Analysis of the generation, disposition and environmental effects of used tires of passenger vehicles in two localities of Barranquilla

Análisis de la generación, disposición y efectos ambientales de las llantas usadas de vehículos de pasajeros en dos localidades de Barranquilla

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Abstract

Introduction– There is a problem in the city of Barranquilla (Colombia) regarding the lack of knowledge about the generation and treatment of used tires, a difficulty present not only in Colombia but globally. City shows a vehicle increase of 6% in 2015, 5% in 2016 and 4% in 2017. To date, the number of vehicles continues to grow (December, 2018); and there is no official system to regulate the generation and proper disposal of this waste. Although there are laws that oversee this issue, and preliminary projects with systems for the collection and proper disposal of tires (mostly in the city of Bogotá), they are not properly enforced by the environmental authorities.

Objective– To analyze the current state of generation, disposal and environmental effects of used tires in the city, focusing on Riomar and the Centro Histórico del Norte, since the field data on which the analysis is based was collected there because it has a greater concentration of establishments. It provides a starting point for an estimation of the tires generated and a forecast of the size of the environmental impact. In addition, existing alternatives and processes to manage waste are explored, allowing the use of materials and compounds within its structure for efficient use of resources while reducing its impact on the environment.

Method– Based on 91 surveys applied to the establishments that handle used tires selected by means of the sample size and verifying the results through a Cronbach analysis, showing in figures the weekly generation of used tires in the active points; the current factors influencing the generation of tires are identified; and it is extended with a forecast for the generation of tires for 5 years (2019-2023). Following the forecast, the existing methods for handling discarded tires will be brought to the fore, selecting the most appropriate one using the AHP method, which will contribute to reducing the environmental impact generated by improper disposal.

Results– Most tires are disposed of in landfills, making the correlation between economic growth and registered vehicles evident. The influence of the factors shows that there is a growing positive relationship between registered vehicles and the amount of used tires generated in the year. The best strategy for the final disposal of these is the mechanical shredding of tires, since in addition to mitigating the environmental impact by treating the waste, it also eliminates the possibility of contributing with contaminating agents.

Conclusions– The number of vehicles in Barranquilla by 2023 will reach 231,918, with an exponential growth in the amount of tires generated, highlighting the importance of controlling the disposal of used tires. Therefore, through the AHP methodology, it is established that the best practice to reduce or eliminate these tires is mechanical shredding due to its zero carbon dioxide emission factor, and whose products can be applied to use rubber asphalt for roads and rubber coating for public playgrounds, among others.

Keywords– Used tires; Forecast; co-processing; pyrolysis; Mechanical crushing

Resumen

Introducción– Existe un problema en la ciudad de Barranquilla (Colombia) con respecto al desconocimiento de la generación y tratamiento de las llantas usadas, dificultad presente no sólo en Colombia sino a nivel global. La ciudad muestra un aumento vehicular del 6% para el 2015, 5% al 2016 y 4% en 2017. A la fecha, la cantidad de vehículos sigue creciente (diciembre, 2018); y no existe un sistema oficial para regular la generación y eliminación adecuada de estos deshechos. Aunque existen leyes que supervisan el tema, y proyectos preliminares con sistemas para la recolección y adecuada eliminación de las llantas (la mayoría en la ciudad de Bogotá), no están debidamente reforzadas por las autoridades ambientales.

Objetivo– Analizar el estado actual de la generación, disposición y efectos ambientales de los neumáticos usados en la ciudad, enfocándose en Riomar y el Centro Histórico del Norte, ya que allí se recopilaron los datos de campo en los que se basa el análisis por tener mayor concentración de establecimientos. Proporcionando un punto de partida para una estimación de las llantas generadas y pronosticar el tamaño del impacto ambiental. Además, se exploran alternativas y procesos existentes para manejar los desechos, permitiendo el uso de los materiales y compuestos dentro de su estructura para usos eficientes de los recursos disminuyendo su impacto al medio ambiente.

Metodología– A partir de 91 encuestas aplicadas a establecimientos que manejan llantas usadas, seleccionados mediante el tamaño de la muestra y verificando los resultados a través de un análisis de Cronbach, mostrando en cifras la generación semanal de llantas usadas en los puntos activos; se identifican los factores actuales influyentes en la generación de llantas; y se amplía con un pronóstico para la generación de las mismas a 5 años (2019-2023). Siguiendo el pronóstico, se pondrá en primer plano los métodos existentes para el manejo de neumáticos desechados, seleccionando el más adecuado mediante el método AHP, que contribuya con la reducción del impacto ambiental generada por la eliminación inadecuada.

Resultados– La mayoría de las llantas son eliminadas en basureros, haciendo evidente la correlación entre el crecimiento económico y los vehículos registrados. La influencia de los factores muestra que existe una relación positiva creciente entre vehículos registrados y cantidad de llantas usadas generadas al año. La mejor estrategia para la disposición final de estas es la trituración mecánica de llantas, ya que además de mitigar el impacto ambiental por el tratamiento del residuo también elimina la posibilidad de contribuir con agentes contaminantes.

Conclusiones– La cantidad de vehículos en Barranquilla para el 2023 llegará a 231.918, con un crecimiento exponencial en la cantidad de llantas generadas, se destaca la importancia de controlar la eliminación de neumáticos usados. A través de metodología AHP se establece como mejor práctica para reducir o eliminar neumáticos a la trituración mecánica, por su factor de cero emisiones de dióxido de carbono, y cuyos productos pueden aplicarse para usos de asfalto de goma para carreteras y revestimiento de goma para parques públicos infantiles, entre otros.

Palabras clave– Llantas usadas; pronóstico; coprocesamiento; pirólisis; trituración mecánica

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I. Worldwide context and factor correlation

Seveloped and undeveloped countries alike are aware of the liability that not having systems in place to process and transform these resources into useful products and profits presents. Considering the threat to the environment that this type of waste presents, there have been numerous studies analyzing factors that contribute to the generation of waste tires around the world, covering the main causes for the increment in used tires and forecasting its generation into the distant future.

Leading the global context [2] data was collected on tyre generation in North America, Europe and Japan. According to this research, the global generation of scrap tyres up to 2005 was over 2.5 million tonnes in North America, 2.5 million tonnes in Europe and 1.0 million tonnes in Japan [3].

Following the collection of data, an estimation was made forecasting the amount of waste tire generated in the three regions measured in millions of tons for 2012. The main factor attributed to the increase in the generation of waste tires was to the economic growth and consequent vehicle acquisition power around the world (Fig. 1).

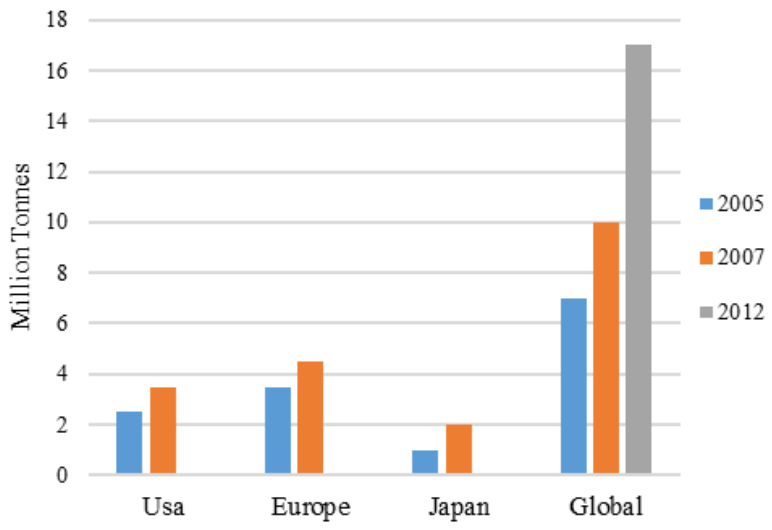

Fig. 1. General Forecast of tire generation in Millions of Tons by 2012
Source: [2].

Most of the civilized world is experiencing exponential growth both in population and in acquisitive power like the previously mentioned vehicle growth in the US. The worldwide vehicle population, as of 2016 was approximately 2.1 trillion vehicles (Only including passenger cars and trucks) and it stood 4.6% higher than the previous year [4]. In addition to the population increase, most countries are experiencing exponential growth in vehicles in circulation. Developing countries such as India, already have a higher VIO (Vehicles in Operation) yearly increase than developed countries such as Germany; with the former being 11% in average and the latter 1.2%; considering India has 16 times the population of Germany [5].

Validating the hypothesis that the increase of vehicles in circulation as the main cause for the increase of waste tires, and localizing the situation in the national context, there have been studies in Colombia whose results suggest a most certain relationship between these two factors. According to the MinAmbiente in Bogota D.C, the increase in registered vehicles are linked to the increase of waste tires generated [1]. The following data shows the numbers and the relationship between the number of vehicles and the number of waste tires generated from 2006 to 2010 (Table 1).

Table 1. The number of vehicles and waste tires generated (2006-2010) in Bogotá, Colombia.

Year	Total Registered Vehicles	Total Waste tires generated (Units)
2006	943.550	2.148.671
2007	1.062.698	2.177.465
2008	1.168.685	2.207.164
2009	1.254.857	2.229.939
2010	1.392.930	2.270.020

Source: Authors.

In order to clearly display and validate the relationship between the numbers of registered vehicles, a linear regression model was used, taking the registered vehicles as an independent variable and the total of tires generated as a dependent one.

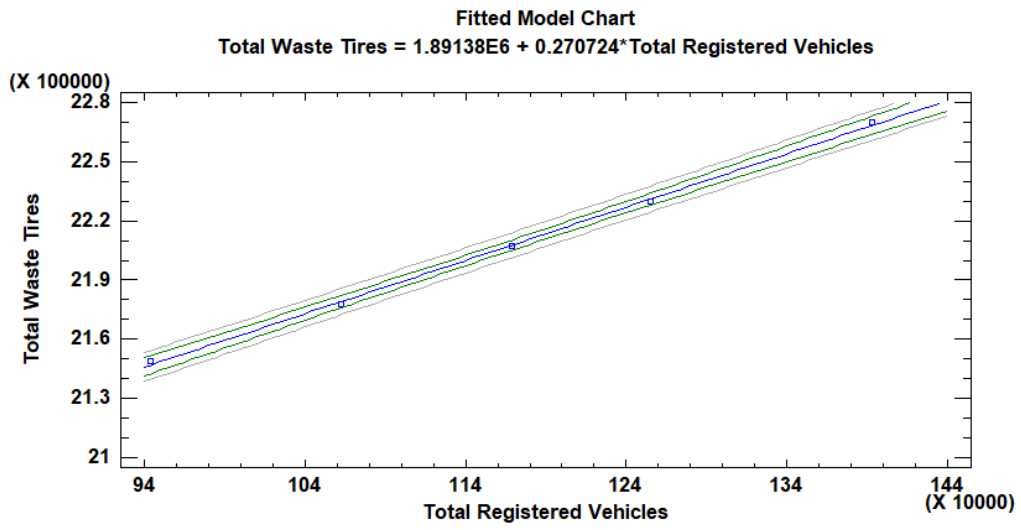

Fig. 2. Forecast for the relation between total registered vehicles (X) and total waste tires (Y).
Source: Authors.

The equation shows a correlation factor R of $R = 0.999$; indicating a strong correlation. The R^2 value of $R^2 = 99.83$ indicates that the model explains 99.83% of the variability. The P-value $P = 0.000 < 0.05$ indicates a reliability level of 95%. It is understood then that the number of vehicles in circulation will continue to increase in the foreseeable future and so will the number of tires generate.

On the other hand, to determine the influence of the economic acquisition power factor, a multiple linear regression analysis was carried out to analyze the behavior of GDP respect to the number of vehicles registered annually for these years (2006-2010) in Bogotá. The result shows that there is a strong positive correlation that fully explains the impact of one factor with the other. The above mentioned, demonstrated under the equation (1) were the data was obtained by the Nacional Administrative department of statistics [6].

$$\text{Year} = 1996.48 + 0.0000513249 * \text{GDP} + 0.00000456855 * \text{Total Registered Vehicles} \quad (1)$$

Using the model of the study made in Bogota D.C and working within the context of Barranquilla; a similar analysis will be made. This analysis will be focused on the Riomar and Northern historic Centre of the city and is going to use historic data from the number of registered vehicles from the past 5 years along with real data gathered on the field regarding the generation of used tires. Due to the lack of historic official data regarding the numbers of waste tire generation, this study is going to take the data collected from 91 establishments obtained from a sample to identified as the main generators of waste tires in the two localities and it expands upon, building both a forecast for the expected amount of registered vehicles for the next 5 years and a forecast for the subsequent waste tire generation in the same period.

II. Registered vehicle growth and used tires forecast

historic data made publicly available by the Barranquilla City´s Mayoralty displays the registered vehicle growth from the year 2013 to 2017. Additionally, and for the purpose of complementing the base data, the Mobility Department provides information about the number of registered vehicles as of 2018 (Table 2).

Table 2. Historic of the number of registered vehicles 2013-2018 in Barranquilla.

Year	Number of Registered Vehicles
2013	147.517
2014	157.970
2015	167.531
2016	175.820
2017	183.487
2018	188.250

Source: [7] [8].

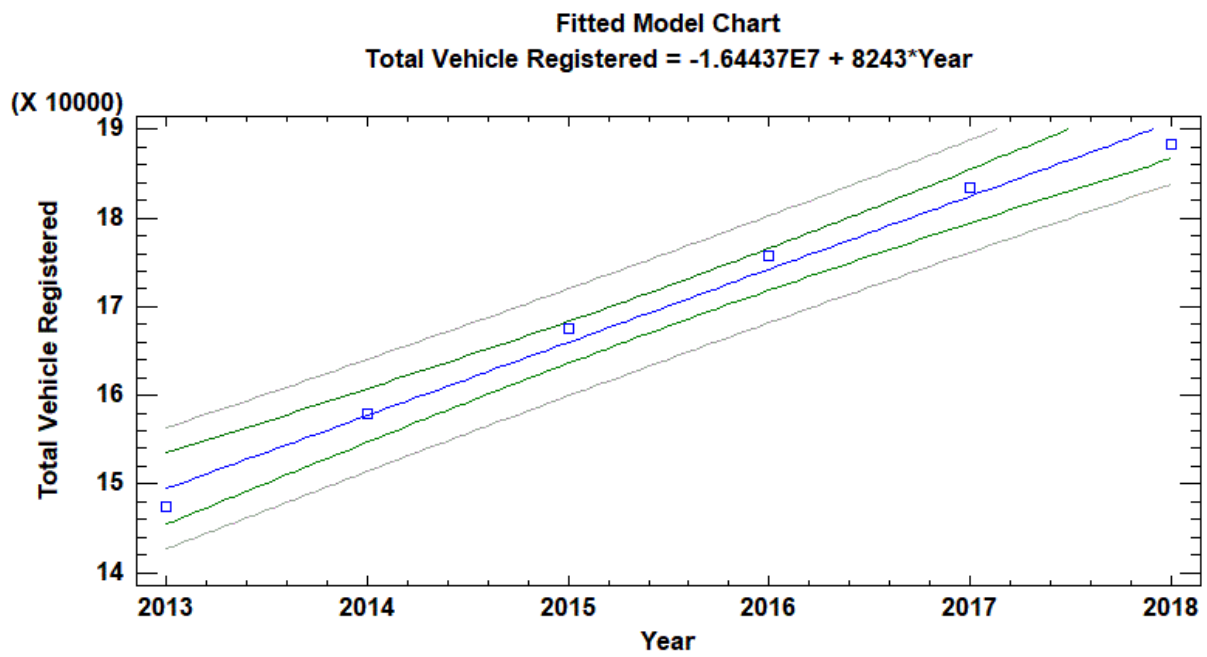

Fig. 3. Simple Linear Regression of the number of registered vehicles 2013-2018 in Barranquilla.
Source: [7], [8].

With the data obtained of the confinable source, the value = 93.73 explains the variance of 93.73% in the number of registered vehicles from 2013 to 2018, which means a strong adjustment of the model. The P-value P = 0.0015 < 1 shows a confidence level of 95%, reinforcing the reliability of the model and the correlation between the years and the number of registered vehicles.

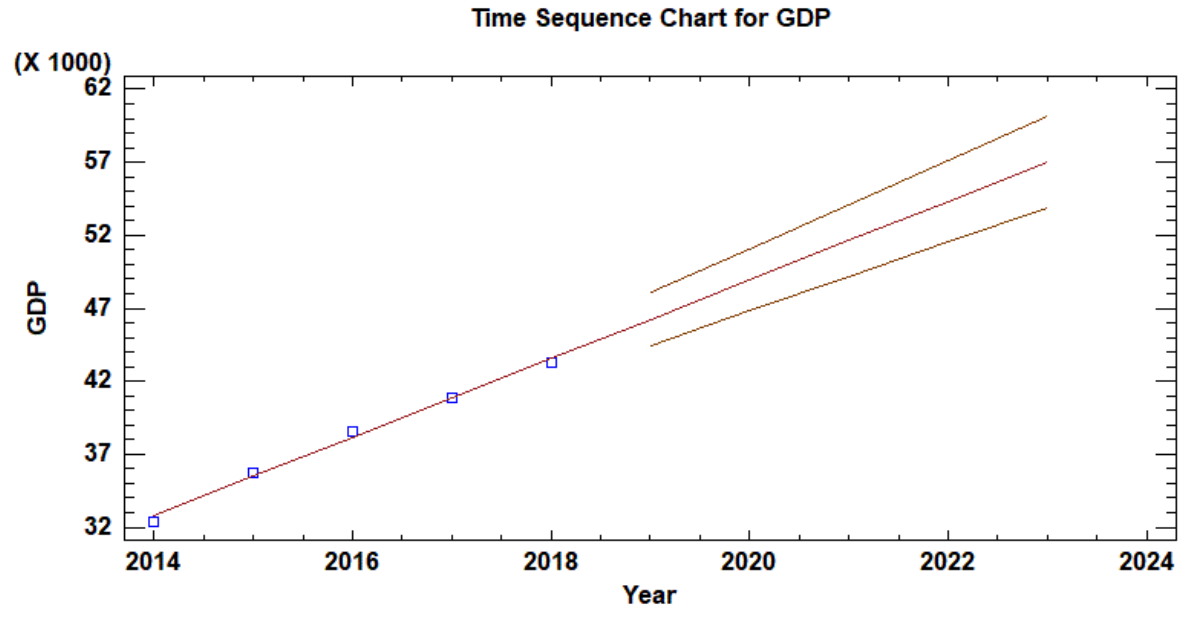

Fig. 4. Time Sequence Chart – Forecast for GDP 2014-2023 in Barranquilla.
Source: [6].

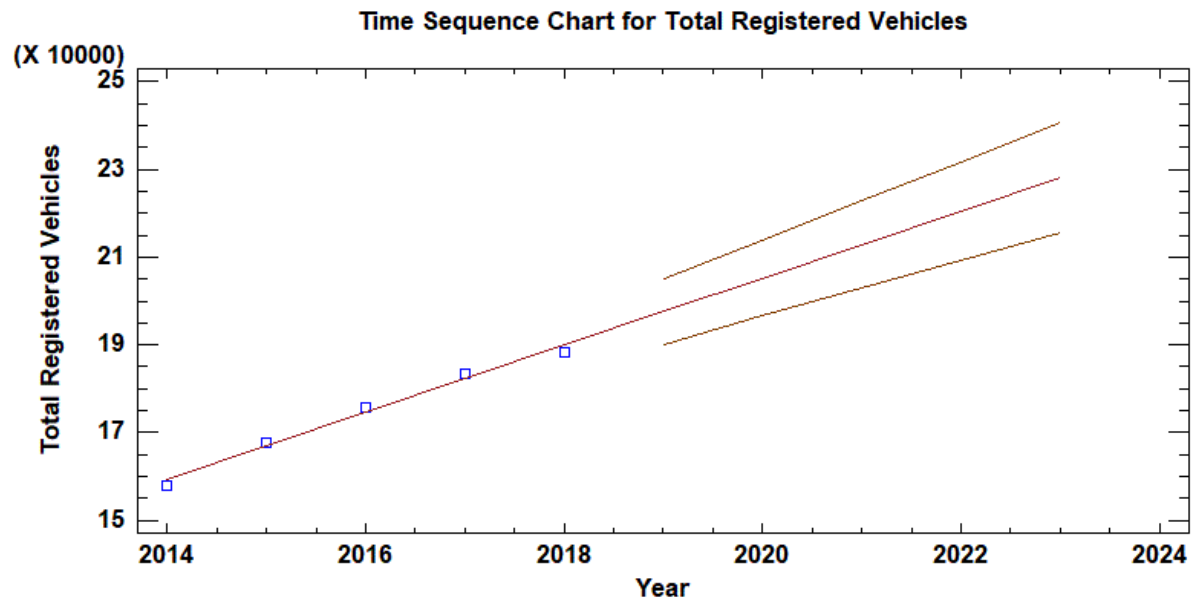

Fig. 5. Time Sequence Chart – Forecast for Total Registered Vehicles 2014-2023 in Barranquilla.
Source: [6].

To analyze the influence in Barranquilla of economic acquisition power, the multiple linear regression study was repeated, which showed that the increase in total vehicles registered annually has an absolute influence on GDP [6] growth. As economic growth is greater, vehicle purchase capabilities are also increased, and at the same time the generation of used tires as demonstrated previously for the Bogotá City. The model has the equation (2).

$$\text{Year} = 2006.11 + 0.00055009*\text{GDP} - 0.0000635868 * \text{Total Registered Vehicles} \quad (2)$$

In order to build the forecast for the expected amount of vehicles in the next five years following 2018, and subsequently the number of tires that will be generated in that period of time, the relationship between the year interval and the number of registered vehicles was demonstrated using a regression linear model, in which was proven that the amount of vehicles is increasing as the years go by. This is observed in the behavior of the data, for the rapid economic growth that the city is experiencing [9].

Using the previous model calculated for the correlation: *Registered Vehicles* = 141245 + 8243.0 *X, as* well as the historic data as a basis for the estimation; the followed forecast was built for the number of expected vehicles from 2019 to 2023.

Table 3. The forecasted number of registered vehicles 2019-2023.

Year	Vehicle Registered (Y)	Forecast (Y)
2013	147.517	
2014	157.970	
2015	167.531	
2016	175.820	
2017	183.487	
2018	188.250	
2019		198.946
2020		207.189
2021		215.432
2022		223.675
2023		231.918

Source: Auhtors.

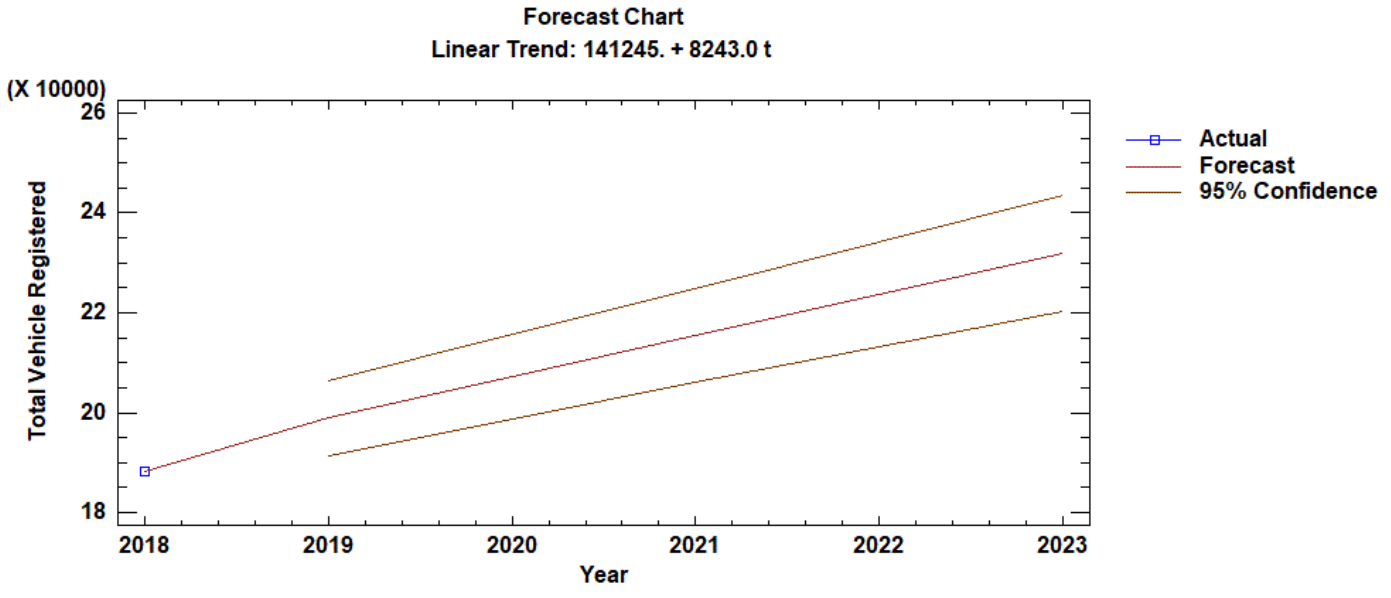

Fig. 6. Forecast Chart for the number of vehicles
Source: Authors.

The Fig. 6 shows the increase in vehicles that is to be expected by the year 2023. Following the factor correlation threat and using the data collected in the field in the Riomar and Northern Historic Centre of the City, which indicates a total weekly generation of 1.137 tires on the 91 establishments surveyed, that is, 59.124 waste tires yearly. The forecast for the expected waste tire amounts for the next 5 years will be established.

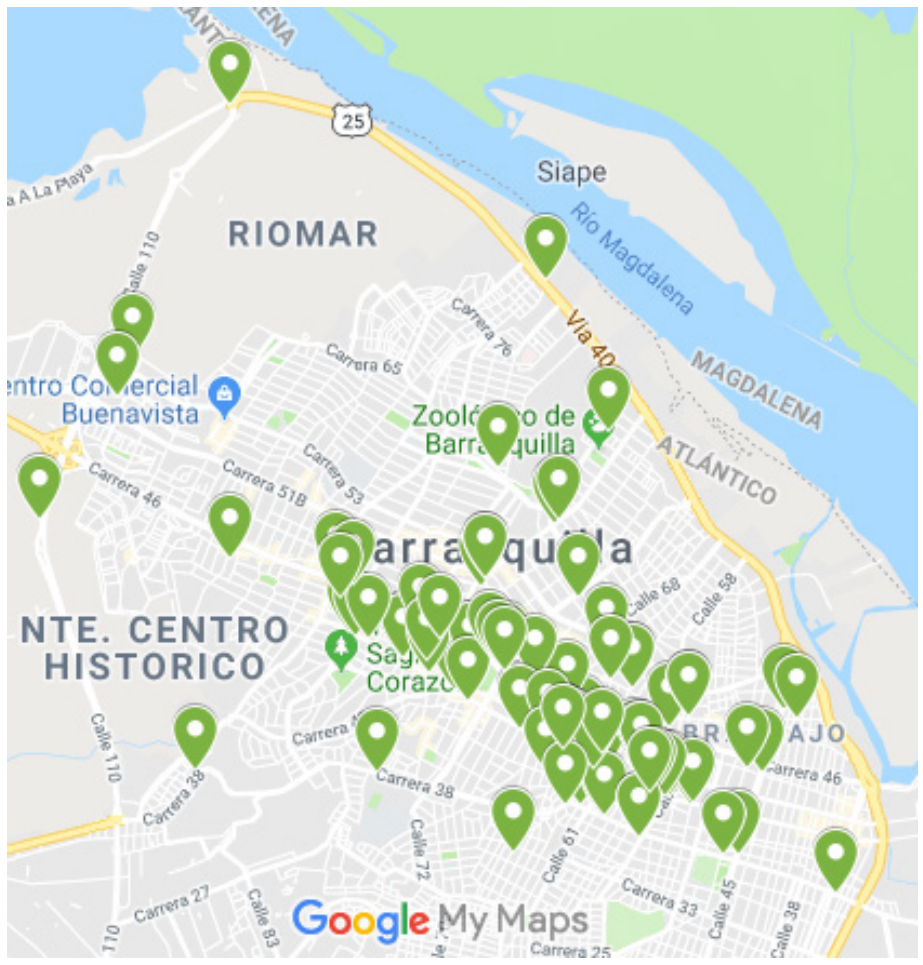

Fig. 7. Mapping of the main generators surveyed in the study locations (Barranquilla, Colombia).
Source: Google Maps.

Having already built the forecast for vehicle growth from 2019 to 2023, the yearly percentage increase in the number of registered vehicles is used to calculate the forecasted waste tires amount (Table 5).

Table 4. Forecast vehicles registered 2019-2023 in Barranquilla, Colombia.

Year	Number of registered vehicles	Change rate	% Increase	Waste tire forecast
2018	188.250			59.124
2019	198.946	0.0568	5.7%	62.483
2020	207.189	0.0414	4.1%	65.072
2021	215.432	0.0398	4.0%	67.661
2022	223.675	0.0383	3.8%	70.250
2023	231.918	0.0369	3.7%	72.839

Source: Authors.

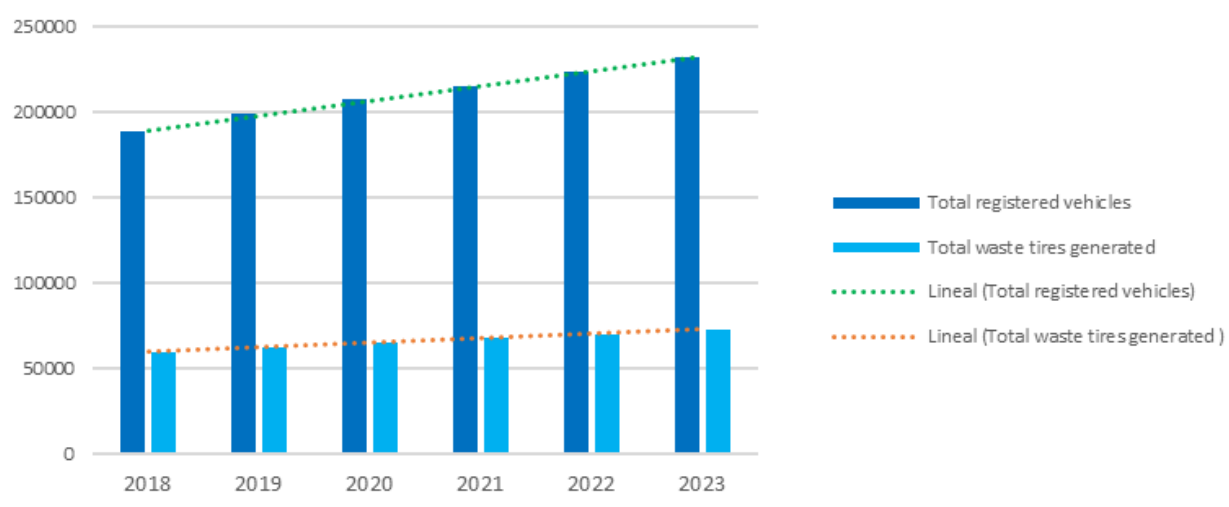

Fig. 8. Comparison forecasted the number of vehicles and scrap tires 2018-2023 in Barranquilla, Colombia.
Source: Authors.

Using the existing literature on the approximate weight of car tires, especially passenger tires, as they are the majority in this study. The information to be used establishes a weight of a new tire of 25 pounds -11.34 kg- and the tires used 20 pounds on average -9.07kg- [10] probably because tire material is lost due to friction. It was estimated that as of the end of 2018, the Riomar and Northern Historic Centre of the city are generating an approximate of 536,25 tons Tons of waste tire material, an amount that is going to increase in accordance to the number of registered vehicles in the city, as shown in Table 6.

Table 5. Forecast of used tire generation 2018-2023 in Barranquilla, Colombia

Year	Waste tire forecast (Tons)
2018	536.25
2019	566.72
2020	590.20
2021	613.69
2022	637.17
2023	660.65

Source: Authors.

III. Existing methods for the processing of waste tires

There are numerous methods that are used to treat the waste tire materials, implementing strategies that enable the use of the compounds found within the tire while making possible the completion of other processes.

The co-processing method consisting in the usage of the calorific value of the tire materials for the cement production process in cement kilns. This reuse of the waste as war material as a source of energy can replace other energy sources like petroleum and coal [11] and having a better price-performance ratio than conventional energy sources, with the calorific value of the rubber compounds being higher than the one in coal and petroleum [12]. As of December of 2018, there are no official records of the use of this process in the city of Barranquilla. On the other hand, despite being a relevant and revolutionary process for the industry, for issues of reduced benefit for different organizations and at the social level it's not considered for this project.

Following the undocumented methods of waste tire processing in Barranquilla are the processes of Thermolysis and pyrolysis, consisting in the chemical process of decomposition by the heat of the main compounds if the waste tire material, process being carried out in the presence and absence of a catalyst [13]. There are no records of their implementation in the locally registered entities in Barranquilla.

In accordance with the literature review, these processes are a solution for eliminating tires volume but aren't clean process totally. Some of the consequences are the intense carbon emissions, emissions of persistent organic compounds (dioxins, furans, mercury), heavy metals, suspended material, nanoparticles and other pollutants [14]. In the same way, 20% - 30% of the weight of waste becomes ash [15]. According to authors [16] pyrolysis could generate excessive emissions of persistent organic pollutants (POPs) such as dioxins and polychlorobiphenyls (PCBs), lead, arsenic, mercury, and heavy metals, polycyclic aromatic hydrocarbons. The thermolysis generates air pollution by the gases generated by the fuel used at the beginning of the process. However, effluents are less dangerous than those from landfills [17]. These two processes have not demonstrated economic viability [18].

Gasification is other of the process that consists of a thermochemical decomposition of organic matter in an environment characterized by an air deficit with respect to the stoichiometric necessary to perform its complete combustion. The authors [16] affirm that high capital costs and high energy consumption make gasification unattractive financially. The gasification results are emissions like those of conventional incineration. These may include NOx, SOx, hydrocarbons, carbon monoxide, suspended material, heavy metals, greenhouse gases such as CO2, dioxins, and furans [19].

The documented use and implementation of scrap tire material, mechanical crushing appears. This is a process in which blades are used to shred the tires; generally, this process is performed in cascade, that is, the tires are crushed gradually until reaching the minimum required size and then pneumatic and magnetic sorters are used to separate the textile [1]. From the result of mechanical crushing, the literature shows the uses of the compounds found in the tires on rubberized asphalt for roads and rubber coating for child public parks. Rubberized asphalt was successfully implemented in the roads of the Cortissoz airport, where more than 70.000 meters of rubberized asphalt was used in its traffic roads [20], meaning significant profit and performance benefits for the parties involved, as the presence of rubber in the asphalt mix increases the useful life of the construction matrix and reduces the cost of compound production by about 4% . The usage of the rubber found in scrap tires in public parks rubber coating for the surfaces has also met a positive successful implementation in the city, with the main benefit being the anti-slipping and radiation absorption properties [21].

Through the AHP methodology [22] the best alternative was selected among the processes of pyrolysis, thermolysis, gasification and mechanical crushing. The weights were obtained due to the evaluation of the experts and the review of the literature and, to develop the AHP, three factors were considered: machinery costs, polluting emissions and economic viability (Table 6).

Table 6. Results Matrix AHP methodology according to weights.

Results Matrix	
Pyrolysis	1.08982056
Thermolysis	1.08982056
Gasification	0.71043567
Mechanical Crushing	0.10992321

Source: Authors.

The way to evaluate the matrices was analyzing the negative impact of objective i in correspondence with objective j, where a more positive number meant a greater negative impact on the objective. Finally, Table 6 shows that the strategy of final disposal selected was "mechanical crushing" being that was the best-weighted respect to negative impacts.

This article promotes the process of tire grinding since it generates zero emissions. To the date, in Barranquilla doesn't exist companies that are dedicated to mechanical crushing. This concept includes the fragmentation of the tire into granules (GTR, Wheel Rubber Granulate) and separation of components (steel and fibers) and devulcanization or not [23]. This GTR is obtained by grinding processes of used tires, decreased in size, this material is used in different civil engineering works, as they are in landfills, containment materials, park floors, as a modifier in asphalt mixtures, among others [24], in addition, synthetic rubber is used to build floors, rubber grain can be used to make shoe soles, the steel content can be sold to companies to be scrapped [25].

To analyze the economic viability, a cost-benefit analysis was carried out in which the bank loans corresponding to the necessary investment in the purchase of the truck and the mechanical crushing machine were considered. The model took the variable costs such as the cost of fuel consumption, energy cost and the cost of the bags where the rubber granules would be packed. Operating expenses such as leasing, depreciation, labor and financial expenses were also measured. In the same way, the total production costs were obtained. It's relevant to the analysis to consider an annual sales growth projection rate and regard that. A protagonist in the study is inflation, which for this case was obtained through a forecast of the historical data [26]. The results show that the net flow of the project evidence profits that grow exponentially, provided that the sales objectives are met, which requires significant marketing work.

IV. Legislation problem

The definition of used tires according are those whose wheel is less than or equal to 22.5 without including motorcycles, bicycles and wheel vehicles higher than the aforementioned

[27]. From this precept, there are some tires that are left out that the law supposedly doesn't accept. However, with the publication of resolution 1326 of 2017 [L1], which replaced resolution 1457 of 2010, the tires of bicycles, motorcycles, motorcycles, mopeds or Moped and tires of off-road vehicles are also included in the consumption plan. This resolution establishes the systems for selective collection and environmental management of used tires, which will be formulated and implemented by the producers. The submission of the formulated collection system must be approved by the ANLA and will be updated annually. The standard also establishes collection goals that producers must meet. Although, the producers are not the only ones who will have legal obligations. It also shows direct obligations of managers, distributors, consumers, municipalities and districts, of regional environmental authorities, including "montallantas", and mining vehicles.

Apparently, everything is contemplated. However, at the time of execution, surveillance is lost, especially for the small actors in the chain. The National Environmental Licensing Authority (ANLA) has exposed through resolutions sanctions against producers for not presenting the system of selective collection and openings of environmental investigation for not having fulfilled the established obligations (It's important to clarify that none found for Barranquilla). The above still refers to the previous resolution; In the same way, it issues resolutions to approve collective systems of selective collection and environmental management of used tires for the current resolution. Under questioning, although sanctions are ordered through administrative acts for the repealed resolution embodied in the seventh article, in the new resolution it seems not to be contemplated, while the ANLA on its page presents it [28].

Undoubtedly, reality distorts what is agreed in the norm. Surveillance is absent, distributors are completely unaware of the process and small protagonists even more. The acts of sanction with the new resolution are unknown and compliance statistics are not available. Through the survey applied to the establishments, it was possible to realize the above, since, as 1 distributor of 91 indicated the collaboration of COÉXITO as the responsible company of the system of selective collection and environmental management of tires. The rest mentions ignoring systems that are answerable for collecting disused tires, so most of them end up in open-air dumps (the statistics of surveys will be shown in the next chapter). In the same way for citizens, isn't easy to know which company or containers belong to a collection system that meets the technical and safety requirements [29].

Other background that impact resolution 1457 of 2010, was a demand to the Ministry of Environment and Sustainable Development and others, in which it was requested to implement controls and verify if they were complying with the aforementioned norm, since is possible continue seeing the incorrect disposal of tires in Colombia, in the same way that it indicated that post-consumer programs in the rest of the country are almost nonexistent or unknown [L2] and although the sentence was denied, it's probable to notice how the population, in general, can see a problem palpable by somehow or other lack of efficient actions.

Nevertheless, there are great advantages incorrectly applying the legislation and supporting the environment. Among them are the deduction of income for investments in machinery and improvement of the environment, also exclusion of the acquisition of machinery and equipment required for environmental monitoring systems [30].

V. Current status of disposal and environmental effects for used tires.

Relating the forecasts of the number of registered vehicles to be expected from 2019 to 2023 and the subsequent amount of waste tires generated as groundwork for the analysis of the environmental consequences of the improper disposal of these tires, along with additional data gathered on the field in the Riomar and Northern Historic Centre localities of the city It is perceived that the main option for disposal given to the waste tires by the establishments responsible is leaving the used tires in designated places for general waste.

Fig. 9 shows the proportion of the data, the main options being: Disposal in a dump, selling to recyclers, selling to a certified company and Re-use and therefore the process of commercialization.

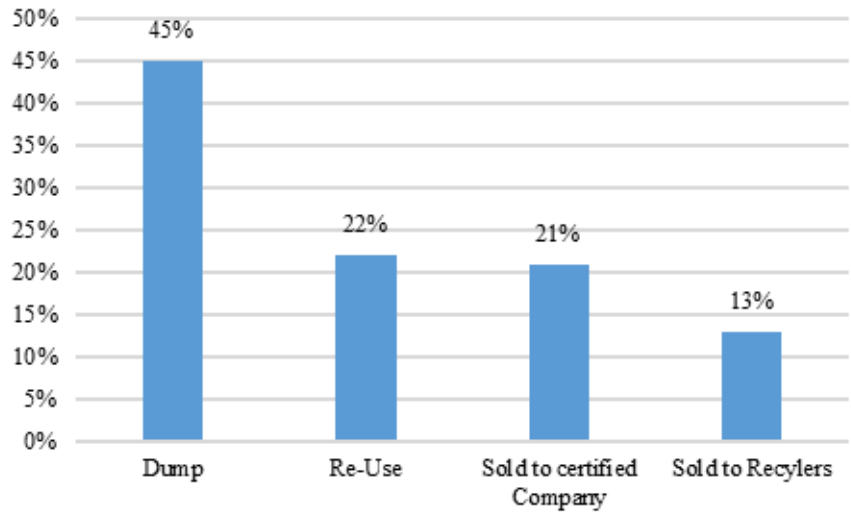

Fig. 9. Final disposal of used tires in Barranquilla, Colombia.
Source: Authors.

Most of the establishments in the north of the city leave the used tires in a specific place along with the other type of garbage. There is no special designation place for the disposition of only scrap tire materials. According to the answers of the surveyed establishments, the local waste collecting company 'Triple A' is the one that handles the disposal of the scrap tires left in these places. Although this waste is often recovered by unofficial recyclers before 'Triple A' can collect it. However, there is an important point that must be cleared. "Triple A" isn't the company responsible for carrying out the collection, because the used tires are considered like "Special solid waste". "Triple A" affirm that they could pick up one or two tires that are accompanying domestic garbage. This can mean that there is no clear information, besides, in Barranquilla, a bad culture persists, and people are not interested in learning about good practices of used tires scraps.

The final destination of some used tires that are recovered by 'Triple A' is the landfill waste disposal site located in 'Km 15, Tubara, Tubará, Atlántico' where they are disposed and processed with the rest of the more than 500 mil tons waste generated in a yearly basis by the city and following the local regulations [31]. In 2011 there was a proposal to create a free zone for waste processing in Barranquilla, with alliances with DAMAB and the Spanish Environmental Council in Mallorca, this free zone will have a tire recycling and processing facility and it is planned to be operational in the year 2020 [32].

Out of the 91, only 10% of the disposed of tires in the establishments visited (which are the main generators of tires in the Riomar and Northern Historic Centre of the city) are sold to recyclers at no specific price; these waste tires are treated in the same manner as other scrap material. Also, is relevant to mention, only one establishment has its scrap tire generation handled by a certified business. On the other hand, the 22% corresponding to re-use refers to the establishments that oversee the business of marketing used tires, which are mostly "llanterías", a type of auto service. It's hardly logical that these types of establishments response to the question of final disposal as the handle of the used tire is recycling for reuse.

About the final disposal of the waste tire material and the methods involved in dealing with the tires that have met the end of its life cycle, there are typical procedures: Burning in the open and the disposal of the tires in open spaces along with other waste materials. Among the environmental effects of the disposal of waste tire material in the open are the proliferation of mosquitoes and rodents due to the stagnation of water. About the inaccessibility of storage areas, exists risks of fire, obstruction of public space and deterioration of the solid and adjacent landscape. The noncompliance of behaviors acting against public welfare, the collection of waste and bad environmental practices is punishable for the establishments that do not have a standard method for the disposal of waste tires, as it is stated in the National Police Code, Chapter II, numerals 2, 3, 4, 8 and 14 [L3].

Regarding the open burning of the waste tire materials, besides being noncompliant with the local law and regulations, is most harmful to the imminent environment and its inhabitants. Air emissions from burning open tires include reference pollutants, such as particulate matter, carbon monoxide (CO), sulfur oxides (SOx), nitrogen oxides (NOx), and volatile organic

compounds (VOCs).), with Data from research and test laboratory programs suggests a high mutagenic emission from uncontrolled open burning waste epicenters especially dangerous to vulnerable population, like children and the elderly, meaning a high priority health hazard [1], as in Barranquilla, the open fires for waste tire burning are virtually next to the streets and houses.

VI. Conclusions

The generation of waste tires is a danger to the environment if not handled properly. Factors such as the increase in economic acquisition power and the economic growth of the population worldwide are contributing to the increase in vehicles and, subsequently, to the generation of waste tires as evidenced by historical data along with mathematical regression models, where a positive correlation is shown between economic growth, the number of registered vehicles and the generation of used tires.

In the national context, Bogotá has a historic increase in vehicles since at least 2006. This rise in the number of vehicles is directly related to the increase in the generation of waste tires. As demonstrated, Barranquilla presents a similar

situation, with the historical data that showing constant growth in the number of vehicles since 2013, in addition to the current economic development of the city, which suggests that this behavior will continue to act in the foreseeable future. Is then that the current approximate 59,124 tires generated only in the Riomar and the Historic Center of the North of the city along with the 660.65 tons of waste tire material for the year 2023 are of serious concern, since in spite of the existence of legislation that regulates the environmental issue of used tires, there isn't really a surveillance that allows for proper handling and disposal of the tire at the end of its life cycle.

This is how it's possible to show that the disposal of waste tires is not currently regulated, since even the official sanitary waste collection company "Triple A" doesn't collect these special solid wastes and hasn't planned to do so, according to what is stipulated in the law. The action of most distributors is associated with depositing tires in open landfills or performing other inappropriate actions, which are activities that are of concern for the environment and health, then it generates the emission of cancer-inducing compounds, the proliferation of vectors and the overall air pollution.

From the AHP analysis it was obtained that the best final disposal treatment of used tires is to perform mechanical crushing; In fact, there are records of several uses that the local industry gives to waste tires from this type of process, among which the most prominent is used in the production of modified rubber asphalt and the use of rubber in coatings non-slip. It's expected that this project can be replicated, and the results show the great impact of the generation of used tires for future research to be carried out and business ideas for the economic and environmental growth of the city. According to the similarity with other cities, it is considered that the project can be applied to the general context of the country.

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