

Solid Waste Management in a Sustainable Smart City in Brazil

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Abstract: *This study aims to highlight the management of solid waste in the development of the smart city located in the State of Santa Catarina (SC), Brazil. Sustainable smart cities incorporate sustainability parameters for a public and private development to improve the structuring of public investments in the promotion of more balanced, fair and inclusive cities for society. The article presents the methodology of the qualitative approach using the case study of the Cata Treco Program of the municipality of Itajaí, SC. The data are analyzed and presented through the qualitative results of content analysis. It is verified that the practices of solid waste collection management in the municipality can allow the reuse and a certain destination that corroborates a more sustainable and conscious citizen culture. The use of the Conecta. í application allows advanced planning of the collection routes. The work contributes to the implementation of environmental public policies in the municipality.*

Keywords: Solid waste management. Sustainable smart city. Public policies

1. Introduction

The debate around the access to applications, quality services and information made available by municipalities in Brazil to citizens has been the subject of research for the development of sustainable smart cities with the use of artificial intelligence (AI). More recent meetings in Brazil have debated the theme of intelligent sustainable cities: the meetup "The challenges of small and medium - sized municipalities" and the "Connected Smart Cities - intelligent, human and sustainable cities" that took place in the city of São Paulo (São Paulo - SP); "Smart City Expo Curitiba" in the city of Curitiba (Paraná - PR); "Smart City Fórum: which are the ways for Florianópolis to advance as a smart city" in the city of Florianópolis (Santa Catarina - SC); and, the IV Forum of Digital Cities of the Itajaí River Mouth, held in Itajaí (SC).

The development of sustainable smart cities is an important issue for the development of *insights* when it comes to public policies for citizens focusing on programs with collaborative technologies that assist in reducing social problems (Alperstedt Neto, Rolt, & Alperstedt, 2018; Bamwesigye, & Hlavackova, 2019; Duygan et al., 2021; 2022) and increasing social, economic, and sustainable well - being (Jia et al.2019). Studies have been evidenced in other countries (Shearmur, & Poirier, 2016), and few highlight Brazil from this perspective (Guo, Huang, Guo, Li, Guo, & Nkeli, 2019). The study of smart cities (also found as digital cities, electronic cities, information cities, knowledge -

based cities, wired cities) (Ismagilovaa, Hughesb, Dwivedic, & Ramand, 2019) is relevant for employment benefits and challenges that integrate various stakeholders.

One of the services offered by the Municipal Department of Works (SMO) of the municipality of Itajaí, located in the State of Santa Catarina (SC), Brazil is the Cata Treco Program that can be requested through the "Conecta. aí" app by municipalities (i. e. citizens). The products discarded by society have been a concern of municipal governments with environmental issues.

The Cata Treco Program was created to prevent vacant lots and sidewalks from becoming garbage dumps. People who dispose of furniture and electronic products can make the correct destination for their belongings. The Cata Treco Program collects the materials by scheduling and sends them to the Cooperative for Recycling of the Itajaí Valley (Reciclavale, 2015), where they are reused. The partnership meets the principles of sustainability by generating social, economic, and environmental development for the cooperative members and the entire municipality (Prefeitura Municipal de Itajaí, 2020).

Law 12.035, of August 2, 2010, which is known as the National Solid Waste Policy determines the management and proper disposal of waste generated in the country and establishes the shared responsibility of all parties (manufacturers, traders, consumers, among others) that somehow generate waste (Brazil, 2010). Thus, recycling can

be one of the alternatives for the treatment of solid waste (Vishnu et al., 2021) being more profitable for the environment and society (Krupp, Silva, & Vieira, 2017). Therefore, this research has the following guiding question: How has the Cata Treco Program in the municipality of Itajaí been promoting social, economic and environmental development for its residents?

This article aims to highlight the management of solid waste in the development of the smart city in Santa Catarina, Brazil. The study is justified by the importance of the implementation of the National Policy on solid waste and the articulation of the Cata Treco Program implemented in the municipality. It presents its originality by verifying practices that can allow the reuse and a certain destination, corroborating for a more sustainable and conscious citizen culture.

The study is structured as follows: the first section refers to sustainable smart cities presenting characteristics for the development and improvement of the quality of life of citizens. We then introduce solid waste management and its management. These sections were important for conducting empirical research in a Brazilian municipality. The methods and the operationalization of the research are described in Section 4. In Section 5 we present the research results and their implications and in Section 6 the conclusion.

2. Literature Survey

This section presents a review of the academic literature on smart sustainable cities and solid waste management.

2.1 Smart Sustainable Cities

The concept of smart cities has been developed for years, and there is no consensus on the concept. Sustainable smart cities are associated with the use of efficient technologies to build and integrate product and service infrastructures in the face of the demands of a city with sustainable dimensions such as environmental, economic, political, cultural and social, and participatory governance for the development of a better quality of life (Kummitha, 2019; Duygan, 2022).

Smart cities constitute smart environments generated by the agglomeration of creativities, innovation systems operating in cities (technology districts, technology parks, innovation hubs, innovative clusters), and digital networks and online services that add value through three ways: the human intelligence of the city's population, the collective intelligence of innovation from supporting institutions, and the artificial intelligence of services from digital and online networks (Komninos, 2008; 2011). The concept of smart cities is used to characterize areas (cities, regions, city districts, clusters) where the local innovation system is supported and enhanced by digital networks and AI applications (Komninos, 2002; Nählinder, 2013). Smart sustainable cities incorporate sustainability parameters for a public and private development to improve the structuring of public investments in the promotion of more balanced, fairer and inclusive cities for society. Lombardi *et al.* (2012) characterized smart cities as an innovation system consisting of five clusters - smart

governance, smart economy, smart human capital, smart living, and smart environment, involving key players including universities, government, civil society, and industry.

The *smart city* or smart city uses digital and information tools to improve service performance, reduce expenses, and increase the *performance* of available resources (Duygan, 2022). In recent years, it has been possible to identify an increase in the migration of the world population from rural to urban areas, increasing the difficulties in the management of cities, and creating various problems with structures as social. As per data from the Department of Economic and Social Affairs, United Nations Population Division (2018), universally, more people live in urban areas than in rural areas, with 55% of the global population residing in urban areas in 2018. In 1950, 30% of the global population was urban, and by 2050, 68% of the world's population is projected to be urban.

Further, the United Nations Department of Economic and Social Affairs, Population Division (2018) states that the increase in urban population is leveraged by the overall population increase and the increasing change in the percentage of people living in urban areas. Thus, the United Nations highlights that together, these two factors are expected to add 2.5 billion to the globe's urban population by 2050, and further states that sustainable urbanization is the key to successful development (United Nations, 2018).

As the world continues to urbanize, sustainable growth needs thriving management in urban development, especially in low - and middle - income countries where the fastest urbanization is expected between now and 2050. Joint policies are needed to improve the quality of life for both city and rural dwellers, thus strengthening the economic, social, and environmental links between these zones.

Well - managed urbanization, informed by an understanding of long - term population trends, can help maximize the benefits of agglomeration while minimizing environmental degradation and other potential adverse impacts of increasing numbers of city dwellers. To ensure that the benefits of urbanization are shared, policies to manage urban growth need to ensure access to infrastructure and social services for all. To minimize these difficulties, one option is the development and application of technologies focused on sustainability. The deployment of technologies in cities can cooperate with issues about the control and management of infrastructure and services, improving the management of metropolises and thus maximizing the quality of life (Vu, & Kaddoum, 2017).

The transformations generated by rapid growth influence some challenges for cities, and some basic features such as smart management is one example. They need effective participatory efforts of citizens, intelligent combinations of human, collective, and artificial distinctions, and the use of information and communication technology. In addition, they seek solutions with solid fulfilment of human promises, with constant changes driven by the intelligence of smart citizens.

An important issue in understanding smart cities is to describe the ability of another former digital space, i.e. digital city and smart environment. All smart cities are digital cities, and all digital cities are smart. There is an ability to solve problems with the ability of smart cities because of the ability of digital cities to provision services from which communication interacts with the city (Komninos, 2009). Komninos (2009) states smart cities are ways of allocating urban areas based on the request of three bits of intelligence, artificial, human and collective and affect territorial transformations in search of contemporary solutions to the social, economic and cultural problems they face.

Caragliu, Del Bo, & Nijkamp (2009) point out that when *smart cities* articulate the human resources of infrastructure, communication, sustainability, and management of natural resources generate quality of life contributing to society. They also state that the definition of *smart cities* is fundamentally efficiency based on intelligent management with the technological connection. The concept of the city is not a consensus among authors, but we notice some similarities, such as the management of resources, human and natural, information and communication technology, and the strong influence of citizens and governments improving the efficiency of cities (Duygan, 2022).

A sustainable smart city is defined as a city with at least some defined qualities: there is an interconnected and managed smart connection, which has methodology and innovation tools to evaluate urban intelligence with aware citizens. Thus, a smart city must maximize innovation and technology in its performance with smart mobility, smart economy, smart people, smart governance, smart living, and smart environment (Giffinger et al., 2007; Duygan, 2022).

2.2 Solid Waste Management

Key challenges facing cities are improving municipal waste collection services and achieving more efficient waste management, mainly due to population growth (Duygan et al., 2021). Smart waste management is a key factor, a fundamental and priority pillar of sustainable smart cities, presenting direct impacts on health, duration of life, and the human and natural environment. Waste, especially solid waste, when left untreated causes and spreads waterborne diseases (UN - HABITAT, 2010).

To understand its importance, one must take into consideration that municipal waste management is composed of different steps, from collection and transportation to treatment, with the collection being the key factor in achieving this efficient municipal waste management for two reasons: its costs and its logistical component. The focus on cost reduction, which is especially costly, involves many workers and vehicles, and includes waste collection planning, for the logistics component, allowing ample room for improvement through smart solutions using strategies for efficient waste management that aim to avoid irreparable environmental damage.

While proper development of a smart city holistically addresses waste management, waste collection is key to

improving service to the citizen and the environment, as well as achieving savings for the administration. In a scenario that seeks efficiency, according to the goals and pillars of sustainability, effective projects with the community are essential for the development and growth of the management of a smart city. Thus, it is essential to use the tools available for such management, such as the National Policy for Solid Waste (PNRS), created by Law No.12.305 of August 2, 2010, regulated by Decree No.7.404, of December 23, 2010, which defines rules, models and forms of waste management (Brazil, 2010) and defines solid waste as material, substance, object or discarded well resulting from human activities in society, to whose final destination is proceeded, proposed to proceed or is obliged to proceed, in solid or semi - solid states, as well as gases contained in containers and liquids whose particularities make it unfeasible to discharge them into the public sewage system or bodies of water, or require for this solutions technically or economically unfeasible given the best technology available.

Article 1 of the PNRS states that the law establishes the National Solid Waste Policy, providing its principles, objectives, instruments and guidelines for the integrated management of solid waste, including hazardous waste, the responsibilities of generators and the government, and the applicable economic instruments (Brazil, 2010, p.1). Thus, the law on waste management determines the responsibilities of the government, which must responsibly and transparently use this important tool to manage their waste. It also highlights the concept of integrated solid waste management as a "set of actions aimed at finding solutions for solid waste, to consider the political, economic, environmental, cultural and social dimensions, with social control and under the premise of sustainable development" (Brazil, 2010, p.1). Solid waste refers to any useless material produced by human activities in industry, commerce, and households. However, most of them can be collected, recycled, and reused selectively, and bring profits to businesses, society and the environment (Garcia, 2016).

Cities encounter many difficulties in the disposal of waste, problems most of the time caused by neglect of public officials and the lack of adequate landfills and sufficient equipment, as well as the lack of community awareness regarding the proper disposal of waste. The practice of selective collection is the first step that must be implemented as a co - responsibility, an alliance between public power, society, and private initiative.

3. Methodology

3.1 Methodological aspects

This paper presents the qualitative approach methodology grounded in the critical - interpretive paradigm. This paper used the case study with a descriptive - exploratory research purpose (Godoy, 1995) to examine a phenomenon in its natural environment. Yin (2003, p.32) stated that the case study is an empirical investigation of a contemporary phenomenon within a real - life context. Goldenberg (2004) pointed out that the case study makes it possible to penetrate social reality. The case is linked to the Secretariat of Works of the Municipal Government of Itajaí - PMI, located in the

State of Santa Catarina (SC). Thus, the city of Itajaí was considered to position 29th in the total ranking of Brazil's smartest and most connected cities by Smart Cities Brazil 2022 (Smart Cities, 2022). In this research, the case was chosen non - randomly, but with a strong connection with the theory, to be more useful as an explanation (Eisenhardt, 1989). As for the definition of instruments and protocols, several methods of data collection were combined, such as interviews, observations, newspapers and articles published in the media, PMI official documents, to triangulate evidence to promote perspectives that would strengthen the research (Eisenhardt, 1989; Yin, 2005).

For this research, two semi - structured interviews were conducted, and observations were made with field notes. The first interview was with a civil servant from the Municipal Department of Works who works integrally with the Waste Recycling Program, which took place in June 2020 and lasted 47 minutes. The second interview was with a manager of a company that uses the program's services, which took place in August 2020 and lasted 31 minutes. The interviews were transcribed to facilitate the understanding of the topic. The interview protocol was developed in the research topics: (a) solid waste management and (b) sustainable smart city. The data were analyzed and presented through the qualitative results of the content analysis with the description of the relevant information for possible contributions to the literature and academia.

4. Search Results

In this section we present data from the municipality of this study, the interviews with a manager of the "Cata Treco" Program and an entrepreneur and the discussion of the results.

4.1 The city of Itajaí, Brazil

Itajaí is a Brazilian municipality located in the State of Santa Catarina (SC), the southern region of Brazil. It has an estimated population of 219, 536 people in the year 2019. The population in the last census of 2010 was 183, 373 people representing a demographic density of 636.11 inhabitants per km². The municipal Human Development Index - HDI in 2010 was 0.795 which is considered high in the 0.700 - 0.799 range. The dimensions that contribute to

the HDI of the municipality are Longevity with an index of 0.884; Income with an index of 0.778 and Education with an index of 0.730 (*Atlas of Human Development in Brazil*, 2010). As for the Territory and Environment dimension, the municipality has 88.6% of households with adequate sanitary sewage, 33.2% of urban households on public roads with trees, and 79.6% of urban households on public roads with adequate urbanization (presence of culverts, sidewalks, paving, and curbs) (Instituto Brasileiro de Geografia e Estatística - IBGE, 2020).

According to data from Connected Smart Cities (2019) which involves companies, entities, and governments in a platform whose mission is to find the DNA of innovation and improvements for cities that are smarter and connected, whether they are small or megacities, Itajaí ranked 24th in urbanism, 72nd in technology and information, 62nd in health, 89th in entrepreneurship, 5th in governance, 46th in mobility and accessibility, 60th in economy, 30th in security thus remaining in 16th position in connected smart cities. In sustainability, the city is represented by wooded areas in the streets, public spaces such as Beira Rio full of restaurants, the Church with the Parish Santíssimo Sacramento, the Public Market of Itajaí, Casa da Cultura, several beaches such as Atalaia for surfing, Cabeçudas and Praia Brava, Praia do Morcego, Morro da Cruz, the Marina Itajaí, and several attractive points as the Bico do Papagaio, Molhes da Barra, the Port of Itajaí, the historical museum, the municipal theatre, among others (Litoral de Santa Catarina, 2020).

4.2 The management of the collection program

The Cata Treco Program was created by PMI's initiative to collect furniture and appliances that residents wish to dispose of. In addition to avoiding litter in vacant lots and sidewalks, the program receives the most varied products such as mattresses, sofas, and computers. It has two trucks with a schedule to attend to the neighbourhoods and offer the correct disposal. Throughout the years 2019 to 2021 fluctuations in the demand for services were observed with the highest number of attendances in the year 2021 followed by 2020 (Fig.01). In general, the months with the highest demand for the collection were February, July, and September.

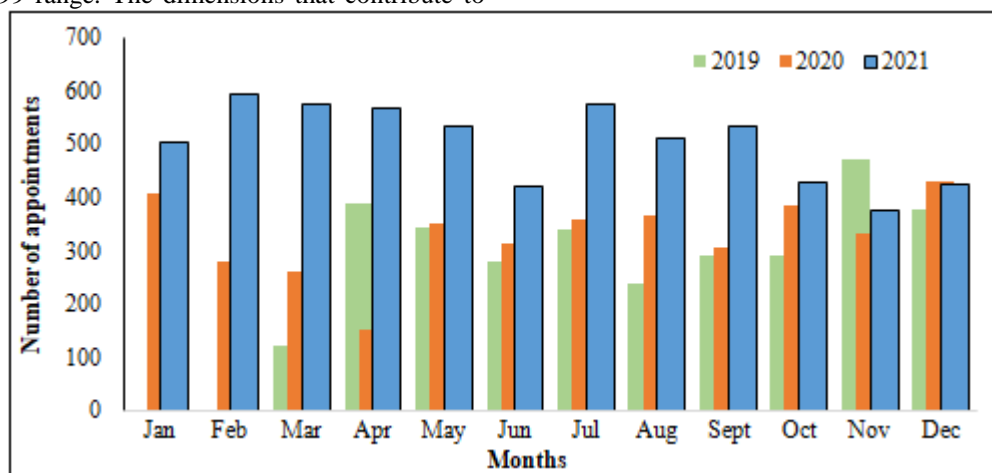


Figure 1: Number of monthly calls made by the "Cata Treco" Program, Source: DataPemi (2022).

A great deal of routine and itinerary care is taken, especially to combat Dengue fever, regarding the accumulation of water in certain materials. Regarding the disposal of civil construction material, the "Cata Treco" Program does not attend, because it is the responsibility of the resident to offer the correct destination. Thus, the Secretariat of Works has the Voluntary Delivery Point (PEG) that receives 1 meter of solid waste according to the guidelines of Law 12.305 of August 2, 2010, which establishes the National Policy for Solid Waste (PNRS) (Brazil, 2010). The PEG places the materials in separator collection boxes and then performs the correct disposal (TVBE, 2020).

The Cata Treco Program has about 14 years of existence and belongs to the Secretary of Works of the municipality. In 2007, PMI was facing difficulties in sequencing the Cata Treco program initiative and needed a general review and organization. With his and his team's intervention, a system was developed to cover the municipality's neighbourhoods from Monday to Friday.

On Fridays, the demands received are reviewed and the planning for the following weeks is done. For the civil servant, one of the tools used that generated positive results in the initiative were the creation of the service channel through the Conecta. í application, "we have a schedule based on the number of requests we receive, today we have a channel, a very good tool that works well".

The employee describes that before, the requests for collection and removal of materials were made by phone and often the information collected had incomplete or wrong addresses, which caused some rework and loss of time in the initiative: "when you arrive at the person's house, you knock on the front door and the number is wrong. Before, two trucks would go out and do it street by street, and then it generated problems [. . .] the truck passed by my street and didn't stop, José from the such - and - such street opened a call".

The server reports that the information collected by the application is complete, with less risk of error. The requester himself writes the address information for collection in Conecta. í, an application developed by PMI's Secretary of Technology (SETEC), available for the citizens to request services from the Secretary of Works. The server reports that the information collected allows for planning of the trucks' route, so the planning occurs according to the demands that arrive during the week and on Friday it is consolidated.

The employee explains that the service system is well organized and keeps records of the requests "we have the person's report, since the scheduling of the Cata Treco service, the opening of the call and the date of the service closure". The employee guarantees that there is traceability and follow - up of the requests and considers it very efficient.

When asked about how the requests that have not been scheduled are handled, he describes that when another resident of the same street where the truck is collecting also requests the removal of some material, even if the resident has not scheduled it, the material will be collected, because

the intention is to meet all requesters in the best possible way: "we always guide our drivers and our employees to meet everyone's needs, just call us and we will do it".

To meet the city's demand, the program has three trucks, of which two trucks meet the scheduled routes and the third truck provides support for the other demands. The Cata Treco program team is made up of 15 people, including a public servant.

Regarding the services provided by the program, Alfa reports that the collection is carried out and in the warehouse of the Department of Works an initial sorting is done, segregating electronic materials, household appliances, and furniture among other materials. The material that has added value is passed on to a cooperative in the region, the Cooperativa de Reciclagem do Vale do Itajaí (RECICLAVALE). At the cooperative, the materials go through a new selection process, are separated and later sold. The profit on the materials sold by RECICLAVALE is shared among the cooperative members.

In the case of wood and *Medium Density Fiberboard* (MDF) or similar, the treatment follows another alignment. The wood is separated from the MDF, which is sent to the landfill because this material is not yet reused. The wood, on the other hand, is sent to another partner cooperative, where it is chopped and transformed into sawdust to be sold.

About the materials that are not destined for this cooperative, such as sofas, mattresses and similar, the employee describes that the mattresses are destined for other cooperatives, or for four women who make handmade mattresses for dogs.

The employee adds that there is also a partnership with the Centro de Referência de Assistência Social (CRAS) and adds that "All the furniture that arrives in full working condition is donated". The community comes to CRAS and informs their needs, being directed to the Secretariat of Works. The furniture in good condition is sent to RECICLAVALE, and people remove the material at the cooperative. The program has a positive impact on several dimensions: generation of jobs and income, use and recycling of materials, social support for needy people with the donation of materials in good condition, in addition to the environmental and sustainability issue by giving the correct destination for the collected materials.

The employee describes some difficulties and opportunities for improvement. The first difficulty is related to bad weather such as rain that hinders the whole collection and logistics process, and damage to some furniture and materials in good condition that could be collected and donated. There is also the issue of impassable streets, narrow streets where the truck cannot pass: "There are narrow streets that the truck cannot enter, there is a whole factor of difficulty [. . .] for the day to day, but even so, we do not fail to serve, we leave the truck on a closed street and go to the citizen's house to clap hands". The second is the issue of the number populations of the municipality, about 230 thousand inhabitants generating waste daily and the geographical size of the city. Normally, the two trucks, even

when working under a scheduled route, are not able to cover the entire municipality on the same day. According to the server, for this suppressed demand to be met it would be necessary to increase the team, as well as the fleet of route trucks which should be five trucks.

There are other challenges related to the awareness of the population. Although the municipality of Itajaí is a reference in the issue of urban waste management: the selective collection, the regular trash collection system, the Cata Treco program, and more cleaners are applied. The server regrets, "even so the population puts their waste in vacant lots, sofas where they should not be put".

Despite the difficulties faced, the employee says that the initiative has generated positive results and opportunities: "we generate income for these people with the waste from the "cata - treco", and leave the city clean, organized, and beautiful". The Secretariat of Works makes available space for up to 1 cubic meter of disposal per citizen, which can include construction material waste. However, this benefit is only granted to individuals, i. e., only to citizens of the city. In the case of a legal entity, the employee advises that the company must be responsible for the disposal, and the Cata Treco program and the Secretary of Works are not responsible for absorbing this demand.

About the service metrics, the server informed us that the program does not perform a follow - up on the level of satisfaction of the service to the residents and that they collect about eight trunk trucks. The trucks have a capacity of up to three tons, but the weight can vary according to the load and material collected. A system to control the exact amount of materials collected per day has not been implemented. There is a base control of entry and exit of materials in the warehouse, performed with the materials that are reused and requests for removal of materials, making it possible to estimate an average per neighbourhood based on the service history. When the estimate is lower than expected, the trucks are redirected to other locations that have more demand.

The employee adds that the ideal is for the residents to contact the Department of Works through the Cata Treco's Conecta. í application, informing the material to be disposed of, remaining at the resident's home until it is removed. In cases where the materials are directly discarded on sidewalks, streets, or land, the resident who made the incorrect disposal can be fined.

The program is directly related to other actions that help improve the city's conservation and cleanliness. Every 15 days or over a longer period one of the Cata Treco trucks assists the campaign called Mutirão de Limpeza (Cleaning Task Forces). The Cleaning Task Force is a joint initiative of the Department of Works, the Municipal Department of Urbanism (SMU), and the subprefectures of the city of Itajaí that aims to serve the entire city.

The employee points out that the program helps many people, and the work is intense. He describes that besides managing the teams he ends up helping others: "people who work, [. . .] sometimes they come with problems from

home, we need to talk, help, have a word, I am a very good friend". Thus, resilience ends up motivating the whole team.

4.3 The Alfa Company

The Alfa company appeared in the municipality of Itajaí in 2018. The entrepreneur is a seamstress and produces upholstered furniture, sofas, pillows and mattresses, emphasizing that "the bed has a very good, acceptable sale, we do a neat job, very good, wood base, pine wood, we use spring, we use pressed foam, right, other foam, in the finishing of the bed.

The entrepreneur has lived in the city for about 10 years. With a high school degree and technical courses in fashion design and business management, she also works in a marina in town manufacturing upholstered furniture. In the year 2020, with the impacts of the pandemic, the manager reports that there was a drop in services at the marina. Concerned about keeping the jobs of all her team, she decided to direct her resources to the company Alfa, focused on manufacturing beds, and emphasizes that "the bed has a very good sale, acceptable, we do a neat job, very good, wood base, pine wood, we use spring, we use pressed foam, right, other foam, in the finishing of the bed. The model produced is a box bed type and among its components are: a pine wood base, fabric, foam, springs, and the entire assembly of the bed is performed in the company.

The manager adds, "I have customers, both small stores and the customer itself, direct sales, right", and points out that the beds produced have an excellent acceptance. In this sense, she invested in more machinery and equipment, as well as in the acquisition of materials for making the beds. The company employs 3 people, and with the increase in demand and production, foresees a team of at least 6 people. With the Covid - 19 pandemic came several opportunities and some difficulties, being necessary for the quick adaptation to maintain the business. The manager describes that due to the pandemic some inputs such as springs became scarce and her suppliers stopped supplying her. As a result, the company was forced to reduce its production capacity, "two companies supplied me with springs, so there was no shortage. But then Londrina stopped supplying us, São Paulo also stopped supplying us and then our factory started reducing its production because there was a shortage of springs". The weekly production was approximately 40 beds.

With the scarcity of this main raw material, the manager saw the opportunity to keep her company running by recycling: "Then came the idea of recycling this spring from mattresses that are thrown away [. . .] the spring is intact, it is light, there is no rust, there is nothing. Inside the mattress there is this use of springs, it is clean, there is no rust, there is nothing, you just don't let it get wet. For this recycling to be done efficiently, the manager invested in new equipment and tools: "I ended up buying pliers to cut springs, to cut springs. Because I thought that there would be a large quantity of them, that would supply the beds' needs. After some time, the number of mattresses for recycling decreased, just when he was planning to buy more tools and larger machinery to increase the production of beds and their components.

The frequency of mattress collection was reduced to two to three mattresses per week, and sometimes no mattresses were collected at all. The manager suggested that the creation of a central warehouse for the collected mattresses could be a solution to increase the amount available for recycling, and consequently, the greater use of the springs that are necessary inputs for the manufacture of their beds. Many times the collected mattresses are discarded or deposited in different places, and even exposed to the weather, which hinders the recycling of the material.

The creation of a program aimed at the centralized disposal and organization of these and other materials would facilitate the process of sorting and reuse of materials. These actions would, directly and indirectly, impact the generation of jobs and resources for the municipality itself: "because it's generating jobs right, [. . .] it's staying right here in the municipality. This bed is sold right here".

The manager has been seeking alternatives to establish a productive partnership and stresses that the reuse is important not only for her factory but also for job creation, revenue for the municipality, cleaning and organization of the city with the reduction of environmental impact. He describes the added value and the value chain that the handmade bed has and the cost - benefit: "the bed factory is something that worked out very well. I make a bed that everyone can afford, it's a comfortable bed, well made, handmade. A handmade bed, but very well made, with very good fabric".

As there was a reduction in the number of mattresses collected, the difficulty in acquiring springs once again hurt his business. He adds that the actions of cooperatives and associations in the city of Itajaí could optimize and improve the recycling system of the city and the region.

Regarding the dissemination of their products (beds), the manager reports that she uses social networks such as Facebook and the application *WhatsApp*. He highlights that he has many customers who are in *WhatsApp* groups, and when he advertises, the beds are sold quickly. "There, when production was good, when there were enough beds, we advertised in groups, we have several groups [. . .] and there it comes out very fast, people are interested.

Again, in the face of adversity, the manager states that due to the stop in the manufacturing of mattresses and aiming to keep her employees' jobs, she redirected her production to making armchairs: "Actually, I have the factory stopped. It is making armchairs, reinventing itself, because I don't want to send anyone away, I can't send anyone away. They are people that have been with me for a long time and it is not now, during this crisis, that I am going to stop working, we have to reinvent ourselves, to try to get out of this crisis".

4.4 Discussion of results

Solid waste management in a smart city needs to be developed as a way to decrease the intensive use of energy and greenhouse gases emitted in the creation of new products. Recycling is good for the environment because it

substitutes the use of virgin materials for scrap, conserving natural resources and reducing pollution.

It was found that the "Cata Treco" Program has a differential when it meets a request or request from a citizen for the collection of his or her material through the *Conecta*. *í* application. The collection made by the truck to a neighbourhood or community is already a differential because it is reducing the costs if the citizen had to go there to make the delivery. So, employing the planning of the SMO, the service presents efficiency in its provision.

With the collection of the material, the Cata Treco Program directs it to the cooperatives that perform the sorting of solid waste (paper, aluminium cans, electronics, personal computers, mattresses, furniture, paper, and glass) generating jobs and income for associated workers and contributing to a better quality of life for the population and to the sustainability of the intelligent city.

The Cata Treco Program brings positive results such as the reduction of air pollution because with the collection of solid waste fewer quantities of waste are stored in the city's landfill. Another point is the frequency that the truck passes through the neighbourhoods to make an effort for the servers and the management not to accumulate a large number of residues. On the other hand, it is important to point out that the number of trucks in the program is still small considering the number of inhabitants in the city and the number of requests for collection.

The program provides a stimulus for companies and organizations in the municipality to recycle, not only the waste generated but also the use of paper and packaging that comes from recycled raw materials. This local effort for a global movement to meet the Sustainable Development Goals (SDGs) no 12 - Responsible Consumption and Production by companies and citizens, no 01 - Eradication of Poverty through employment and income offered by *RECICLAVAL* and no 11 - Sustainable Cities and Communities with the management of solid waste implemented by the smart city.

In this study, the manager of the company Alfa needs the resources to run her company. It is an example of entrepreneurship that can be replicated in other cities with better management of the availability of resources used by companies. It can be highlighted that recycling can conserve wood, springs, and inputs that still have a life cycle and that are reused for the production of new materials or products. The development of the circular economy is relevant (Lakatos et al., 2021; Sgroi, 2022). It can be seen that employment and income from recycling need to play a more prominent role in the development of public policies that strengthen municipal actions.

5. Conclusions

This article aims to highlight the management of solid waste in the development of a smart city located in Santa Catarina, Brazil. It was found that the development of sustainable smart cities requires the use of collaborative technologies that can assist in reducing social problems (Alperstedt Neto,

Rolt, & Alperstedt, 2018; Bamwesigye, & Hlavackova, 2019), for social welfare and economic development.

This research presented the Cata Treco Program developed by the Municipal Secretary of Works (SMO, 2020) and partnership with the Secretary of Technology (SETEC) of PMI highlighting the actions and attributions of the program with the neighbourhoods. A theoretical review of the concepts and published works related to sustainable smart cities and waste management was conducted to integrate the theory with the analysis of the Cata Treco Program.

The results revealed that the municipal government has a primordial role in the application of the National Solid Waste Policy, through its management for the adequate disposal of the waste generated. It was also verified that the Cata Treco Program is important for the recycling and treatment of solid waste that brings benefits to the environment and the neighbourhood community.

The research presents the guiding question: How has the city's Waste Recycling Program been promoting social, economic, and environmental development for its residents? It can be seen that the "Cata Treco" Program promotes social, economic and environmental development, but that it needs to readjust some actions, such as the redirection of used mattresses so that it can better reach those in need. The work presents this case, but it can be seen that other demands (MDF wood) need to be aligned with the program.

The work contributes to the study of the implementation of public policies that can bring improvement actions that influence the environment, especially on the issue of cleanliness, the correct disposal of the waste generated, and for entrepreneurship, actors who use this ecosystem to generate income.

In generating future research, we suggest the development of qualitative research with other entrepreneurs who also use the resources of the program, with the employees of RECICLAVALE and a study with the garbage collectors of the city.

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