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TIRE RECYCLING AND PROFITABILITY IN AUTOMOTIVE VEHICLE MAINTENANCE AND REPAIR COMPANIES IN THE MAULE REGION

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Abstract. This study presents an approach to the growing market of rubber available for recycling, incorporated into the costs of the evaluation of projects related to tire recycling, for which the behavior of companies related to the economic activity of maintenance and repair of motor vehicles in the Maule region in Chile is studied. The topic corresponds to the field of research on environment, quality and prevention and will be framed in the Law of Extended Producer Responsibility and Promotion of Recycling, recently enacted in the country. The methodology used will consider a systemic model composed of inputs, processes and outputs, as well as standards and resources. To establish the inputs, it will be necessary to resort to primary sources of information, which will involve identifying the population of companies that generate tires and determining the sample to be measured through the use of information collection tools and designed so that they can satisfy acceptable scientific criteria, which can be applied by other researchers and their results can be validated, statistically and corroborated by secondary sources. When a real case was used for a given population, a cross-sectional descriptive design was used. The result of the analysis of the information obtained by the SPSS statistical software for quantitative methodologies, determines the discussion and conclusions.

Keywords: Recycling, tires, rubber, recovery, Hevea brasiliensis.

RECICLAJE DE NEUMÁTICOS Y RENTABILIDAD EN EMPRESAS DE MANTENIMIENTO Y REPARACIÓN DE VEHÍCULOS AUTOMOTORES DE LA REGIÓN DEL MAULE

Resumen. Este estudio presenta una aproximación al creciente mercado del caucho disponible para reciclaje, incorporado en los costos de la evaluación de proyectos relacionados con el reciclaje de neumáticos, para lo que se estudia el comportamiento de las empresas relacionadas con la actividad económica de mantenimiento y reparación de vehículos automotores de la región del Maule en Chile. El tema corresponde al campo de investigación del medio ambiente, calidad y prevención y estará enmarcado en la Ley de responsabilidad extendida del productor y fomento al reciclaje, de reciente promulgación en el país. La metodología utilizada, considerará un modelo sistémico compuesto por entradas, procesos y salidas, además de normas y recursos. Para establecer las entradas, será necesario recurrir a fuentes primarias de información, lo que implicará identificar la población de empresas que generan neumáticos y determinar la muestra que se medirá a través del empleo de herramientas de recolección de información y se diseñarán para que puedan satisfacer criterios científicos aceptables, que puedan ser aplicadas por otros investigadores y puedan ser validados sus resultados, estadísticamente y corroborados mediante fuentes secundarias. Al usar un caso real para una población determinada, se utilizó un diseño descriptivo transversal. El resultado del análisis de la información obtenida mediante el software estadístico SPSS para metodologías cuantitativas, determinan la discusión y conclusiones.

Palabras clave: Reciclaje, neumáticos, caucho, valorización, Hevea brasiliensis.

Introduction

This study aims to describe the characteristics of the recently created tire recycling market in the Maule region of Chile and to compare the recycling process among the provincial capitals of the region and contribute to solving an alarming environmental problem of concern to the scientific community, by encouraging the disposal of unused tires, preventing them from accumulating in landfills, seas, rivers, lakes, wastelands, deserts, or being burned inappropriately, posing risks to society, such as fires, infectious outbreaks, and disease transmission.

Studying tire recycling in this region of Chiles is relevant since this information allows us to identify the provinces that need to recycle the largest quantities, the sale prices in the new market, and the risk that may arise when tires are improperly stored.

Chile's macroeconomic indicators present a Gross Domestic Product Per Capita at Purchasing Power Parity (GDP Per Capita PPP, USD-FMI) of US$ 24,744 for 2018 (Central Bank of Chile, 2018), which has produced an increase in the aggregate demand components, impacting the growth of transportation needs and affecting the automotive fleet, which reached 4,680,533 units in 2017 (Cámara de la Industria del Neumático de Chile A.G., 2018). The growth in automotive demand has led to an increase in the number of tires incorporated into new vehicles, and also in the number of tires available as replacements to be used when first-use tires are discarded.

In 2017, 134,860 tons of end-of-life tires were generated in Chile, which is about 10% higher than the 122,757 tons generated in 2016. Regional statistics reveal that the Maule

region contributes 7.9% of end-of-life tires of the country's total (Cámara de la Industria del Neumático de Chile A.G., 2018).

The disposal of tires produces environmental contamination in several ways, such as solid waste as potential shelter for rodents and insects, fire sources that generate air pollution or soil, and groundwater contamination.

This research presents the problem of cost increase in recycling projects, as a result of the creation of a market in the context of the implementation of the Extended Producer Responsibility Law and the promotion of recycling. This type of projects contribute to the decontamination through an industrial recycling system, environmentally friendly, to transform it into a finished product based on rubber, according to world class recycling standards, with quality, innovation, and satisfactory results and with the environmental standards to make it sustainable over time. Likewise, mitigating the environmental impact and the consequences on the health of the population caused by the incineration or inappropriate storage of end-of-life tires, which requires quantifying the available raw material that will allow determining the required plant size for an investment project in a recycling plant for this material.

End-of-life tires are a product with great potential for utilization because they are composed of rubber, metal and textile fiber, which can be separated, transformed, and reincorporated into new production processes through recycling operations (Zarini, 2011). It is important to increase interest in reducing the environmental impact produced by end-of-life tires by reusing them through sustainable methods, which at the same time generate profitability, within the framework of the Law on Extended Producer Responsibility and Promotion of Recycling, which obliges tire producers, whether they are manufacturers or importers, to take care of the waste derived from these products at the end of their useful life.

The study contributes to solving an alarming environmental problem of concern to the scientific community by encouraging the control of the disposal of unused tires, preventing them from accumulating in landfills, seas, rivers, lakes, wastelands, deserts, or from being burned inappropriately, posing risks to society, such as fires, infectious outbreaks, and disease transmission.

The accumulation of tires should be managed through a productive process from a polluting waste that is not biodegradable to a useful good, taking advantage of the existing technological capacity, with the objective of implementing a recycling plant that is adequate, sustainable, and generates profitability from the financial point of view, adding products with value to society (Olivares, 2016). The problem is aggravated by the incineration of accumulations since this fact produces dangerous atmospheric pollution due to the combustion of toxic components.

Tire recycling in Chile is a recent issue that has become important, mainly because in the last decade the ecosystem in several regions of the country has been affected by this cause due to the fact that private self-regulation has not been sufficient to provide an adequate solution to the acute problem of pollution caused by the collection of end-of-life tires. This has led actors such as the state of the republic and the land transportation industry to seek solutions to the accelerated generation of this negative externality, within a framework of cultural change that in each new generation awakens more and more ecological sensitivity and societies that press for change to be instrumentalized.

The greater ecological awareness of the new generations (Pavez, Leon & Triadú, 2016) responds to a global phenomenon, which has produced effects on legislation in several

countries, including Chile. Since a few years ago, the Chilean state has shown the willingness to implement a law that extends the responsibility to the producer who generates waste, so as to encourage its recycling through a partnership with a third party, with gradual implementation.

On July 01, 2016, the Law of the Republic of Chile number 20,920 on extended producer responsibility and promotion of recycling and its regulations that are established by two Decrees, Decree 7 associated to Article 31 of the Law and Decree 8, associated to Article 4 of the Law, are enacted. Among the wastes considered in this Law of the Republic are end-of-life tires. This law obliges producers, who are manufacturers or importers of priority products, to take care of the waste derived from their products at the end of their useful life.

According to Law 20.920, priority products are lubricating oils, electrical and electronic equipment, batteries, containers and packaging, tires, and batteries.

The criteria for choosing these products are their mass consumption, their significant volume, the generation of hazardous waste, the feasibility of recovery, and the possibility of comparative regulation between them. The end-of-life tire in particular meets all the criteria with the exception of the hazardous waste criterion.

The Law itself defines its objective of reducing the proliferation of this waste and promoting its reuse, recycling, and recovery through the determination of the producer's share of extended responsibility and also determines instruments for the management of this waste in order to protect human health and the environment.

It is the obligation of the entities that generate waste to use an authorized manager for its adequate treatment, unless it decides to manage it by itself, considering that its storage and management must comply with the legal regulations in force at the time (National Congress, 2016).

It is intended to encourage recycling management at the end of the life cycle of products, tending to significantly improve the system of collection, storage, and recovery of materials. Instead of supplying landfills with waste or exporting it to other countries for recycling, it is proposed to take responsibility for the waste generated in Chile, thus make the most of the waste materials produced. Concretely, this law constitutes an economic instrument for waste management that defines the actors who have complementary roles and obligations to achieve such management. (Raglianti, 2018).

The generator of the priority product must register in a public registry, organize, and finance the collection and treatment of priority products, ensuring that the treatment is carried out by authorized managers and must also comply with certain goals and obligations defined by the Ministry of the Environment.

The consumer of the priority product must deliver the end-of-life product to an official waste manager. In the case of an industrial consumer, he may recover his waste himself.

Waste managers, on the other hand, are entities registered with the Ministry of the Environment, whose mission is to declare the type, quantity, costs, origin, treatment, and destination of waste in order to ensure the long-term traceability of waste. Waste managers include collectors and recovery companies.

The Ministry of the Environment has the obligation to establish goals to be followed for priority products, implement and manage the registration system for product traceability, prepare regulations to govern the entire process involved in the Law, and propose environmental education programs to make recycling something intrinsic to consumers.

Other actors are importers and exporters. Extended producer responsibility corresponds to a special waste management regime, under which producers of priority products, such as tires, are responsible for the organization and financing of waste management of the priority products they market in the country (National Congress, 2016).

Decree 7 dated March 17, 2017, associated with Article 31 of Law 20.920, regulates the fund for recycling and states its object that the Ministry of the Environment will have a fund for the prevention of generation, promotion of reuse, and recovery of waste, whose purpose is the total or partial financing of projects, programs, and actions that prevent the generation of waste, promote its separation at source, selective collection, its reuse, recycling, or other type of recovery, executed by municipalities or associations thereof (National Congress, 2017).

Decree 8 dated March 17, 2017, associated with Article 31 of Law 20,920, regulates the procedure for the elaboration of the Supreme Decrees established in said Law (National Congress, 2017).

The Extended Producer Responsibility Act is based on at least the following principles: free competition, transparency, and polluter responsibility, so that "the polluter pays."

They apply to producers, which the Law itself defines as any person who, regardless of the commercial technique used, sells tires as a priority product for the first time on the domestic market or imports it for his own professional use.

In the case of new tires, there are two types of markets globally, the new tire market, which supplies tires for the vehicle industry and for rolling machine manufacturers, and the dedicated replacement market, which allows consumers, carriers, and other companies to have a supply of tires needed to replace those that, due to wear or deterioration, can no longer operate.

Those tires manufactured for original equipment technically do not present significant differences with those manufactured for replacement since both provide the same performance to the vehicles in which they are installed and, therefore, the environmental impact that any of them will have at the end of their useful life will be exactly the same (Cámara de la Industria del Neumático de Chile A.G., 2018).

According to the Chilean Tire Industry Chamber A.G. (2018), in Chile there are practically no vehicle assembly plants, so all original equipment tires enter the market as replaceable components in imported vehicles. For the replacement market, there is only one tire factory in Chile, located in Maipú and owned by "The Goodyear Tire & Rubber Company," a North American company with headquarters in the city of Akron in Ohio, United States. This is a technologically complex plant that produces high-performance tires for passenger cars and light trucks for export markets, of which only a small quantity is sold in the local market. For this reason, just as for the original equipment tire market, it can be considered that the replacement tire market is also composed, almost entirely, of imported tires (Cámara de la Industria del Neumático de Chile A.G., 2018).

According to what was established in the study of technical, economic, and social background for the preparation of the Supreme Decrees that establish the collection and recovery goals for end-of-life tires (Cámara de la Industria del Neumático de Chile A.G., 2018), the tire replacement market in Chile, represents approximately 65% of the total and the remaining 35% corresponds to tires entered as original equipment for vehicles and rolling machinery.

Although Law 20,920 does not consider end-of-life tires to be hazardous waste, they generate significant environmental problems. In general, it is difficult to control fires in places where tires are stored, and tires discarded outdoors accumulate humidity inside them, creating an ideal environment for the reproduction of disease transmission vectors. To minimize these effects, generators must comply with their recycling goals set by the authority, either directly or through managers who collect at collection centers.

The cost of scrap tire handling should be included in the price of replacement tires purchased by a small businessman to continue operating his business; however, it should not be included in the price of a new vehicle purchased by an individual or a large company. Excluding original equipment tires from extended producer responsibility would constitute a discriminatory practice in international trade by subsidizing only vehicle and machinery manufacturers.

It is necessary to consider that tires are manufactured for the sole purpose of being installed on the vehicles or rolling equipment that need them to move, so an out-of-use tire is generated each time a tire is removed from a vehicle and replaced by a new or retreaded tire, provided that the used tire that is discarded is not installed again on the same or another vehicle after being subjected to a repair, redrawn, or retreaded process.

The aforementioned study by the Chilean Tire Industry Chamber A.G. (2018) concludes that the generation of end-of-life tires corresponds to the units of new tires that enter the market to replace them. Tires are replaced because when rolling, the rubber of their upper tread wears out, an element of the tire that is in direct contact with the surface on which it rolls, or because it suffers impacts or damages in its structure that render it useless to continue operating safely. In both cases, the tire reaches the end of its life, or end-of-life tire, and will weigh less than the original new tire, due to the loss of mass due to wear.

The classification of the Chilean Chamber of the Tire Industry A.G. (2018) is presented, which is generally simplified by typifying tires into two types, for light vehicles and for heavy vehicles:

- Car and van: Those used in vehicles for the transportation of passengers or goods.
- Truck and bus: All those used for the collective transportation of passengers or for the transportation of cargo.
- Mining and construction, small and medium: Used in vehicles operating off-highway, in mining or construction sites.
- Mining, large diameter: Used in mining trucks and loading shovels in mining sites.
- Agricultural, forestry, and industrial: Used in industry, ports, agricultural, or forestry tasks.
- Other: Tires for motorcycles, bicycles, wheelchairs, manual carts, and many other applications.

There is an international market called "Tire-Derived Fuel" of sufficient size to export all the end-of-life tires generated in the country that cannot be valorized locally, which limits the cost of collecting end-of-life tires, but although it may seem easier to export end-of-life tires for recycling in countries that have better recycling infrastructure, it is convenient for Chile to be independent in terms of its waste, especially if it wants to make tire generators responsible for the treatment of their waste.

In general, in Chile, end-of-life tires for cars and vans and for trucks and buses are normally recycled, but depending on the region, tires that have been used in mining and agricultural activities need to be incorporated into recycling. Although the costs incurred in

waste treatment may be somewhat higher for tires used in mining activities, transportation costs may be lower when the recovery facilities are located near the mining centers, where the collection of these types of end-of-life tires is concentrated.

After a cutting process to reduce their size, the technologies for the treatment of these tires derived from mining or agriculture need not be significantly different compared to the technologies used in the treatment of tires from other categories. Considering that mining sites have high energy requirements, energy recovery and fuel generation from scrap tires presents opportunities for the development of more sustainable mining.

The collection of large quantities of end-of-life tires at mining facilities, or their transport to generator collection sites, currently presents a complex challenge for mining companies, generators, and managers, in addition to the costs to mining companies of shutting down their sites.

It is advisable to expand the installed capacity in regional collection centers, which requires longer deadlines, investments, and higher technological levels. In this way, it will be possible to know the destination of end-of-life tires, in collection centers of duly authorized managers, in places protected against fires of the accumulated material and that avoid humidity to reduce the risk of proliferation of vectors dangerous to human health indicated in the aforementioned study of the Chilean Tire Industry Chamber A.G. (2018).

The Law on Extended Producer Responsibility and Promotion of Recycling (National Congress, 2016) establishes that the generator of end-of-life tires has the obligation to deliver the respective waste to the management system, but the management system will not have the capacity or the legal obligation to remove volumes above its collection goal. If the collection goals are limited, serious conflicts of interest and distortions to free competition may arise when deciding which generators will be favored with the removal of their end-of-life tires and which will have to store them indefinitely in their own facilities.

The case of large diameter end-of-life tires used in mining constitutes an exception since, due to their large volume, it would not be efficient, from an economic point of view, to transfer them to collection centers for subsequent recycling. For this category, the collection targets should be equal to the recovery targets (Cámara de la Industria del Neumático de Chile A.G., 2018).

The collection of already treated end-of-life tires in known locations is important information for investment decisions for end-of-life tire recycling plants, to plan their best location, to stimulate and facilitate the development of the tire recycling industry, and also to reduce the cost per ton transported to recycling plants since whole tires occupy a large part of their volume containing air (Tirel, 2017).

Removing a percentage equivalent to the plant capacity equally for all end-of-life tire generators would impose extremely high collection costs on the management system, consumers, and the transportation industry, without solving the disposal problem for the generator for non-removed end-of-life tires either (Cámara de la Industria del Neumático de Chile A.G., 2018).

On the other hand, withdrawing only from larger generators and those closest to the recycling plants would optimize collection costs during the first years but would be highly unfair to smaller generators, small and medium-sized companies and establishments in the regions, accentuating the excessive centralization of the Chilean national economy.

A business opportunity is envisioned by conceiving a project to install a tire recycling plant in the Maule region, which will process tires that have reached the end of their useful

life to generate crumbs or rubber powder as the main product, which can be used in different product lines detailed in the study.

An end-of-life tire recycling project constitutes a source of sustainable economic development and generates employment, allows replacing imports, freeing productive land, generating environmental awareness, determining the degree of knowledge, and application of the Law of Extended Producer Responsibility and Promotion of Recycling of the Republic of Chile and its regulations (National Congress, 2016 and 2017), provoking concern for generating new laws on the subject and encouraging research work on the properties and uses of recycled material.

It is expected that the study will contribute with an analysis methodology that will allow its transfer to the environment, to evaluate the profitability for investors who have as an alternative projects with the same level of risk, and that can be implemented through innovative applications that are attractive and useful for the market.

Methodology

A descriptive cross-sectional study was carried out in companies related to "Maintenance and Repair of Motor Vehicles" in the Maule region (Chile). The Maule region is located approximately 250 km. south of Santiago, the capital of Chile. This region has four provinces with capitals called Talca, which is also the regional capital, Curicó, Linares, and Cauquenes.

According to the Chilean Internal Revenue Service, the universe of companies in the Maule region is 273 companies. To select the sample size, the probabilistic (systematic) type was chosen. The following formula was used:

$$n = \frac{Z^2 \cdot N \cdot p \cdot q}{e^2 \cdot (N-1) + Z^2 \cdot p \cdot q} \quad (1)$$

Where: N = 273, size of the universe, corresponds to the companies in the Maule region; Z = 1.96, confidence level corresponding to 95% certainty; p = 0.5, corresponding to the probability of success or expected proportion of companies that generate end-of-life tires; q = 0.5, corresponding to the probability of failure or expected proportion of companies that do not generate end-of-life tires; e = 0.1, precision or maximum admissible error considered to be 10%, using equation (1); n = 71, i.e., the sample size corresponds to 71 companies. To identify the companies, the platform of the Chilean Internal Revenue Service was used for those companies with the line of business of "Maintenance and Repair of Motor Vehicles," which corresponds to the economic activity code "502080."

All companies in the industry and those that agreed to the survey through a representative were included. This procedure was carried out in accordance with the local ethics committee.

A questionnaire of eight questions validated by a panel of experts was used to evaluate the tire recycling variable. The tire recycling variable corresponds to the valued quantity of tires available for recycling, which is composed of the quantity, price, and risk indicators operationalized in Table 1 below.

Table 1
Operationalization of the tire recycling variable

Variable	Indicator	Sub-indicator	Question No.
Tire recycling	Quantity	Generation	P1
		Quantification	P2
		Type	P3
		Action	P4
	Price	Agreement	P5
		Valorization	P6
	Risk	Type	P7
		Regulation	P8

Note: Source: Expert panel. Legend: P1: Tire generation, P2: Monthly tire quantity, P3: Tire type, P4: Tire use, P5: Agreements, P6: Price, P7: Risk due to accumulation, P8: Awareness of the Producer Responsibility Law.

It should be noted that prior to the enactment of Law 20.920 on Extended Producer Responsibility and Promotion of Recycling (National Congress, 2016), tires were available free of charge and if removed ended up in landfills.

The instrument was applied by telephone and in person, for which contact was made previously describing the objective of the survey and a second time to carry out the survey. This procedure was carried out by an experienced researcher.

The reliability of the instrument was verified by means of Cronbach's alpha in which a consistency of $r=0.89$ *was* obtained, indicating a high reproducibility of the instrument.

The data were analyzed using descriptive statistics (mean, arithmetic mean, standard deviation, and percentage). A one-way Anova was used to compare between provinces. In all cases, the probability was $p<0.05$. Calculations were performed in Excel spreadsheets and SPSS.

Results

Table 2 shows the number of tire companies in the Maule region by province. Table 2 shows that the city of Talca has the largest number of companies that recycle tires, followed by Linares, Curicó, and Cauquenes.

Table 2
Number of companies in the Maule region that recycle tires

Number	n	%
Talca	32	45%
Curicó	11	16%
Linares	15	21%
Cauquenes	5	
Others	8	11%
Total	71	100%

Note: Source: Own elaboration. Legend: Others: Hualañé, Maule, Rio Claro, Romeral, Sagrada Familia, San Clemente, and San Rafael.

Comparisons of the tire recycling process by province are shown in Table 3. It can be seen that the provinces of Talca, Curicó, and Cauquenes reflect significantly higher average values in relation to Linares and other cities in the Maule Region. The cities of Linares and others have shown lower average values than the other cities in the three indicators (quantity, price, and risk).

Table 3
Comparison of the tire recycling process according to quantity, price, and risk among provinces of the Maule region

Indicators questionnaire	Ciudad									
	Talca		Curicó		Linares		Cauquenes		Others	
	X	DE	X	DE	X	DE	X	DE	X	DE
Quantity	9,66	3,62	9,55	3,72	6,33	3,64	8,40	4,04	7,88	3,76
Price	6,41	2,66	6,45	3,11	3,73	2,99	5,20	3,35	4,50	3,07
Risk	4,63	1,58	4,27	1,49	3,53	,99	4,20	1,10	3,75	,89
Total	20,69	7,01	20,27	7,81	13,60	7,43	17,80	8,17	16,13	7,20

Note: Source: Own elaboration. Legend: X: Average, SD: standard deviation Others: Hualañé, Maule, Rio Claro, Romeral, Sagrada Familia, San Clemente and San Rafael.

There were no differences between Talca and Curicó ($p>0.05$); however, between these two cities (Talca and Curicó), there were significant differences when compared with the other cities (Linares, Cauquenes and others). In addition, no differences were found between the cities of Linares, Cauquenes, and others ($p>0.05$). These results, shown in Figure 1, indicate that the cities of Talca and Curicó recycle more tires than the other cities.

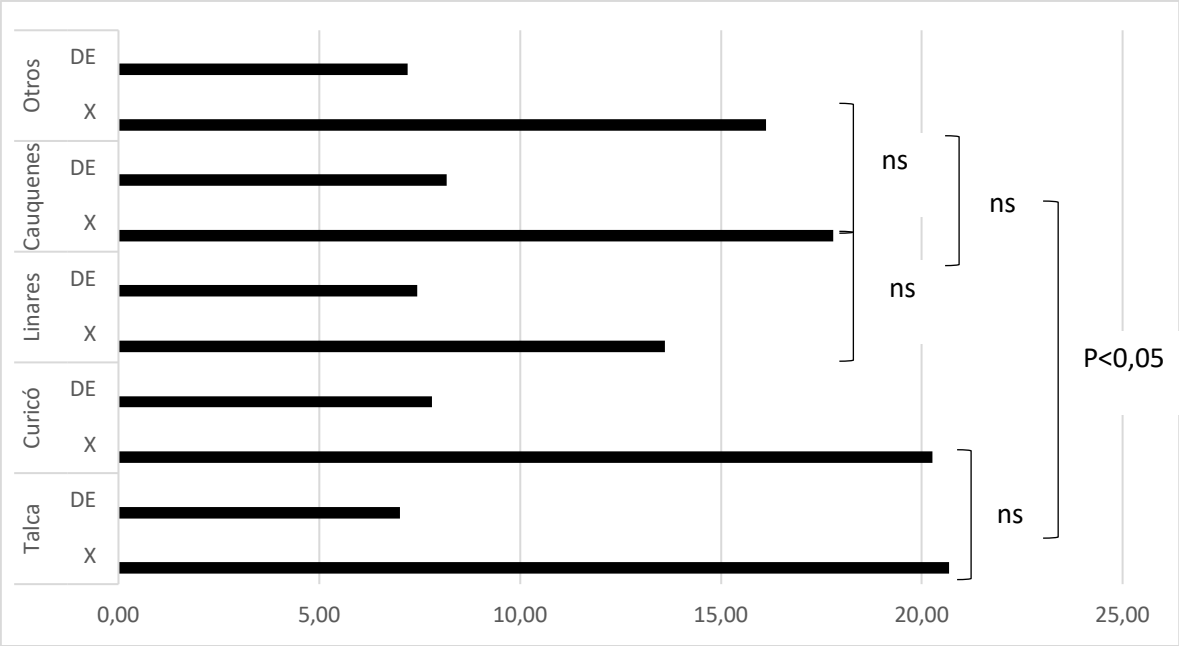

Table 1. Descriptive values of the tire recycling process obtained from the tire recycling questionnaire in the Maule region.

Note: Source: Own elaboration. Legend**:** P: total score of the questionnaire, ns: mean score, X: average, SD: standard deviation, Others: Hualañé, Maule, Rio Claro, Romeral, Sagrada Familia, San Clemente, and San Rafael.

Discussion

The results have shown that of the four cities, Talca, Linares, and Curicó, have the highest number of companies that recycle tires, followed by Cauquenes and others.

When compared by quantity, price, and risk, the cities of Talca and Curicó presented higher values in relation to the other cities. This is due to the fact that these cities had 32 and 11 companies, presenting consequently higher quantity, price, and risk, respectively. In addition, these cities have greater vehicular flow, population density, and development of services.

The city of Linares, despite having 15 companies, has shown low average values in relation to the other cities, which could be due to the fact that these companies are redistributors of companies from Talca, the capital of the region, but do not have an agroindustrial development comparable to Curicó, which is located to the north of the region and closer to the capital of the country.

Regional statistics reveal that the Maule region contributes 7.9% of end-of-life tires of the country's total (Cámara de la Industria del Neumático de Chile A.G., 2018).

Peláez, Velásquez, and Giraldo (2017) argue that the remains of disused rubber have become an environmental and public health problem. Governments have enacted legislation with the objective of mitigating the negative impact caused by end-of-life tires, which, in the case of Chile, considers tire generators responsible for exercising a recycling quota, thus accelerating the search for alternatives for the use of the end-of-life tire and modifying the

profitability of the recycling plants of this raw material that acquires greater economic value for this market.

This research aims to contribute to the study of costs leading to the solution of a serious environmental problem of concern to the scientific community, which is to encourage the control and disposal of unused tires, preventing them from accumulating in landfills, seas, rivers, lakes, wastelands, deserts, or being burned inappropriately, posing risks to society of fires, infectious outbreaks, and disease transmission.

Under the right conditions, the reuse of rubber obtained from recycled end-of-life tires is not harmful to either human health or the environment, functional characteristics that are desirable to encourage its use (Peláez et al., 2017).

The increase in the cost per raw material becomes relevant with the implementation of Law 20.920 on Extended Producer Responsibility and Promotion of Recycling (National Congress, 2016) since, prior to its enactment tires, were available for free as generators had the options of keeping the waste in storage or paying for its removal to municipal dumps.

It is the obligation of the entities that generate waste to use an authorized manager for its adequate treatment, unless it decides to manage it by itself, considering that its storage and management must comply with the legal regulations in force at the time (National Congress, 2016).

The regulation of Law 20.920 establishes mandatory recycling quotas corresponding to 30%, 2021 will reach 50%, and 2028 should reach 90%, which forms a regulatory framework for a market that opens business opportunities, varying prices and available quantities of its raw material recycling (National Congress, 2017).

The average variable cost, identified by Sapag et al. (2014), represents the marginal cost of producing one more unit, which, in terms of raw material, corresponds to the acquisition price of each unit which in our sample is US$1.7, the quantity of the population corresponds to 7,402 units, so the total variable cost is US$12,853.

Conclusions

This study shows that the recycling process in the Maule region (Chile) is a function of the number of companies in the city, so that the cities of Talca and Curicó, which have a greater number of companies, consequently have high recycling values in relation to the other cities. However, the city of Linares, which has a large number of companies, had low recycling values, which apparently may have low levels of recycling and could present a greater risk of contamination in the region; however, it was verified by telephone corroboration that they are distributors of companies in the city of Talca or Santiago, the capital of the country.

The increase in the cost of raw materials affects recycling costs and is, therefore, a relevant factor to consider when calculating the profitability of recyclers with respect to the previous situation of eventual free recycling (Pérez and Pérez, 2006).

The sales price in a scrap tire recycling project must absorb the cost of raw material, which is a fundamental part of the cash flow that must be projected to determine the profitability of the investment (Tirel, 2007) of installing a scrap tire recycling plant in the Maule region of Chile.

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