of information on the composition of sustainable materials and products (figure 8).

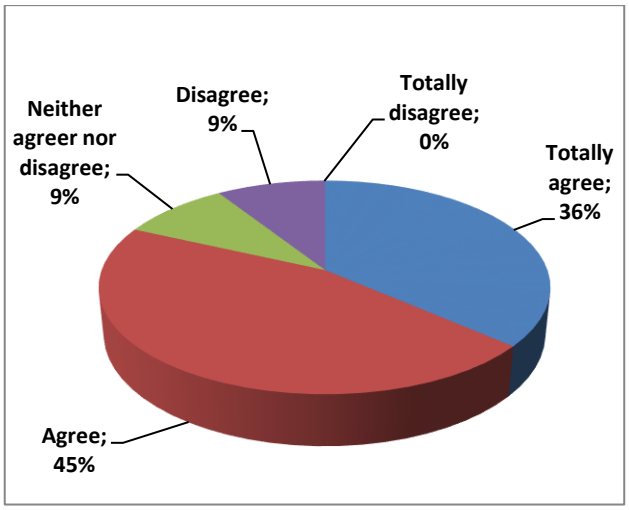

Fig.8: Difficulty in finding technical specifications about products and services that meet sustainability standards.
Source: Own work.

Complementing this perception, point out that intensifying information and raising awareness about sustainable public procurement can strongly support sustainable procurement [1]. As with studies already mentioned a lack of information about products with influences on the supply chain as a major problem [54].
A barrier to the purchase of sustainable products is the lack of knowledge of the buyer to assess the characteristics of a specific product and recognize the existing advantages in relation to the others. Sustainability does not come in itself, it requires sufficient resources and capabilities [8].
The second question with the highest proportion of agreement was if there is difficulty to obtain information about the value chain of products, since the manufacturing and supply process. The information needed for the selection of suppliers and manufacturers is seen by industry and academia as a critical issue for long-term success[41]. Careful distinction and supplier assessment in the early stages are necessary to ensure the sustainability of these chains. A solution to this problem would be communication between the interested parties about the technical specification before the purchase [19].
The barriers found in the literature review and corroborated through the issues discussed above allow us to understand that there is a consensus on the difficulty in obtaining knowledge about sustainable criteria and standards as well as, if this information is still available, the difficulty in verifying it in the act from bidding to the requirements related to the manufacturing process and the supply of products along their path through the supply chain. Studies suggest the use of tools

that encourage those responsible for opting for this purchase model, helping both in consulting the criteria to be specified and charged in the bidding process and in verifying them, as suggested by [54][55]. Future research is aimed at investigating dissemination systems for sustainable public procurement practices [56] and also proposes the use of electronic procurement systems (B2B) for government procurement[57].

Historical supplier performance and sustainability data can be made available through this technology, thus making it easier for employees to examine internal energy savings and pollution abatement practices and records to determine suppliers' environmental activities, as suggested [56]. Therefore, with the use of blockchain, information on product sustainability standards could be shared with confidence among government agency employees, reducing the difficulty of finding these standards on the internet.

It's been sought then to understand the managers' perception of the use of a single system among the members of the value chain and if this tool would be useful in verifying the specifications and sustainable criteria required in the bidding process. The answers to this statement reached the highest proportion of agreement (63% - totally agree and 32% - agree) among all the questions presented, totaling 95% of the approval options, as shown in figure 9.

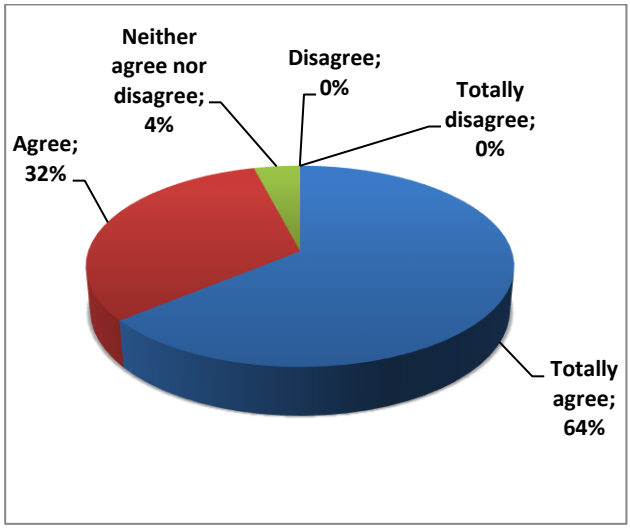

Fig.9: Usefulness of a single purchasing system, integrating producers and suppliers with the city hall.

Source: Own work.

Organizations should design tools that can assist sustainable procurement [54]. The barrier of misinformation can be effectively alleviated using blockchain technology [41].

The key success factor in sustainable public procurement is based on the knowledge necessary to support the information and training needs of the personnel involved in related tasks [1], as public procurement managers are not very sure how sustainable procurement can be implemented and what type of product is available on the market [54]. Considering that each product can have several specifications, this information can be recorded on the blockchain, along with its historical data. For example, Ikea has a table made of wood cut in a sustainable forest. The wood must be followed from cutting to manufacture to the final product to ensure that the tables were actually manufactured with that specific wood. This process is complex, but it can be managed with blockchain technology [9].

The aim was also to assimilate the idea of managers about this complexity and specificity of the composition of the various products and how they become a barrier to transcribing them in the bidding documents. Only 5% disagreed that there is no difficulty and 68% agreed that it is complex, as illustrated in figure 10.

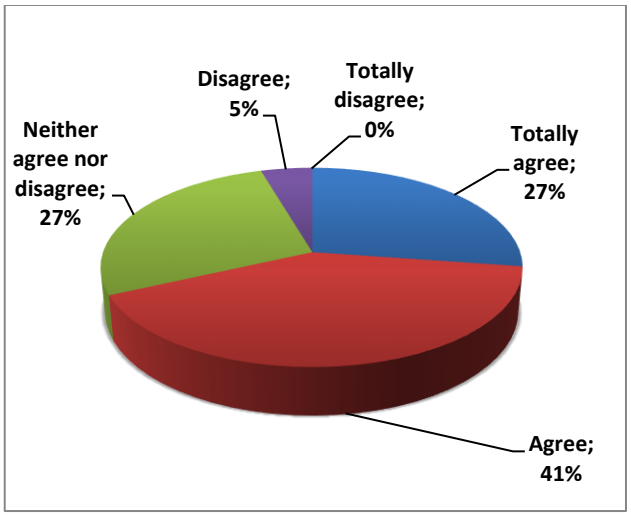

Fig.10: The complexity and specificity of the composition of products and services to be purchased.

Source: Own work.

Government agents express concern about the complexity of product components [49]. Even though it is generally difficult to obtain information about products, as well as to verify the manufacturing process, blockchain can be used to guarantee the purchase of sustainable products [9]. An integrated and online system could solve these problems from the moment that suppliers would keep their data available [49]. A proposal then would be to use a system, based on blockchain technology that integrates several members of the

value chain and society, forming an ecosystem of open innovation. This model consists of a dynamic and interactive network inserted in an innovation mindset, a configuration focused on the creation and diffusion of knowledge, including governments, the value chain, and users [8]. The knowledge shared by the blockchain could provide organizations with information on the catalog of products and suppliers, which would be an advance for this model and purchase [55].

Innovation is strongly linked to problem-solving and, currently, challenges are related to complex problems that require structural changes in individual and collective life, such as sustainable development [8]. The historical record remains forever unchanged [41]. It can also be understood that the traceability of products would facilitate the location of scarce products. Taking as an examplein the context of pandemics such as that of Covid-19 [50], government officials would be able to locate suppliers of masks, gloves, and other equipment and materials to fight the disease. It is suggested that companies can track hard-to-find products [41], as well as more sustainable products [5], among other examples already cited. It is possible to verify products with a higher or lower level of greenhouse gas emissions [9]. The traceability of medicines as a solution to avoid counterfeit products in the supply chain [47]. It is cited for controlling cannabis production [58], for controlling meat production [49], and agricultural production [46][48]. Blockchain can help supply chains detect unethical suppliers and counterfeit products as all information can only be registered by members with permission [9]. It can also assist in monitoring, developing, and selecting suppliers. These, in turn, must also take care of the environment at all stages of production, from the point of purchase to the point of sale [54]. The verification of this information by the purchasing sectors could be facilitated through this shared system, integrating the interested parties, allowing inquiries such as the origin of the wood and whether the food comes from family farming, for example. By recording product data along the supply chain, the blockchain allows the chain to be inspected from raw material records to the final sale [9]. This tool model allows transparent and efficient control of raw materials and products, according to production standards [38]. The ability to trace the origin of products, in line with concerns about the environment and the contribution of products to the conservation of resources, are two cases that affirm the blockchain's role in ensuring the sustainability of products [41]. There is also the difficulty in tracking the origin of the products in the case of the outbreak of salmonella in the United States and E. Coli in Chipotle Mexican Grill establishments, which together made hundreds of people sick and it was not possible to identify all the contaminated products [9]. When a person becomes ill, it can take days to identify the product, the shipment, and the supplier. That said, Walmart has implemented a blockchain tool that can obtain crucial data, including suppliers, details about how and where food was grown, and who inspected it, from a single receipt [38]. Using a similar system, the governments can be just as careful with school feeding. Crops can be packaged, labeled with RFID tags, and entered into a system that allows for the storage of relevant information [38]. This same model could be used by wood buyers who demand that the products come from verifiable and sustainable (or at least legal)sources for the timber trade to maintain credibility in public opinion[33].

4.2 Product Life Cycle

It was also possible to identify that 55% of the managers indicated that they do not carry out the life cycle analysis to make the purchase decision, as illustrated in figure 11.

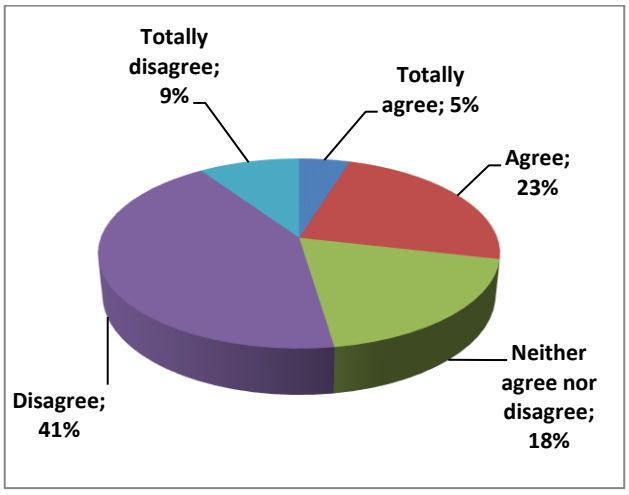

Fig.11: Analysis of the life cycle of products, from acquisition to disposal.
Source: own work

Public procurement awareness can mean changing from a strategy focused only on cost to an orientation on the cost of the life cycle [1].

In the context of sustainable public procurement, it is essential to demonstrate that purchasing processes and decisions need to go further, as the purchase price does not reflect the financial and non-financial gains offered by environmentally and socially better assets. The possibility of tracing a product from its production to disposal via the blockchain also

allows, through this history, to facilitate the calculation of the value of the entire life cycle of the product, and to create a base with increasingly safe estimates [18].
It is noteworthy that not all the necessary specifications for the analysis of the life cycle are contained in the product labels [28]. The need for reliable product comparisons also requires the development of information-sharing instruments [59]. The possibility of tracking a product from its production to its disposal by the blockchain also allows, through this history, to facilitate the calculation of the value of the entire product life cycle, and to create a base with increasingly safer estimates [18]. It is quite challenging to carry out the lifecycle analysis without a database to register the products [28]. Using blockchain technology, lifecycle analysis of products can be completed using actual product data rather than estimating values, as in current life-cycle analysis methods. The total cost of the product can be related to the production processes or any other stage of the cycle, for example, the consumption of water during manufacturing, the capacity for recycling, or biodegradation at the end of its useful life [18]. This accurate and real information is a great contribution of blockchain technology in the domain of lifecycle analysis.[41].

4.3 Unethical and Malicious Employees

With 77% agreement, the managers pointed out the influence of unethical and malicious employees on sustainable acquisitions, which are responsible for the preparation of the public notices, as a barrier, as shown in figure 12. The managers transmitted the perception that there is a negative influence of these malicious people on the specification of products and services. In the study on sustainable procurement in Malaysia, they found that political corruption is one of the serious problems for sustainable public procurement, given the favoring of some suppliers [60].
A revolution has occurred by blockchain technology in unreliable processes by replacing unethical intermediaries with smart contracts, excluding corrupt agents from the value chain [44]. Malicious employees and intermediaries take advantage of the fact that procurement processes are difficult to be audited by control bodies or interested citizens, however, the basic benefits of blockchain are related to improving data integrity and transactions that are irrefutable, which in turn can result in information traceability and transparency, which support the reduction of corruption and fraud [10].
With this technology, fraud can be avoided due to fidelity and transparency, and it is also possible to remove unethical agents and hold the corrupt responsible for social damage [9].
Blockchain-based smart contracts eliminate human judgment on transactions and the role of intermediaries as professionals involved in traditional contracts can be minimized [41]. The breach of agreements in a blockchain chain is more difficult than in traditional centralized systems, due to the sharing of data and the possibility of auditing and transparency [9].

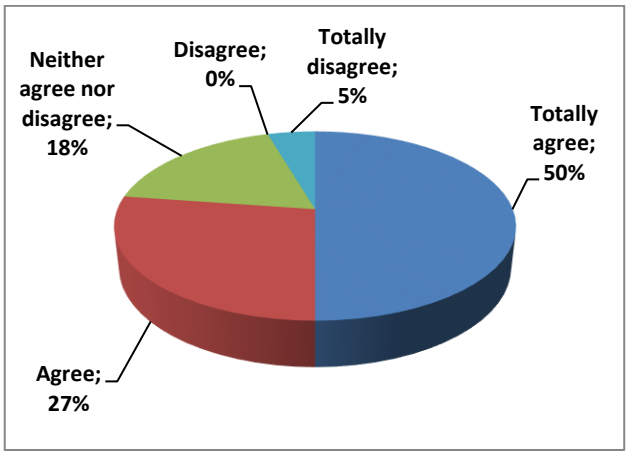

Fig.12: Unethical and malicious employees being responsible for purchasing documents.
Source: own work

Disintermediation, which is a crucial effect of applying blockchain technology, can mitigate potential opportunistic behavior [9]. However, the basic benefits of blockchain are related to improving data integrity and transactions that are irrefutable, which, in turn, can result in information traceability and transparency, which support the reduction of corruption and fraud [10].
From the understanding of the respondents, 73% agreed that the concept of decentralized autonomous organizations (DAO) is a useful system model.

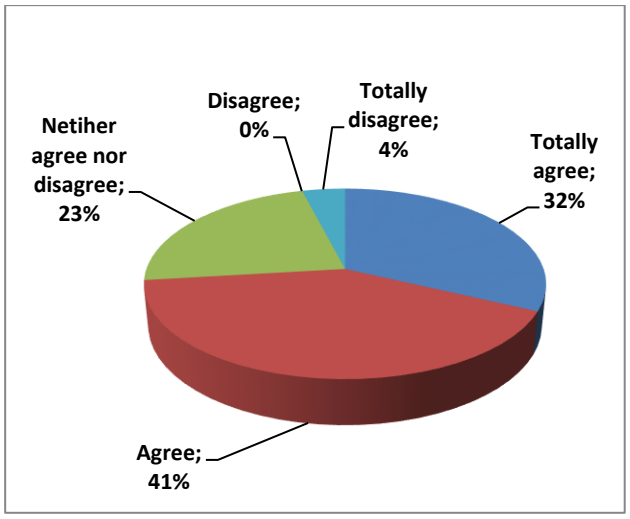

Fig.13: Utility of an autonomous computerized system for the storage and management of purchase data.
Source: own work

After choosing the products and materials necessary for administration, a DAO could take over the operationalization of purchases, already with a panel of suppliers and products, with prices based on the cost of the life cycle. The purchasing process can be automated, integrating the stages of electronic auctions, eliminating the favor of suppliers and prices. With this technology, fraud can be avoided due to fidelity and transparency, and it is also possible to ward off unethical agents and hold the corrupt accountable for social damage [9].

5 Conclusion

This work pointed out some sustainable public procurement actions, their possibilities of providing a better quality of life for society, and the barriers to its implementation. With the advancement of innovation 4.0 and blockchain technology, it is possible to understand the proposals and possibilities to reduce barriers related to public procurement. After these observations and the analysis of the results, we return to the problem initially raised and it can be concluded that blockchain technology has a great potential for transformation for governments and in the promotion of sustainable actions, in the creation of an innovation ecosystem, and the requirements of the activities of suppliers and actors in the value chain.
The perception of public procurement managers made it possible to verify that one of the main difficulties of these managers is related to the lack of knowledge and information that ends up making public procurement unfeasible with a good economic result and that meets the environmental and social perspectives. However, studies are found that cite examples and models of actions that meet these objectives through government acquisitions. The creation of an open innovation ecosystem, on a distributed basis, integrating prefectures and other government agencies, would make it possible to share this knowledge.
The feeling about transparency and confidence in public procurement has also been seen by this work. Both variables were very well evaluated by the participants as to their relevance in public procurement. The transparency required from public bodies is seen as a relevant factor for sustainable procurement. The need for consensus on the blockchain network for data changes and an ecosystem through a distributed network, where interested parties could actively participate in the network, would guarantee the required transparency in public administration. In other words, control and inspection bodies, courts of accounts, and members of organized civil society could be part of this ecosystem and would have full visibility of the products and services being purchased, in addition to being nodes in the network and part of the consensus needed to the data alteration.
This work did not reach the study on the application of cryptocurrencies or tokens in the solution of the proposed method.
It is therefore suggested that future studies and research are focused on the practical application of these findings on blockchain technology in sustainable public procurement processes.
It is possible to conclude that innovation has disruptive potential for sustainable public procurement, allowing to meet economic and environmental aspects, but also to attend mainly to the pillar of social interests, giving the possibility of reducing social inequalities and unemployment and improving the quality of life of the population, made blockchain an agent of change for governments.

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