Circular business model through the recycling of scrap tires: A case study in the city of Manaus

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ABSTRACT

The article describes a case study of reverse logistics of scrap tires in the city of Manaus. The study concerns a company that transforms scrap tires into new products, closing the production cycle, following the principles of the Circular Economy. The objective is to verify and collect information about the process of reverse logistics of tires in the city of Manaus carried out by a transformation company, whose main production input is scrap tires. In order to achieve the expected result, bibliographic research, searches and consultations of statistical data from official agencies, on-site visits and interviews with the company's management were carried out, along with observations of the processes. The survey results in several barriers faced by the company in adopting a circular business model. Reverse logistics for the collection of end-of-life tires, in the city of Manaus and in the interior of the State of Amazonas, still faces several logistical bottlenecks for tire collection; There is no greater dissemination or awareness of this service in the production chain and there is a large amount of tires that are not properly disposed of. The study points out a series of opportunities for improvement in the creation and production of various products using tires as the main input. The reuse of tires emerges as a new Circular business model, for a change of paradigms and culture, combining a more conscious consumption, with a destination aimed at monetizing a waste that would be incorrectly disposed of in the environment.

Keywords: Circular Economy, Reverse Logistics, Scrap Tires.

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INTRODUCTION

In recent years, the vehicle fleet in Brazil has shown a considerable increase. According to data from the National Traffic Secretariat - SENATRAN, an agency of the federal administration, in April 2022 there were 112,444,241 vehicles registered throughout the national territory, this is equivalent to 41 million tires produced per year in the country (BORGES *et al*., 2021). The State of Amazonas follows this growth and the problem materializes in places of random disposal, which fatally turn into addictive points of disposal. This improper disposal is favored mainly by the proximity of urban areas to the areas of the Amazon rainforest. The lack of oversight by the responsible bodies opens up a space to be frequently filled by business and non-governmental initiatives that turn actions into results.

The research problem in question is "What are the solutions identified, by the company in question, to solve the problem of the large amount of scrap tires in the city of Manaus?". Thus, the objective of this study is to explore the business model of a company that transforms scrap tires into new products using reverse logistics as a circular economy practice to close the production cycle, by demonstrating the possibility of manufacturing products with differentiated inputs. Research on the applications of circular business models and tire reverse logistics practices in the state of Amazonas is still little explored, which demonstrates the importance of such research.

By keeping up with society's demands, companies have adopted practices and actions that contribute to closing the cycles of production and consumption by using sustainable strategies and practices such as those of Cradle to Cradle (McDONOUGH; BRAUNGART, 2010), Industrial Ecology (ANDERSEN, 2007) and Circular Economy (ELLEN MACARTHUR FOUNDATION *et al*., 2015; GHISELLINI *et al*., 2016; KORHONEN; HONKASAL, 2018). The circular economy acts on aspects that signal and enable practices to narrow, slow down and close the resource loop of recyclable products and thus prolongs and develops a new cycle for end-of-life products (BOCKEN *et al*., 2016).

Reverse logistics is an important circular economy strategy that works in favor of environmental policies by allowing the closure of production chains, such as end-of-life tires, as it is an item of great potential to be explored (ELLEN MACARTHUR FOUNDATION *et al*., 2015; BOCKEN *et al*., 2016). Tire reverse logistics is a market that still has great possibilities for expansion. Data from the Ministry of Transport (2023) indicate that approximately 1,083,624 motor vehicles circulate in the State of Amazonas, which in turn translate into a large amount of tires circulating in the environment at the moment and that will be available for disposal in the future.

The study is structured in five sections. In the first section is the introduction, with the justification and objectives of this work. In the second, the theoretical foundation with a review of the literature on circular economy, production process and disposal of tires, reverse logistics and reverse

flows. The third section describes the methodology used in the research and, subsequently, the results of the case study. In the fifth section, we present the final considerations and, finally, the references used.

THEORETICAL BACKGROUND

In the theoretical foundation of this work, a circular business model is presented, which uses reverse logistics for the proper collection and final disposal of scrap tires. The importance of the reverse logistics of tires as a mitigating factor of the negative impacts caused by the incorrect disposal of tires on the environment.

CIRCULAR ECONOMY AND REVERSE LOGISTICS

The current consumption model, known as the linear model (EL) of production (extracting resources from nature, transforming, using and discarding) has faced limitations, especially regarding the need for continuous exploitation of natural resources (LIEDER; RASHID, 2016). The consequences of the current consumption model have led companies to adopt strategies aimed at combating waste and creating new markets and trends with recycling. The circular economy is a strategy that aims to adopt new sustainable business models with products already discarded or discarded with no value. According to Murray *et al*. 2017, circular economy is understood as an economic model that does not have any net effect on the environment; on the contrary, it restores any damage caused in the acquisition of resources, by ensuring that little waste is generated throughout the production process and in the life history of the product. The search for reducing impacts, advocated by the Circular Economy, has innovation as an essential tool to ensure this mitigation in the environment. In a circular model, the retention of value loss can be accomplished through technological innovation in SMEs (Small and Medium Enterprises). Thus, technologies are also important in closing the cycle of the value chain between the waste and energy production process, in addition to assisting in the reuse of waste (DERHAB and ELKHWESKY, 2023).

The current model of industrial development is responsible for the immense accumulation of waste. This is a model of democratic development, as it is present in all societies, whether developed or not. According to Halog and Aniele (2021), the problem of this waste is generally a global problem, which affects all countries, whether developed or developing countries. To ensure that future generations will have sufficient resources such as food, water and prosperity, it is therefore necessary to transition from a linear economy to a CE one. The implementation of circular economy (CE) principles is increasingly recommended as a convenient solution to achieve the sustainable development goals (SAIDANI *et al*., 2019).

Reverse logistics plays an important role in the application of product life cycle assessments,

since it reduces the generation of solid waste and its proper management, helping the processes of obtaining inputs and equating post-consumer products (SANTOS *et al*., 2013). Reverse logistics has been a differential in modern companies that have realized that the consumer has become more ecologically sensitive, and more and more laws related to the environment are being created (GABRIEL *et al*., 2020).

THE CIRCULARITY OF TYRES

The correct disposal of large-scale manufactured products, after their useful life cycle, has challenged societies to find solutions that postpone their disposal in the environment as much as possible. This effort for a solution aims to find a method that solves this situation, which for many scholars, will only be achieved through actions that promote sustainable attitudes at the time of disposal of commercialized products. In a universe of great varieties of solid waste and its harmful consequences, tires, commonly known as tires, have their prominent place as a problematic item in terms of disuse and disposal, despite their unquestionable usefulness in human needs, the tire industry is making significant efforts towards a greener and more sustainable production. taking into account CO2 emissions, recycling, material sources and implementation of the use of plant-based biomass instead of petroleum-derived alternatives. When talking about sustainability in the context of tires, the usual interpretation is about the use of raw materials, recycling of raw materials, circular economy, and material sourcing (TRUSSO *et al*., 2022).

THE PRODUCTION AND DISPOSAL OF TIRES

An essential component in the performance of motor vehicles, the tire is a complex of natural and synthetic rubbers, wires, cables, tarpaulins, steel wires, nylon and polyester that form a resistant structure that has the attribution of meeting rigorous technical specifications that encompass safety and durability. Among the products that reuse rubber from tires, there are mainly materials used in rainwater ducts, sealing items, soles, industrial floors, sports floors, carpets for automobiles and compounds to be added to asphalts, but even with the existence of technologies that enable the reuse of this type of waste, there is still no effective destination and its incorrect disposal, It is an environmental problem in most cities due to non-compliance with reverse logistics and its enforcement.

According to the National Association of the Tire Industry (ANIP), approximately 52 million new units were sold in Brazil in 2020. Also according to ANIP, in 2017, about 90 million units were collected for subsequent recycling, and 71 million tires were produced, that is, the collection of scrap tires exceeded about 20% the number of new units produced (GABRIEL *et al*., 2020).

In Brazil, approximately 450,000 tons of tires are discarded per year, which is equivalent to

about 90 million units used in passenger cars. According to data from Reciclanip, in ten years, the correct disposal of this type of material prevented more than 3.7 million tons of tires from ending up in the wrong places. (SILVA *et al*., 2022).

According to the Resolution, tire manufacturers and importers have to respect deadlines and meet targets in order to reduce the environmental liability of tires. This forces companies in this area to practice reverse logistics programs for the collection, use and return of tires that no longer serve companies that are qualified to dispose of them in an environmentally appropriate manner (CONAMA, 2009).

However, when the tires reach the end of their period of use, becoming inoperative, in addition to becoming a reason for precaution and fear about the environment, there is a marketing opportunity for many institutions that operate with the offer of products or services aimed at reverse logistics, reuse, reprocessing and recycling, which enable the continuation of the follow-up and, in a way, they put waste back into the useful and profitable cycle in the production chain (MELO *et al*., 2018).

REVERSE LOGISTICS AS A STRATEGY FOR THE DISPOSAL OF TIRES.

The National Solid Waste Policy, enacted with Law No. 12,305/2010, establishes a sectoral agreement between manufacturers, distributors, and traders, regarding the need to properly dispose of used and unusable tires (OLIVEIRA, 2021). Tires that present irreversible damage to their functionality are called unserviceable, which need to be disposed of correctly through insertion into their logistics chain and reverse flow that allows the product to have an environmentally correct destination.

Resolution 416 of September 30, 2009, of the National Council for the Environment, determines that manufacturers and importers of new tires, weighing more than 2 (two) kilograms, must collect and dispose of unserviceable tires existing in the Brazilian territory, while determining collection points in municipalities with a population of more than 100 thousand inhabitants. The legal provisions related to the subject matter allow for a greater debate regarding reverse logistics practices as an efficient method to implement them. However, the environmental liability related to scrap tires still poses a considerable threat to the environment and public health.

Reverse logistics has been essential for this waste to return to the production chain cycle with the viability of the recycling network, providing economic health through the reuse of products and parts after consumption. In relation to tires, the biggest obstacles are picking up and driving, because of the difficulty of picking up and the large volume, which hinders locomotion, because the procedures often become unfeasible (OLIVEIRA, 2021). The concern with the problems generated in the environment, caused by the incorrect disposal of waste resulting from a company's production

process, as well as the disposal of waste generated by the end of the useful life of some products and their packaging (GABRIEL, 2020), has led to the emergence of companies that implement sustainable and profitable actions for the local economy, tire disposal is a product that has awakened and made this market viable.

Tires have their unquestionable positive utility today, without which, transport as we know it would be unfeasible. On the other hand, when they become useless due to wear and tear due to use and deterioration due to time of use, their improper disposal causes great damage to the ecosystem, since their deterioration is very slow and, when disposed of inappropriately, they pose risks to public health, the environment, with probable emission of toxic substances into the atmosphere. in addition to generally becoming breeding grounds for disease-transmitting mosquitoes (CONRADO, 2009).

APPLICABILITY OF TYRES

Chart 1 summarizes research papers on the applications and reuse of scrap tires.

Table 1 – Applicability and destination by authors

Authors	**Tire Applications**
IGLÉSIAS, Fabricio Agrizzi *et al.* Characterization of the Reverse Logistics of Automotive Tires in Brazil. Integrated Faculty of Aracruz. Department of Production Engineering. Aracruz. ES.2019.	Addition of rubber powder from the shredding of scrap tires to the asphalt mix. Asphalt-rubber has a longer useful life, in addition to generating a lower noise level and offering greater safety to road users.
RODRIGUES, J. R. F.; BEZERRA, L. G. S. Main techniques for the reuse of scrap tires in Brazil. Rev. Bras. Gest. Amb. Susten. [online]. 2021, vol. 8, n. 20, p. 1407-1417.	The tires are disposed of through a recycling process where they are shredded and the powder is transformed into carpets, slippers and asphalt. Of the ten works identified, three discuss the reuse of unserviceable tires as concrete/concrete block for use as interlocking flooring for sidewalks, guides, gutters and urban furniture, three discuss the use in mortar, whether cement or lime, two about reuse in asphalt, and two others classified as "other uses" refer to the use in agglomerated panels and as thermal insulation.
SILVA, Antonia Félix *et al.* Sustainable fashion: reuse of scrap tires. Federal Institute of Education, Science and Technology of Piauí, Teresina Sul Campus. 2022.	Brazilian researchers are turning tires into gasoline. Researchers from the Federal University of Pernambuco (UFPE) have shown that it is possible to convert one ton of old tires (about 75 units) into 300 liters of fuel, enough to run about 3,600 kilometers in a popular car. (Diário de Pernambuco, 2018).
VUCOVIC, Nicolas Fernandes. Evaluation of alternatives for disposal and reuse of tires: Incorporation into the asphalt mass for the production of rubber asphalt. 2021.	Tires can be used as fuel for the production of electricity and also as a filler in the clinker furnaces of the cement industry.

Source: Prepared by the authors (2023)

RESEARCH METHODOLOGY

The methodological procedures adopted in this work were outlined by the bibliographic research, and the type of research used is characterized as exploratory and descriptive. Data collection involved the technique of indirect documentation, particularly data from secondary sources. The information available on the web, such as the website of environmental regulatory agencies and associations linked to the tire segment, was analyzed.

In the bibliographic research, through the descriptions of qualitative studies, consultations were carried out in articles containing subjects such as concepts and definitions to strengthen the foundation and deepening of the study by following the theme addressed. A survey was carried out regarding the number of vehicles in the State of Amazonas, with the consequent projection of the number of tires available in the most common types of vehicles in Brazilian society.

As for the research approach, it is qualitative, as it will provide information for us to understand the process of transition to circular business models, with a case study in a company that adopts sustainable practices that meet the principles of the circular economy. It is a manufacturer of rubberized flooring in the city of Manaus that uses scrap tires as its main input. For the feasibility of the research, two technical visits were carried out, previously scheduled for the application of a research instrument (interviews) in the company itself, with questions pertinent to reverse logistics and the effectiveness of the commercialization of the manufactured products. The interviews were conducted with 2 (two) employees, one of whom was a production coordinator who explained the entire process of transforming the elastomers of the tires; the second interviewee was the Executive Director who presented the strategic guidelines along with the company's current and future planning.

In the interview, subjects that were the basis of the research in the field were addressed, some guiding questions collaborated with the study, among them:

a. Has the company been able to carry out Reverse Logistics for the collection of unserviceable and discarded tires in the city of Manaus?
b. At what point does the registration of the place to be collected from the tires begin and at what time and how often does the collection vehicle start?
c. What is the relationship between the researched company and other tire collection associations or organizations?
d. What is the relationship between the company and the authorities of the Manaus city hall?
e. What are the bottlenecks faced in the collection and production of consumer goods?
f. What is the planning and forecast for the beginning of the collection of tires in the interior of the State of Amazonas?
g. What is the daily quantity of processed tires, processed products and finished products?

h. What are the products made from recycled tyre?

i. What is the current production capacity?

j. Is there waste at the end of the production process?

To achieve the proposed objective, the methods of study of tire recycling processes in a company, within the modality of circular economy, in the city of Manaus, together with bibliographic research, documentary research in official bodies related to the segment studied, laws, regulations, reports and photographs. With all the data, information was built that, in turn, was analyzed to architect and structure knowledge and provide new possibilities within the benefits of the Circular Economy.

ANALYSIS AND DISCUSSION OF RESULTS

The company in the case study is AMERA (https://amera.com.br/), a company established in the Manaus Industrial Complex, being a pioneer company in the collection, recycling and production of 100% sustainable materials, made of rubber. The organization was born in 2022 with the purpose of transforming the latex market through the circular economy, reducing the impact of deforestation in the Amazon region. Through the principles of the circular economy, strategies were adopted for cleaner production, using fewer natural resources. A genuinely Amazonian company that meets all environmental certifications, therefore legally qualified and supported to operate in the market.

To carry out the research, an *on-site visit was carried out to* better verify all production processes, from collection to production of the final product. In this visit, the separations by types of tires were observed, the removal of the steel wiring that supports its edges by a specific machine, the cuts of the tires to break their internal structure, forwarding of the cut rubber to a shredder machine with output in 3 (three) different sizes of grains, after which came the manufacture of the different objects. By getting to know the company, we had the opportunity to see in depth the entire process and how the activities are carried out, from the collection of tires to the manufacture of the product. In the visits we carried out, we saw the separation of the types of tires, how the shredding is carried out, the transformation and the entire production cycle of the finished product.

The daily shredding comprises approximately 1450 tires, which results in 12 tons of the so-called "chip" which is a rustic shredding whose result is pieces of approximately 3.0 cm by 2.0 cm. A second crushing results in the raw material of 2 different granulations separated by mechanical processes, for a total of 7 tons ready to enter the final production line. There is also a very fine 3rd granulation, which at the moment is classified as tailings and therefore stored until the appropriate destination is found. Currently, due to limitations of machinery and raw material due to the scarcity of collected tires, only treads in 2 (two) different sizes are produced and sold: 1.0m x 1.0m and 0.50m x 0.50m.

The biggest bottleneck faced by the recycling company is in two points:

a) due to the logistical limitation represented by the collection of tires in the capital Manaus, which is paid for by the recycler when it involves small businesses and small tire shops, through its own truck and by a second truck made available in partnership with the municipal government. The large tire dealers, on the other hand, arrange and pay for the delivery of these unusable items and in exchange, receive a certificate of correct environmental disposal.

b) due to the lack of registration of small businesses and rubber shops. Such a list would facilitate the planned and scheduled collection with the rationalization of costs and time savings.

The potential of raw materials in the capital Manaus is great, as well as in the entire state of Amazonas, but the costs are high and the need for partnerships is still necessary to enable reverse logistics with environmental benefits. The company faces some logistical bottlenecks in the primary collection of tires, as this process is restricted to the company's own truck, and another in partnership with the city hall. A projection of the approximate number of tires currently circulating in the capital Manaus and in the interior of Amazonas can be seen in table 1, whose total quantity expresses the future possibility of tire availability. These numbers remind us of the great potential to be explored.

Table 1 - Vehicle Fleet - July 2023

Vehicle Types	**Number of Vehicles in the State of Amazonas**		**Number of pneus per**	**Projection of the amount of tires in the State of Amazonas**	
	Manaus	**Interior**	**vehicle**	**Manaus**	**Interior**
Car	424.690	26.930	04	1.698.760	107.720
Truck	18.468	4.307	10	184.680	43.070
Truck - Tractor	4.516	344	04	18.064	1.376
Pickup truck	90.407	13.229	04	361.628	52.916
Pickup truck	27.569	2.434	04	110.276	9.736
Minibus	3.115	602	06	18.690	3.618
Motorcycle	243.833	114.445	02	487.666	228.890
Scooter	29.199	56.570	02	58.398	113.140
Bus	9.137	1.494	06	54.822	8.964
Trailer	4.396	509	02	8.792	1.018

Semi-trailer	14.500	838	12	174.000	10.056
Tricycle	1.298	976	03	3.894	2.928
Utilitarian	7.568	364	04	30.272	1.456
TOTAL	**878.696**	**223.042**		**3.209.942**	**584.888**

Source: Data collected by the authors (2023)

Table 1 presents updated data from the Ministry of Transport for July 2023 with the number of tires currently used by the number of the main vehicles registered with DETRAN - AM. To arrive at the total, the number of tires was taken into account by the type of each vehicle registered in the government database. Considering the numbers and types of vehicles and tires listed in Table 1, when multiplying the number of tires that each type of vehicle uses, we find the totals in the Capital Manaus and in the interior of the state. In this calculation, we have a total of 1,101,738 vehicles in the State of Amazonas with the number of tires at approximately 3,794,830. When making a quick comparison, and considering IBGE data (2022), with a territorial area of 1,559,255.881 km², the State of Amazonas has 2.53 inhabitants per km², while it has 410.89 tires per km². This calculation of tires/km², although approximate, leads to the classification of a potential number due to the fact that such tires are still in use, running on the various vehicles or in the process of being replaced. This comparison validates the concern, in quantitative terms, of the significant number when reasoning with the improper disposal of these items. The National Solid Waste Policy, governed by Law No. 12,305/2010 (PNRS), has its essence focused on compliance with each imposition, so that any and all disposal is done correctly, where it aims to contribute to the established standards (SILVA, 2021).

NUMBER OF TYRES NATIONWIDE

In the searches carried out via the website, information was found about an institution that adopts the reverse logistics system for scrap tires at a national level. Reciclanip is an entity that brings together the largest manufacturers of this product in Brazil. It organizes the so-called reverse logistics, i.e., the collection of unusable tires and their correct disposal (SILVA, *et al.*, 2022). Brazilian tire manufacturers disposed of 441 thousand tons of scrap tires in an environmentally correct manner in 2022. The program is developed through partners, in most cases with municipalities, which provide a plot of land within specific safety and hygiene standards. This place is used to collect and store material from various sources, such as tire shops, resellers and the citizens themselves.

QUANTITY OF TYRES AT REGIONAL LEVEL

In the state of Amazonas, companies have implemented sustainable practices to minimize the environmental impact in relation to discarded tires, however, such conducts are still limited to only 2 (two) cities. According to the PNEUMATIC REPORT – 2022 (IBAMA, 2022), there are 11 collection points for scrap tires registered in the State of Amazonas, 10 in the capital Manaus and 1 in the city of Parintins. Although there are 11 collection points within the state, the collection capacity limit is 14,198 unusable units. This number of collections does not meet the projections of disposal within the State of Amazonas, according to the figures described in Table 1. It is taken into account that Amazonas still has 60 municipalities without mandatory collection points, because they contain a population of less than 100,000 inhabitants; there is also not much dissemination of information or news about Tire Management Programs (PGP) in other cities in the countryside, as prescribed in specific regulations.

Based on field research carried out, it was observed that the researched company accumulates a waste that can be added to other compounds that can be transformed into a product to be viable for the local economy. However, it is still very premature, because we must carry out research and measure the feasibility of the business to propose research and development on the Manaus campus together with the support of companies that may be interested in this niche that can add value to this waste.

FINAL THOUGHTS

The proper disposal of solid waste is one of the great environmental challenges to be solved. Due to the increasing number of vehicles in Brazil, the generation of scrap tires assumes worrying aspects corroborated by this research, but at the same time explores the great potential that reverse logistics, as a tool of the Circular Economy, presents us with an economically viable opportunity from a waste that was considered waste decades ago. Thus, this research also sought to highlight the concern in identifying solutions for tires at the end of their useful life in the manufacture of other products, combining economic and environmental sustainability.

The research of the activities developed that involve scrap tires as raw material, contributes to obtaining accurate and necessary information to demonstrate which state of Amazonas establishes, based on Law No. 5,737/2009, that companies exercise their demands for the disposal of scrap tires in a sustainable way. The statement by the current Governor of the state of Amazonas, Mr. Wilson Lima, expresses a trend: "Now companies will be forced to assume the environmental responsibility that is theirs" that marks another step towards the application of reverse logistics, said Eduardo Taveira, Secretary of State for the Environment. The company, a pioneer in the segment, has already carried out this work and increasingly intends to expand the engagement and support of small traders,

rubber workers and companies in the industrial district.

In this way, the present work observed and analyzed the production, mapped production processes, the logistical planning of tire collections, ascertain and ponder in a more scientific way the correct destination of a product considered waste until now. The researched company adopts principles of the Circular Economy, by entering the market with an innovative business proposal manufacturing rubberized floors using waste (tires) as raw material. This innovation of the business model that creates value from waste, in such a way as to slow down the consumption of virgin inputs, narrowing and/or closing the production *loop*, which is in accordance with the work of Bocken *et al*., (2016). Regarding recycling, Bocken *et al*., (2016) emphasize that "residual" resources should be recycled, becoming materials with properties equivalent to those of the original material. This requires primary (closed-loop) recycling, also known as upcycling."

Future research may deepen studies to verify the economic and productive feasibility of the finer granulation, considered as tailings and stored until the correct feasibility of use is found. Laboratory research at facilities of the Federal Institute of Education, Science and Technology of Amazonas will be necessary for possible partnerships, with a focus on obtaining new products. Negotiations are already being carried out to coordinate, plan, develop and enable the actions that perpetuate this proposal. It is necessary that all fields of knowledge seek to produce solutions to the complex issues that are presented to us (VENTURE *et al*., 2021).

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