Logistics as an essential area for the development of the solid waste management in Colombia

La logística como área esencial para el desarrollo de la gestión de los residuos sólidos en Colombia

Diana Colorado-Lopera[1]
Gloria Echeverry-Lopera[2]
Henry A. Colorado-Lopera[3*]

[1] Universidad de Antioquia-UdeA; Universidad Autónoma Latinoamericana-Unaula; (Colombia); correo: diana7436@gmail.com

[2] Universidad Autónoma Latinoamericana-Unaula; (Colombia); correo: gloria.echeverrilo@unal.edu.co

[3] Universidad de Antioquia-UdeA; (Colombia); correo: henry.colorado@udea.edu.co

Reception: 05-03-2019 Acceptation: 11-06-2019

Cómo citar: Colorado-Lopera, Diana; Echeverry-Lopera, Gloria; Colorado-Lopera, Henry (2019). Logistics as an essential area for the developing of the solid waste management in Colombia. *Informador Técnico*, 83(2), 131-154. https://doi.org/10.23850/22565035.2065

Abstract

This research summarizes findings of solid waste logistics not only in Colombia, but in other Latin American countries with reference to some of the leading economies throughout the world. All official data and new results are developed and discussed, providing an account for the evolution of solid waste and its logistics regarding time with a focus on transportation and storage. The study also refers to the transportation of waste and its storage in landfills. Due to the situation in Colombia is quite similar to many developing countries, the findings of this study might be of interest to other nations. Results revealed several problems involving the economy, technology, regulations, and political concerns common to several countries worldwide.

Keywords: waste management; waste transport; waste storage; construction; demolition.

Resumen

Esta investigación resume los hallazgos sobre la logística de residuos sólidos no solo en Colombia, sino en otros países latinoamericanos, con referencia a algunas de las principales economías mundiales. Todos los datos oficiales y los nuevos resultados se desarrollan y discuten, proporcionando una explicación de la evolución de los residuos sólidos y su logística en relación con el tiempo, con un enfoque en el transporte y el almacenamiento. El estudio también se refiere al transporte de residuos y su almacenamiento en vertederos. Debido a que la situación en Colombia es bastante similar a la de muchos países en desarrollo, los hallazgos de este estudio pueden ser de interés para otras naciones. Los resultados revelaron varios problemas relacionados con la economía, la tecnología, las regulaciones y las preocupaciones políticas comunes a varios países del mundo.

Palabras clave: manejo de residuos; transporte de residuos; almacenamiento de residuos; construcción; demolición.

Introduction

For most countries in the world, regardless of their economic position, solid waste management has become a matter of priority interest, especially with Construction and Demolition (C&D) waste. This is to the lack of available space in landfills, which are the most widely used system for final disposal in the world (Sosa-Marín, 2014) and because of issues related to environmental protection as the well as emission of greenhouse gases (GHG) produced by industries involved in energy, transportation, agriculture, waste (sanitary landfills or open-air dumps) and industrial processes (Romero-Moreira, 2017). These issues can affect flora and fauna, bodies of water and air quality, leading to soil degradation.

The clash between industry and ecology has led many countries to leave environmental protection behind. However, in the search for more environmentally-friendly practices, the large number of people affected by pollution because of the industrialization has helped to make the environment a priority in the UN as a principle of coexistence between humans and nature (Rojas; Salazar; Sepúlveda; Sepúlveda; Santelices, 2006). For several decades, environmental legislation has been establishing conditions that favor the development of waste management activities on a global level; however, to date, compliance of these regulations remains a challenge throughout all Latin American and Caribbean countries. Even though the fact that the region has made progress in developing environmental laws, especially those on solid waste management, monitoring the violation of these regulations has not been effective, which means that several violations of these regulations occur and few sanctions are imposed. The opposite has happened in Europe, where the regulations that apply to the European Union are very strict and an environmental fine is so costly that is best to carry out a process by adopting a circular economy model that includes aspects such as recycling, reducing or reusing solid waste, especially those related to C&D waste (Comisión Europea, 2016).

Therefore, logistics becomes an important factor of being competitive in both national and international markets (Ballesteros-García, 2016) and it is also a necessary part of achieving the best results for C&D waste management. In solid waste management, transportation and storage are fundamental to countries implementing waste management strategies correctly. While Europe and Japan are working on minimizing the use of their sanitary landfills, Africa is trying to improve its collection system, and the Americas have the majority of their waste in landfills, including the United States. Colombia has implemented the Solid Waste Integrated Management Plan (PGIRS, Plan de Gestión Integral de Residuos Sólidos) (Ministerio de Vivienda, Ciudad y Territorio, 2015). This plan influences the regulatory framework on the provision of public waste collection services, which can be adopted on a municipal or regional level and can vary depending on the characteristics of the area in which it will be implemented. With the help of studies conducted on a global level such as the LPI (Logistics Performance Index) of the World Bank (The World Bank, 2018) and the Global Competitiveness Index (GCI) of the World Economic Forum, (Word Economic Forum, 2018) tactics can be assessed to help each economy improve aspects that reveal shortcomings in indicators such as road and transportation infrastructure. Region-specific analysis (on Latin America and the Caribbean) can be found in reports such as the PERLOG (Logistics Profile for Latin America) (Farromeque-Quiroz, 2015; Farromeque-Quiroz, 2017). At a national level, studies such as Colombia is Logistics (Colombia es Logística) (Departamento Nacional de Planeación, 2015) and the National Competitiveness Index (Informe Nacional de Competitividad) (Consejo Privado de Competitividad, 2017) are also available, which show the state of logistics in Colombia's 32 departments.

While vehicular traffic is a determining factor of logistics, air pollution levels are also concerning. Air pollution levels not only come from the fuel that is used for transportation but they are also a result of different final waste disposal systems – a major source of biogas production. Biogas is the result of the biological decomposition process of organic solid waste (Camargo; Vélez, 2009) that produces Greenhouse Gases (GHG), especially methane gas (CH4), which is estimated to consist of 13 % of all emissions worldwide. The activities that generate this gas continue to exist, even after landfills have been closed for an estimated period of 50 years (Pinzón-Uribe, 2010). In Colombia, 75 % (842) of its municipalities are disposing of their solid waste in sanitary landfills (Superintendencia de Servicios Públicos Domiciliarios, 2018). This trend is similar to that of Latin America and the Caribbean, where sanitary landfills consist of 54.4 % of its final disposal systems for SW (solid waste) (Fundación CEDDET, 2015).

In contrast, Europe is continually working on decreasing the percentage of waste that goes to landfills (Comisión Europea, 2016). By transforming solid waste and biomass in secondary forms of energy such as heat, electricity, and fuel,

Latin America and the Caribbean could produce a new source of the economy towards the development, in addition to have control over the generation and final disposition of these wastes. This positive economy transformation has been conducted already in countries such as Jordan (Al-Hamamre *et al*., 2017), China (Chen; Rong-Gang; Bangrong; Mi, 2017), Brazil (Freitas *et al*., 2019), Argentina (Francisca; Montoro; Glatstein, 2017), and now in Colombia (Andrade; Restrepo; Tibaquirá, 2018).

Studying the transportation (infrastructure) and storage of sanitary landfills can contribute to diagnosing the current situation of C&D waste management in Colombia. Calculations of Colombia's primary cities reveal the distance that waste collection trucks travel to sanitary landfills, the CO_2 emissions produced by the consumption of diesel and how long their trips take, making it possible to analyze the region and compare it with other countries. Reducing C&D waste in sanitary landfills would considerably increase their lifespan and decrease the emission of pollutants, which is why it is important to implement principles of a circular economy in the management of C&D waste. Combining this with investments in infrastructure would reduce travel time to landfills, lower the overall cost to the economy and contribute to construction projects that not only include homes but also bridges, highways, and streets in which it is feasible to reuse, reduce or recycle C&D waste, as warranted by a circular economy.

Methodology

This article is based on a review and analysis of different sources. The first group of sources includes publications on waste management logistics from different places around the world and reports from companies involved in waste collection services in Colombia. The second group includes two important reports: one is the Logistics Performance Index (LPI), published by the World Bank since 2007, and the Global Competitiveness Index (GCI) published by the World Economic Forum since 2008 (Word Economic Forum, 2018), both studies are based on interviews conducted with people who are responsible for logistics processes all around the world. The LPI and GCI are statistical reports categorized both by region and nation and provide a rating for each indicator assessed. This rating helps to assess how Colombia is compared to other countries, such as the ones with developed economies and the ones in Latin American and Caribbean region.

The Development Bank of Latin America (CAF), together with the CAF-LOGRA program on regional logistic development. Created the Latin American Logistic Profile - PERLOG. This program provides a logistics profile that analyzes regional logistics systems. The earliest analysis started in 2014 and includes detailed logistics profiles of eight countries.

Another consulted was the Economic Commission for Latin America and the Caribbean (ECLAC), which provides region-specific information and whose statistics make it possible to compare indicators with other regions or to measure the activity that Latin American and Caribbean (LAC) countries have had in different logistics areas. The government agency responsible for official statistics in Colombia is the National Administrative Department of Statistics (DANE). Its database was used as a source to analyze information from each of Colombia's departments. Information from this database on solid waste generation, solid waste disposal and population growth was examined to verify how these figures compare to those of international studies on logistics.

The Superintendence of Residential Public Services (SSPD) also has an annual report that has been conducted since 2010. The report focuses on solid waste management, final disposal systems, and adequate and inadequate systems. Besides, publications from Colombia Competitiva.gov ("Competitive Colombia.gov") and Compite ("Compete") were used. These publications provide studies on logistics in Colombia, allowing for these results to be compared with those obtained globally.

In order to analyze issues on sanitary landfills, GHG, and transportation and management developed in this area, both national and international research publications have also been reviewed. These were useful to compare Colombia with other countries and helped to identify data sets that can contribute to developing other data to be applied to the situation of C&D in Colombia.

Glossary

- **SW**: Solid Waste.
- **PMIRS:** Planta de Manejo Integral de Residuos sólidos (Integrated Solid Waste Management Plant).
- **C&D:** Construction and demolition.
- **GHG:** greenhouse gases.
- **GCI:** Global Competitiveness Report.
- **LPI**: Logistics Performance Index.
- **LAC:** Latin America and the Caribbean.
- **USL:** Usuarios del Servicio Logístico (Users of Logistics Services).
- **PSL:** Proveedores de Servicio Logístico (Logistics Service Providers).
- **ICLR**: Índice de Competitividad Logística Regional (Regional Logistics Competitiveness Index).
- **Sanitary landfill**: a place designed and operated for final disposal of solid waste, for the confinement and isolation of waste, with control of gases and leachates (Ministerio del medio Ambiente, Vivienda y Desarrollo Territorial, 2005a).
- **Contingency cell:** according to Article 3 of Resolution 1890 of 2011 from Colombia (Superintendencia de Servicios Públicos Domiciliarios, 2018), these cells were an alternative for the final disposition. Municipalities could request to the competent environmental authority that these cells where transformed in a landfill construction and operation project.
- **Integral plant: a** system that integrates the management of solid waste and is composed of processes such as: classification, collection, transport, transformation, destruction, use, sale, and final disposal (Franco, 2016). The unusable materials will be disposed of in a technically operated micro filler (Vargas, 2015).
- **Transitory cell: a** system the final disposition of SW in accordance with article 5 of Resolution 1390 of 2005 from Colombia (Ministerio de Ambiente, Vivienda y Desarrollo Territorial, 2005b) built to be used up to only 36 months (Superintendencia de Servicios Públicos Domiciliarios, 2018).
- **Open-air dump**: it is one of the oldest waste disposal practices, which is carried out without applying sanitary controls; there are no separations or treatments for WS. It works without technical criteria in a recharge area located next to a body of water, a natural drainage. Air, water, and soil deteriorate due to the formation of leached gases and liquids, burns and fumes, dust and bad odors, generating environmental and public health issues (Duarte-Díaz, 2008; Ministerio de Medio Ambiente de Colombia, Organización Panamericana de la Salud, 1996).

Results and analysis

Waste logistics throughout the world

Logistics management, which has been used with solid waste throughout the world, varies a lot from one region to another. It depends on the country's legislation, geographical conditions, its culture surrounding environmental protection, and last

but not least, the incentives and sanctions applied to different economies.

The circular economy is based on a paradigm shift: waste is turned into a resource. Therefore, it is not only a recovery and re-use economy but also and especially a re-creation economy. In doing so, it transforms production chains and consumption patterns and decouples GDP growth from natural resources use (Frérot, 2014). Today's serious environmental problems have led to all international institutions to change their environmental laws and regulations to a new alternative: a circular economy. Most Asian countries, especially powerful ones such as Japan and China, have completely transformed their economic systems to circular economy models. Changing towards a circular economy model is due to a lack of raw material and a rise in waste because of the large populations of these countries. To maintain sustainable growth Japan applies three basic factors: 1) Oil-based emissions reduction and optimization of industrial structures for improving energetic efficiency, 2) Education and public campaigns to increase the participation of society, and 3) Environmental laws lay the foundations for an integral judicial system that regulates waste management and standardizes sanctions for being implemented.

China is also very committed to a circular economy. Most of its circular economy projects have met their established objectives, such as a reduction in energy use by 67 % and an increasing recycled water by 42 %. Their next objectives will be to legitimize environmental decisions through indicators on the use of direct or indirect energy in industrial production processes (Troncoso, 2018).

According to the World Economic Forum report, many of these elements are found in environmental and economic policy, with established policy goals up to 2050 in some specific areas. In many cases, these goals contain important indicators and challenges to analyze the implementation (European Environment Agency, 2013). Nowadays, most European countries have reduced sanitary landfills utilization because of environmental issues and policies (Comisión Europea, 2016).

As the applied studies of the LPI (Logistics Performance Index) (The World Bank, 2018) and the GCI (Global Competitiveness Index) show (Word Economic Forum, 2018), the levels of logistics in several countries from the European Union, USA, and Japan have the highest performance, as their governments have prioritized connecting the nation through the infrastructure that allows for efficient and multimodal mobility. While the quality of infrastructure of EU nations is not equal, these nations understand that an efficient transportation system depends on a solid waste management system that functions adequately and appropriately. This is reflected in a road network that offers options for effective mobility, not only in commerce and with people, but through the application of a waste management system that allows for the collection programs to occur at different schedules depending on the traffic of each region and different waste types, allowing for places to be selected for the final disposal of C&D waste that is nearby and easy to access for materials to be processed.

Waste logistics in Latin America

Countries of the American continent are the least advanced in terms of implementing a circular economy. As an example, one of its leading forces, such as the United States has no policy measures to implement a circular economy (Troncoso, 2018), which is reflected in the findings of the aforementioned logistics studies. Despite the U.S. has an excellent infrastructure in terms of quality, solid waste logistics management is poor for being the country that generates the most waste as, according to the LPI and GCI its road network can implement a waste collection logistics system that does not interrupt the daily activities of its citizens.

In Latin America, solid waste logistic management has progressed significantly in recent years. In Colombia, for example, the solid waste collection rate is 97.8 % in urban areas and just 21.9 % in rural areas (Álvarez; Valenzuela, 2016). In contrast, in México, this rate ranges between 70 % and 85 % (Betanzo-Quezada; Torres-Gurrola; Romero-Navarrete; Obregón-Biosca, 2016). While waste collection in the region has improved, final disposal systems for solid waste have not shown much improvement. Sanitary landfills are considered to be one of the most appropriate systems for waste disposal, as they are regarded as places that can meet the right conditions to store waste; despite clear evidence that landfills have negative short and long-term aspects about them.

Some aspects of Latin America's infrastructure have made progress in the development of the economies, of these countries, such as Panamá, for example. The quality of Panamá infrastructure is a strong point in trading activities. The Panamá Canal is the structural axis for developing its national logistics services, which is why it ranks number two in the region according to the World Bank's LPI index; however, it needs to invest in infrastructure projects that connect the country's roads. Panamá needs a policy on efficiency and systematic competitiveness in its industry, and needs to improve information systems in its freight vehicles. It is important to remark that while Latin America and the Caribbean region has made efforts to improve its logistics (Farromeque-Quiroz, 2016a); as regards the infrastructure area, it is still behind, as in the case of Bolivia (Farromeque-Quiroz, 2016b). While in general, its intermodal connections are essential to trade; more specifically, its logistics waste management system still does not have access to many regions and public works are not being maintained. Therefore, to create a logistics plan for waste collection, different paths must be considered to reduce time, emissions and costs. Waste collection companies are entities that must operate in all countries. In the LAC region, however, a lot of work in the area of public works needs to be done and more importantly, citizens must also be educated so they can dispose of waste in a way that is least harmful to the environment and to the humans that are part of it. The importance of locating wastes in appropriate places, especially in regards to the disposal of special ones, such as C&D waste, should be highlighted so that a cost should be charged for it to be properly managed. Citizens should also be educated so, they can understand that those who contaminate are those who must pay, without expecting incentives to treat waste correctly.

The logistics of waste in Colombia

As figures from the LPI and GCI show on logistics in Colombia, averages for Colombia are low compared to countries with high rankings. It has always received a score of 3.0 out of 5.0 total points in the LPI and a score of 4.5 out of a total of 7 points in the GCI. It means that despite investments in infrastructure, Colombia – as well as the LAC region – has a lot of room for improvement. This is evident in the rankings of the editions of these reports that have been published thus far, where Colombia is behind countries such as Chile, Panamá and México. As the PERLOG shows, however, the Latin American region ranks low in logistics and is at the most basic level of the chain – demonstrating that averages for Colombia are very similar to those of the economies as mentioned above (Farromeque-Quiroz, 2016c). Internally, studies that assess Colombia's logistics reveal inequality in investments, development, construction, and logistics. Departments such as Cundinamarca, Antioquia, Valle del Cauca and Atlántico have transport corridors that make transportation more effective between its regions Instituto Nacional de vías [INVIAS], 2018) and municipalities; these are also the departments that generate the most waste (Superintendencia de Servicios Públicos Domiciliarios, 2018), as they have high populations. In contrast, departments from the Llanos, Amazon and Pacific regions have the lowest levels of investment and development in general. A map of the country's roads is enough to see that these regions are excluded from infrastructure projects (INVIAS, 2018).

Waste management logistics involves having road infrastructure that allows connecting both urban and rural areas; while waste collection in urban centers is managed by specialized companies and covers almost 100% of urban areas, the coverage rate for rural areas is only 21.9 % (Álvarez; Valenzuela, 2016).

Even though the lack of interconnected roads in the majority of Colombia's regions has been already mentioned, it is important to add that programs supported by law must also be implemented through the PGIRS (Ministerio de Vivienda, Ciudad y Territorio, 2015). For example, separated spaces are needed where wastes separation processes can be carried out to classify the materials according to their properties so that they can be processed and sold. Also, depending on the waste type, different methods of reduction can be applied, such as incineration, and leads to reducing the amount of C&D sent to landfills. People need more training and education to help them realize the importance of being a part of implementing circular economy-based strategies to help mitigate the damage they do to the environment by disposing of waste anywhere. People also need to learn to reuse, reduce and recycle.

Since the nineties decade, some European countries have been implementing strategies for there to be alternatives to the final disposal of organic waste in sanitary landfills. In Flanders, Belgium, domestic waste is a secondary resource, as 50 % to 60 % of the domestic waste produced is biodegradable and can therefore, be converted into a reusable product for agriculture (Gellens; Boelens; Verstraete, 1995). Part of what makes this possible is that organic waste is managed by separating it at the source (in homes, schools, among others). One of its strategies for garden waste to be reused is to educate

its citizens about domestic composting through awareness campaigns and by promoting "cyclical gardening." They do this by teaching kids about composting in schools and by performing composting demonstrations at community composting centers – an excellent alternative for obtaining compost and improving the conditions for crops.

Non-organic waste such as plastics, glass, and C&D, must be managed in a special way at the source so that they can contribute to the process of the three R's. In Colombia's rural areas, a logistics management program needs to be created to expand the coverage of its waste collection; in urban areas, however, models need to be applied that can help reduce the use of sanitary landfills as a final disposal system.

Figure 1 shows pictures of public spaces that people have used as places for the final disposal of solid waste, especially C&D waste (construction and demolition waste). The waste consists of items that do not degrade; it is an urban eyesore, affecting not only the region's landscape but also the soil conditions in where these have been disposed of. While the companies that provide waste collection services in Colombia have specific programs to manage special waste properly, users are not interested in paying extra for such services. This is the main reason why C&D waste can be found in public places, or alternatively, users will prefer to pay a lower cost to people outside the cleaning company to get rid of their Construction & Demolition waste and do not worry about where they end up.

Figure 1. Inadequate disposal of construction and demolition wastes (C&D) in Colombia
Source: own

Figure 2 shows the results of the LPI and GCI indexes for 2018. The figure shows the variables or indicators assessed for each report and their respective score for the selected economies, which are countries that ranked first and second (Germany and Sweden); the United States as the most highly ranked nation from the Americas; the number one country from a Latin American country (Chile and Panamá respectively); and Colombia. The lines in Figure 2a on the LPI reveal that European countries hold the first two positions with averages above 4.0, a result of the investments these nations have made in the area of logistics to make their economies efficient, such as with roads. Germany and Sweden ranked first and second respectively. Germany's average was 4.20 and had a performance of 100 %, while Sweden's average was 4.05 and had a performance of 96.43 %. The United States' economy ranked 14th in the index with an average of 3.89 and a performance of 92.62 %, making it the best ranked nation from the Americas. This figure also includes Chile, the first country from Latin

America and the Caribbean to be included in the ranking. Chile ranked 34th, with an average of 3.32 and a performance of 79.04 %. Colombia ranked 58st, with a performance of only 70 % and an average score of 2.94. Of the 160 countries surveyed in 2018, Colombia rose from 94 to 58, gaining 36 positions. Colombia's ranking is lower than countries such as Chile, Panamá, México, and Brazil, which reveals the significant gap that lies between it and most of the economies that are included in the report. While Colombia has invested in its roads in recent years, this is still not enough to truly make it competitive and is shown by the score obtained in "Infrastructure" with 2.67 points out of 5 possible.

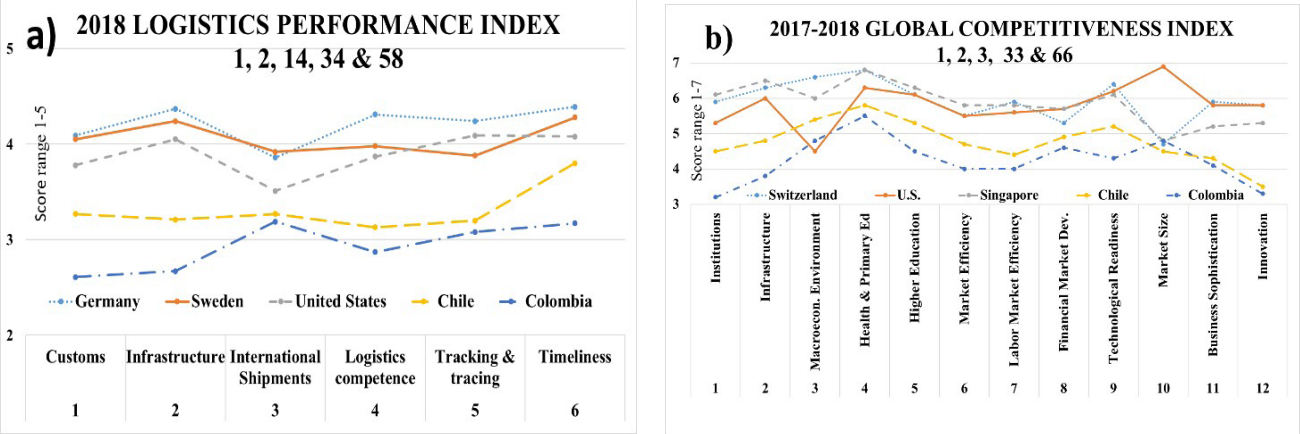


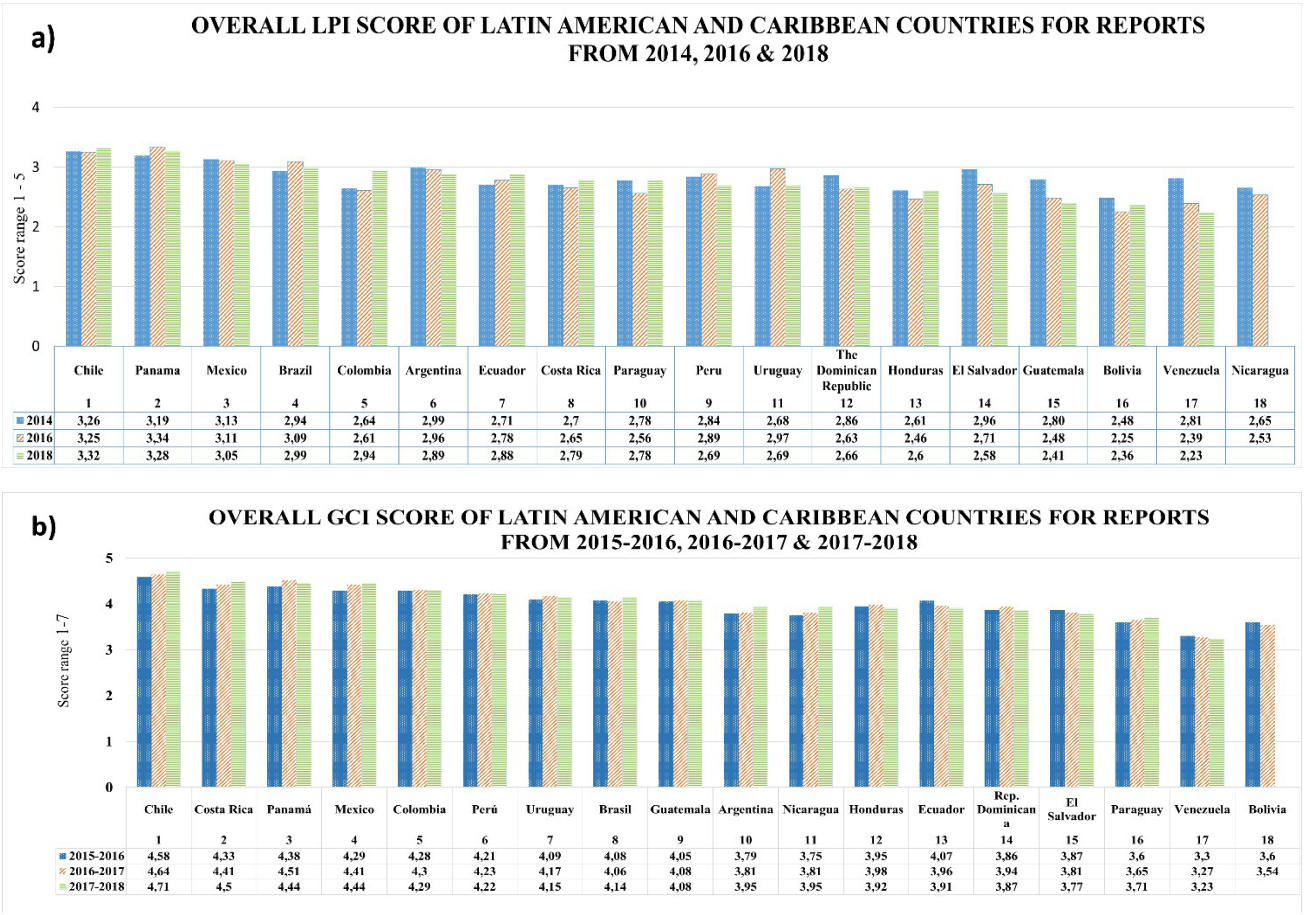
Figure 2. Logistics Performance Index 2018 and Global Competitiveness Index 2017-2018. Data analysis from reports published by the World Bank and World Economic Forum
Source: The World Bank (2018); Word Economic Forum(2018)

Figure 2b shows the results of the GCI report for 2017-2018; this index of twelve pillars places Switzerland in the first position with a score of 5.86, the United States is in second place with 5.85 and Singapore ranks third with 5.71. In position 33 and with an average score of 4.71 is Chile, the first country in Latin America and the Caribbean that appears in the ranking. Chile is above countries such as Costa Rica (47), Panamá (50), México (51) and Colombia (66). With an average score of 4.29, Colombia is located in position 66; it fell 5 positions compared to the previous publication of the GCI 2016-2017, where it was ranked at the position 61. The GCI report takes into account factors such as "financial markets development", where Colombia scored 4.6, however, in "Infrastructure" it obtained 3.8 out of 7 points, which reflects that in this pillar, the country has a long way to go and contributes to the increase of travel time, the cost of transportation which increases the levels of kilometer for CO_2. Issued by the automotive fleet, which is one of the oldest in the LAC region; Colombia has 164,000 cargo vehicles with more than 20 years and this has a negative impact on the environment and productivity.

Figure 3 shows the score of 18 LAC countries for the 2014 - 2016 and period and 2018 reports. They were organized according to the position occupied in the last edition of the LPI 2018 index. The nations that make up this region in a large percentage are developing countries. The figures reflect how by comparing LAC with developed countries in Europe or Japan and the United States, which are pioneers in logistics and commercial operations, there is a large gap. The LPI indexes in Figure 3a ranks Chile as the first nation in the region with a score of 3.26 in 2014, 3.25 in 2016 and 3.32 in 2018. Following Chile is Panamá with 3.19 for 2014, 3.34 for 2016 and 3.28 for 2018. México ranks third with scores of 3.13 for 2014, 3.11 for 2016 and 3.05 for 2018. Brazil takes fourth place with 2.94, 3.09 and 2.99 for the same years. Colombia takes fifth in the region, with scores of 2.64, 2.61, and 2.94, followed by Argentina in sixth place with 2.99, 2.96 and 2.89. In seventh place is Ecuador, which scored 2.71 for 2014, 2.78 for 2016 and 2.88 for 2018This score has improved thanks to the construction of transport routes in the region.

The eleven remaining countries are Costa Rica, Paraguay, Perú, Uruguay, the Dominican Republic, Honduras, El Salvador, Guatemala, Bolivia, Venezuela, and Nicaragua. These nations reflect the low performance of the logistics system in LAC, comparable only to most African states, where not only much investment in infrastructure is needed, but also in the grouping of different aspects of logistics, such as customs, operators and in general, a road network that allows the flow of transport in both urban and rural areas. To implement the seamless logistics of a waste management system,

governments must give logistics the importance it deserves as a fundamental part of the country's economic development and infrastructure.



a)	Chile	Panama	Mexico	Brazil	Colombia	Argentina	Ecuador	Costa Rica	Paraguay	Peru	Uruguay	The Dominican Republic	Honduras	El Salvador	Guatemala	Bolivia	Venezuela	Nicaragua
	1	2	3	4	5	6	7	8	10	9	11	12	13	14	15	16	17	18
2014	3,26	3,19	3,13	2,94	2,64	2,99	2,71	2,7	2,78	2,84	2,68	2,86	2,61	2,96	2,80	2,48	2,81	2,65
2016	3,25	3,34	3,11	3,09	2,61	2,96	2,78	2,65	2,56	2,89	2,97	2,63	2,46	2,71	2,48	2,25	2,39	2,53
2018	3,32	3,28	3,05	2,99	2,94	2,89	2,88	2,79	2,78	2,69	2,69	2,66	2,6	2,58	2,41	2,36	2,23	

b)	Chile	Costa Rica	Panamá	Mexico	Colombia	Perú	Uruguay	Brasil	Guatemala	Argentina	Nicaragua	Honduras	Ecuador	Rep. Dominicana	El Salvador	Paraguay	Venezuela	Bolivia
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2015-2016	4,58	4,33	4,38	4,29	4,28	4,21	4,09	4,08	4,05	3,79	3,75	3,95	4,07	3,86	3,87	3,6	3,3	3,6
2016-2017	4,64	4,41	4,51	4,41	4,3	4,23	4,17	4,06	4,08	3,81	3,81	3,98	3,96	3,94	3,81	3,65	3,27	3,54
2017-2018	4,71	4,5	4,44	4,44	4,29	4,22	4,15	4,14	4,08	3,95	3,95	3,92	3,91	3,87	3,77	3,71	3,23	

Figure 3. An Overall score of Latin American Countries and their positions worldwide and for LAC for the LPI and GCI indexes for 2014, 2016 and 2018 Data analysis from reports published by the World Bank and World Economic Forum
Source: The World Bank (2018); Word Economic Forum(2018)

In contrast, in Figure 3b, the GCI ranks Chile in first place among Latin American countries, with scores of 4.58 for 2015-2016, 4.64 for 2016-2017 and 4.71 for 2017-2018. These scores reflect the progress that the Chilean government has been making in the area of logistics, as in the infrastructure pillar itself it scored 4.80 out of 7 points. Second in the region for the average of these same years is Costa Rica, with scores of 4.33, 4.41 and 4.5 respectively. In third place is Panamá obtaining 4.38, 4.52 and 4.44 respectively; while in the fourth place is México scoring 4.29, 4.41 and 4.44. In fifth place, Colombia scored 4.28 for 2015-2016, 4.3 in 2016-2017 and 4.29 for 2017-2018. The economies that fall behind Colombia in this index are Perú, Uruguay, Brazil, Guatemala, Argentina, Nicaragua, Honduras, Ecuador, the Dominican Republic, El Salvador, Paraguay, Venezuela, and Bolivia (which was not included in the study 2017-2018). This is largely due to the corruption of government leaders that show a lack of interest in the social and economic aspects of their economies, and therefore lack the money to make necessary investments in the logistics.

Chile, Perú, and México, as well as Colombia, are all part of the Pacific Alliance, which has become the nucleus of a new business model. Colombia, however, has remained below the other nations that make up this group in Latin America (The World Bank, 2018; Word Economic Forum, 2018). This Alliance looks for the economic development of the region, which requires an optimal infrastructure in finance, telecommunications, energy, transport, among other sectors (Cortés-Villafradez, 2018).

Figure 4 shows the positions of Latin American and Caribbean countries from the three most recent publications of the LPI and GCI. The bars reflect the significant gap that exists between nations from this region such as Chile, who is ranked among the top 50, and Venezuela, whose rankings have been above 120 in the LPI – a trend that repeats in the GCI.

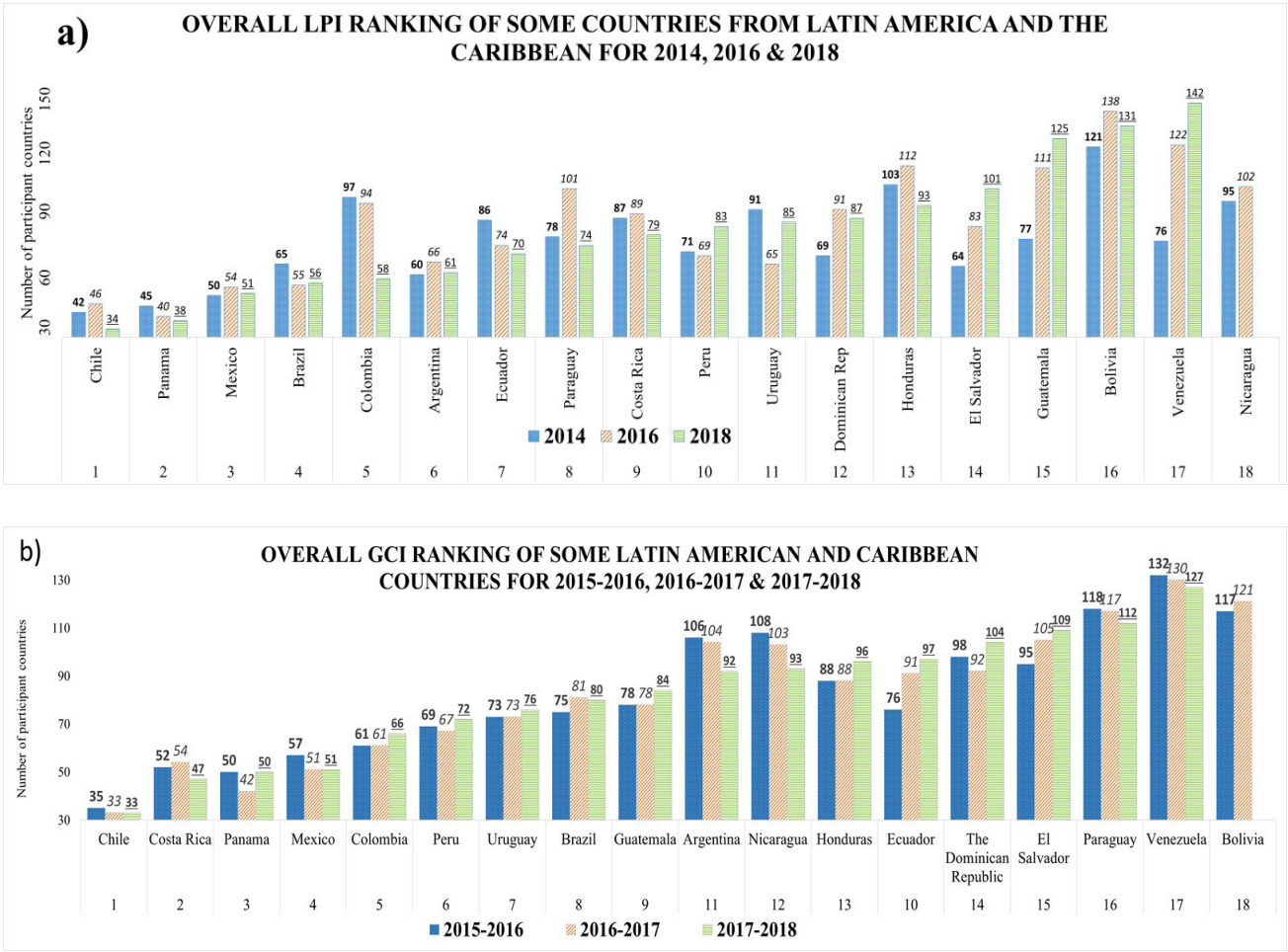


Figure 4. The Overall ranking of some countries from Latin America and the Caribbean from the LPI and GCI reports from 2014 – 2018. Data analysis from reports published by the World Bank and World Economic Forum
Source: The World Bank (2018); Word Economic Forum(2018)

Figure 4a shows the positions that some countries from Latin America and the Caribbean hold on a global level for the LPI reports from 2014, 2016 and 2018. Chile took positions 42, 46 and 34 respectively; Chile took positions 42, 46 and 40 respectively, being ahead of Panamá in 2018. In second place for LAC, Panamá took position 45 in 2014, 40 in 2016, and 38 in 2018. In third place is México, taking positions 50, 54 and 51. Brazil is in fourth place, taking positions 65, 55 and 56. Colombia, on the other hand, went from 97 in 2014 to 94 in 2016. In 2018, however, it gained 23 positions, notably improving its logistic performance in the region. Argentina's rankings were 60, 66 and 61. Ecuador has been improving its performance and went from position 86 in 2014 to 74 in 2016 and to 70 in 2018. The remaining 11 nations were towards the very end of the ranking; El Salvador, Guatemala, Venezuela, and Bolivia were the nations that ranked above 100 other countries, drastically lowering the average for the region.

Figure 4b shows the positions that some Latin America and the Caribbean countries hold globally according to the GCI for 2015-2016, 2016-2017 and 2017-2018. Chile ranked the highest after maintaining its maintained its position from the previous report as country 33. Following Chile is Costa Rica, which took positions 52, 54 and 47, respectively. Panamá ranked 50, 42 and 50; while México, which was ranked 57 for 2015-2016, remained in position 51 for the last two reports. In fifth place for the region is Colombia, which held position 61 for the previous two reports, however, it fell five places for

2018, coming in at 66. For 2015-2016, Perú ranked 69, it rose two positions in the year following, but for 2017-2018 it fell five positions, ranking position 72. The ranking shows large changes in a short time: Argentina, for example, went from ranking 106th in 2015-2016 to 92th in 2017-2018, while El Salvador felt from 95th in 2015-2016 to 109th in 2017-2018.

Figure 5 shows the rankings obtained from the PERLOG report (Logistics Profile for Latin America) for the nine countries that participated in it. The report measures poverty in Latin America concerning logistics. It found México to be the only country to be above the average with a score of 2.62 (Farromeque-Quiroz, 2016d). Panamá score was 2.20, followed by Colombia with a score of 2.12 and Uruguay with a score of 2.06. Perú took fifth place with a score of 2.02, while Argentina, Ecuador, Paraguay and Bolivia's scores were all lower than 2: 1.84, 1.70, 1.58 and 1.54, respectively. Despite a clear trend of Latin America and the Caribbean to use unimodal transport, and having a concentration of highway transportation that is 15 times higher than that of the United States, these low scores are attributed to a lack of ports, a lack of roadways that maintain connectivity in a nation, and poor infrastructure (mostly in the transportation sector) (Farromeque-Quiroz, 2017).

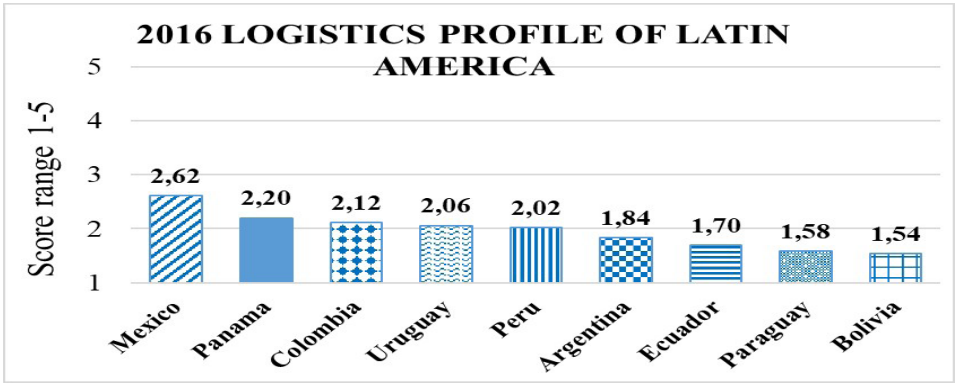


Figure 5. 2016 Logistics Profile of Latin America. Data analysis from the CAF report
Source: Farromeque-Quiroz (2015); Farromeque-Quiroz (2017)

Figure 6 shows the four founding strategic lines of the INDILOG (fulfillment indicators) from PERLOG to obtain the performance level for the participant countries. Logistics performances such as IPL and GCI are not measured, upon the development and fulfillment data required in the PERLOG, therefore going towards a new regional advanced logistics, taking advantages of the local geography in Latin America, and thus beneficing the waste transport as well. Results for Colombia in 2016 according to these numbers were: first, the "Planificación e institucionalización logística" (planning and institutionalization logistics) with 2.67; then, Desarrollo del Sistema Logístico (development of the logistics system) with 2.50. After that, the third, "Desarrollo de Logística Básica y Sostenible" (basic and sustainable logistics development) with 1.67; and finally, "Logística de comercio internacional" (international trade logistics) with 2.13. With these numbers, Colombia is in a B fulfillment position, which means that has some initial plans and actions on the way, but no consolidated yet. Considering the results presented above, Colombia must work for strategies towards a logistic system with a high level of planning and indicators fulfilled. It must include new infrastructure not only for the larger urban areas but also for other smaller cities across the country.

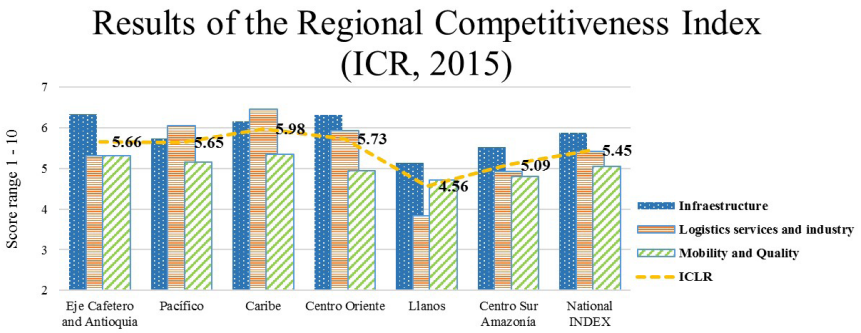


Figure 6. INDILOG for countries of the PERLOG 2016 showing the Colombian score
Source: Farromeque-Quiroz (2017)

Figure 7 reveals other significant figures on Colombia taken from the National Logistics Survey (Encuesta Nacional Logística): the Regional Competitiveness Index (ICR, Índice de Competitividad por Regiones). The objective of the ICR is to assess regional effectiveness in logistics activities and operations. This index is based on a scale from 1 to 10 and provides a Logistics Competitiveness Index. A score of 1 means that the region does not contribute to logistics operations and 10 means that it does. Next, the user companies (USL), who were a total of 504, and those that provide logistics services (PSL), who were 264 (Cámara Colombiana de la Infraestructura, 2016), were asked to assess each region and place them within this ranking. The national average was 5.45 and the results by region are shown in the figure. The scores for Infrastructure, represented by the first bar in the graph, are shown as follows for each region: Eje cafetero and Antioquia, 6.33; Pacífico, 5.73; Caribe, 6.15; Centro Oriente, 6.32; Llanos, 5.13; and Centro Amazonía, 5.53.

This makes for a national average of 5.87 out of 10 total points. Logistics services and industry, represented by the second bar in the graph, scored as follows: Eje cafetero and Antioquia, 5.32; Pacífico, 6.05; Caribe, 6.45; Centro Oriente, 5.93; Llanos, 3.84; and Centro Amazonía, 4.93. The national average for this aspect of logistics is 5.42. While they still have areas they can improve upon, the Caribbean and Pacific regions have a higher score in this area due to their port-related activities and the successful performance of these ports. The national average for mobility and quality, represented by the third bar, is the lowest of the three national averages that were measured with a score of 5.05. The regional scores for mobility and quality are: Eje cafetero and Antioquia, 5.32; Pacífico, 5.16; Caribe, 5.34; Centro Oriente, 4.94; Llanos, 4.72; and Centro Amazonía, 4.81. The national average for this area is low due to a lack of investment in the road system to not only build new transport corridors, but to improve the following situations: the interconnectivity of the country's roads; the excessive amount of vehicles that congest and delay travel time; and the need to stop depending on unimodal transportation and to begin to use and prepare rail, sea and air routes in order to have a competitive and efficient transportation system, not only commercially, but with people and waste.

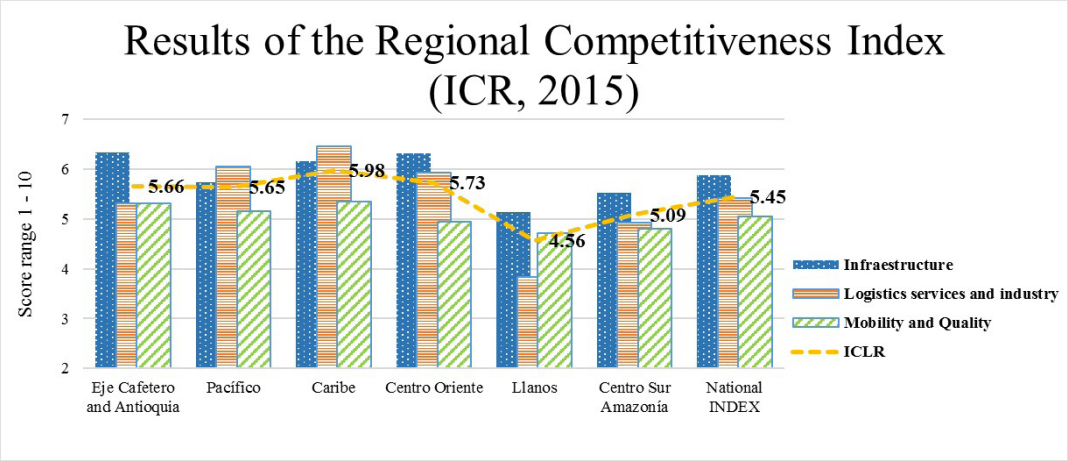


Figure 7. Results of the Regional Competitiveness Index (ICR. Índice de Competitividad por Regiones, 2015)
Data analysis of 2015 National Logistics Survey.
Source: Consejo Privado de Competitividad (2017)

Figure 8 is an overview of the inadequate systems of final solid waste disposal in Colombia between 2013 and 2016. This analysis shows how the investments of Colombia's primary cities have performed each year in this area between 2013 and 2017. This chart accounts for regions with the greatest number of inhabitants, waste, roads and construction. Bogotá, as Colombia's Capital District, is the region with the highest degree of investment in infrastructure, which not only consists of roads but also projects that are needed to improve the development and welfare of a country. For 2013, Bogotá's score was 5.76; 2014, 7.32; 2015, 7.03; 2016, 7.31 and for 2017, it was 7.10. In contrast, Antioquia scored the following: in 2013, it scored 4.60; 2014, 5.71; 2015, 7.03; 2016, 5.45 and for 2017, it scored 5.45. The results for the Atlántico for 2013 were 4.16; 2014, 4.81; 2015, 6.41; 2016, 5.20 and for 2017, it scored 5.30. The scores for El Valle for 2013 were 3.93; 2014, 5.59; 2015, 6.27; 2016, 5.58 and for 2017, it scored 5.36.

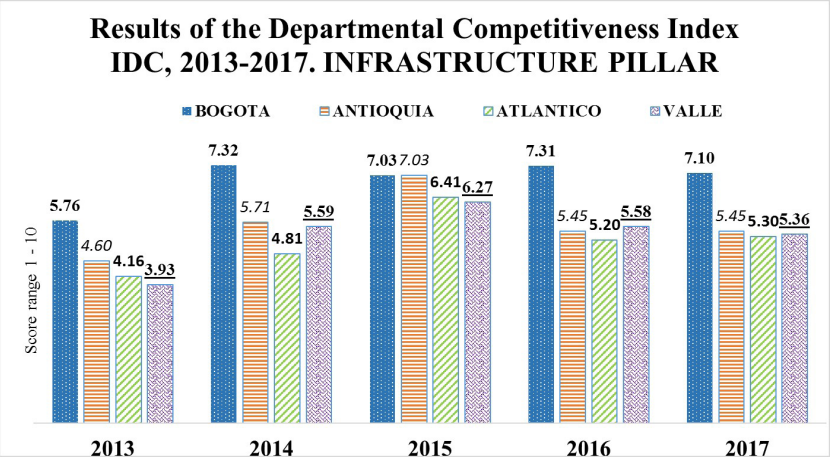


Figure 8. Results of the Departmental Competitiveness Index (IDC. Índice Departamental de Competitividad I.D.C., 2013-2017), INFRASTRUCTURE Pillar. Data analysis of report from the Private Competitiveness Council

Therefore, it is clear that infrastructure in these regions has been growing, that Colombia is going through a construction process as it needs to improve the current situation of public works that serves its citizens. Nevertheless, National Investments remain insufficient, as some regions receive more support than others, such as the Llanos and the Amazonía.

Figure 9 shows the values given to logistic barriers by the logistic service users (USL) and service providers (PSL) in the report "Colombia es logística". From the USL evaluation, "Infrastructure" with 53.4 % in the main problem, the main part corresponds to high transportation costs and insufficient roads, ports, and airports. "Company management" is the second barrier, with 34.8 %. With a lack of human talent and offer of logistic service as the main contributors to this issue. Finally, the third barrier is "Customs management", with 11.8 %, most likely due to the complexity of customs procedures. On the other hand, data obtained from PSL showed that "Company management" is the main barrier with 59.3 %, followed by "Infrastructure" with 32.2 %. These results certainly show a lack of infrastructure, which decreases the competitiveness of the economy.

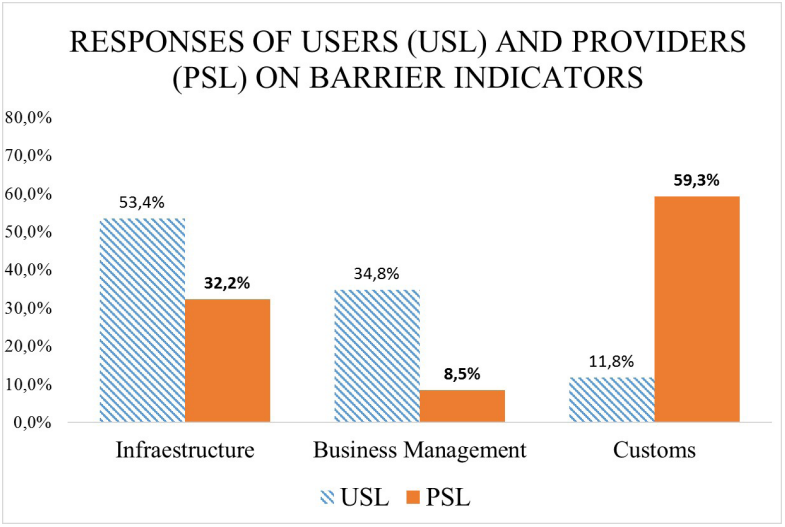


Figure 9. Responses of users (USL) and providers (PSL) on barrier indicators. Data analysis of the 2015 National Logistics Survey, "Colombia Is Logistics," (Departamento Nacional de Planeación (2015)

Figure 10 is a representation of the inadequate final disposal systems that have been used in Colombia from 2013 to 2017 (Superintendencia de Servicios Públicos Domiciliarios, 2018). Open-air dumps show a downward trend after 2013. In this year, 163 municipalities disposed of their waste using open-air dumps; in 2014, this figure fell to 133; in 2015, to 114, and for 2016, this figure was just 54 municipalities; Finally, in 2017 only 41 municipalities used this system. Overall, it represents a total reduction of 63.7 % of municipalities that began to dispose of their waste with another system. The "transitional cell" system is considered inadequate, and has performed as follows: for 2013, it was used in 51 municipalities; in 2014, 58; in 2015, 47 in 2016, 43 and 2017, 18.

The use of bodies of water is one of the final disposal systems most damaging to communities because it not only contaminates the water but also obstructs rivers causing and caused flooding and disasters. In 2013, just one municipality disposed of their waste using this system; in 2014, this number rose to 13; in 2015 it reduced to 5; in 2016 and 2017, there were no reports of communities using this system to dispose of their waste. Moreover, burying waste is nowadays the least used waste disposal method. For 2013, 2014 and 2015, there were no reports of any municipality burying its waste, in 2016, 7 municipalities were reported, and for 2017only 2. Finally, burning has become a less common method. In 2013, 14 municipalities were reported to use Burning as their waste disposal method; while in 2014, 2015 and 2016, only 1, 2 and 1 the municipality was reported to have used this method, respectively. For 2017, none.

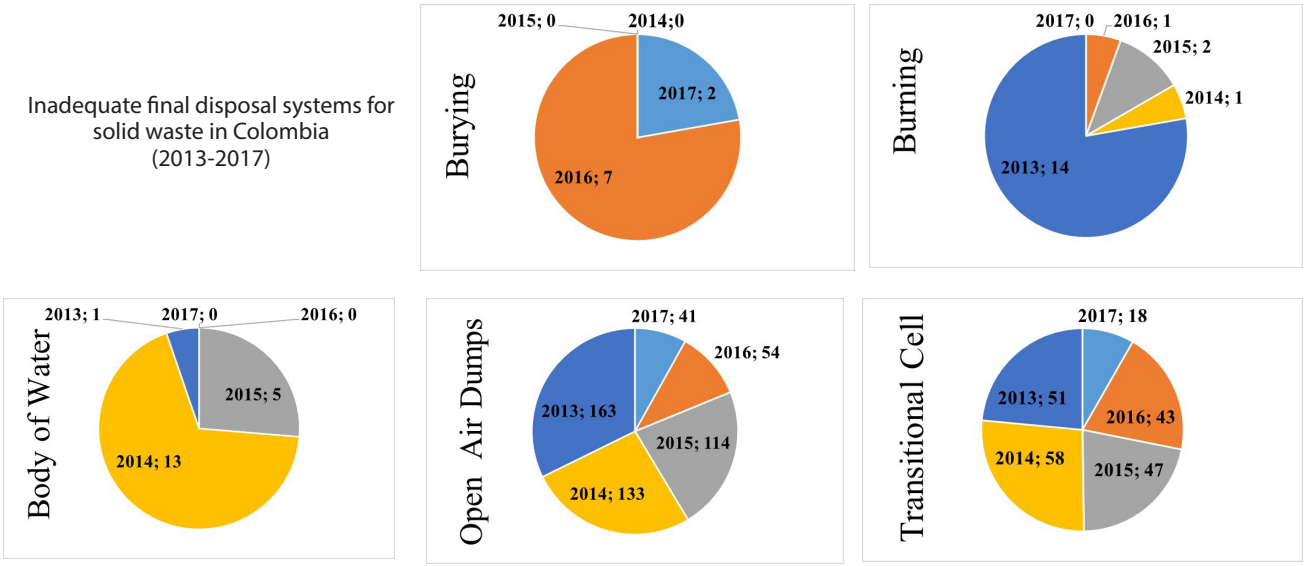


Figure 10. Inadequate final disposal systems for solid waste in Colombia (2013-2017). Data analysis of publications from National Report on Final Waste Disposal (Superservicios)
Source: Superintendencia de Servicios Públicos Domiciliarios (2018)

Figure 11 is an overview of three suitable systems of final solid waste disposal in Colombia from 2013 to 2017. The Contingency Cell, was implemented in 27 municipalities in 2013, and it decreased to 22 in 2014; and as follows for 2015, 2016 and 2017, 14, 15 and 9 municipalities disposed of their waste using this method, respectively. Municipalities using an integral plant system to deposit waste have also been reducing. In 2013, 57 municipalities deposited their waste using this system, and in 2014, it was reduced to 46. In 2015, only 34 municipalities used this system, while in 2016, this number dropped to 9. In 2017, the number of municipalities increased to 14. Landfills are the most widely used waste disposal system in the country, as shown in the SSPD report. In 2013, 789 municipalities out of 1120 used this system; 829 municipalities in 2014; 886 in 2015; 891 in 2016 and finally 842 in 2017. Although this system has a special adaptation process as part of its final waste disposal process, it also leaves negative impacts on the environment and population living near the site.

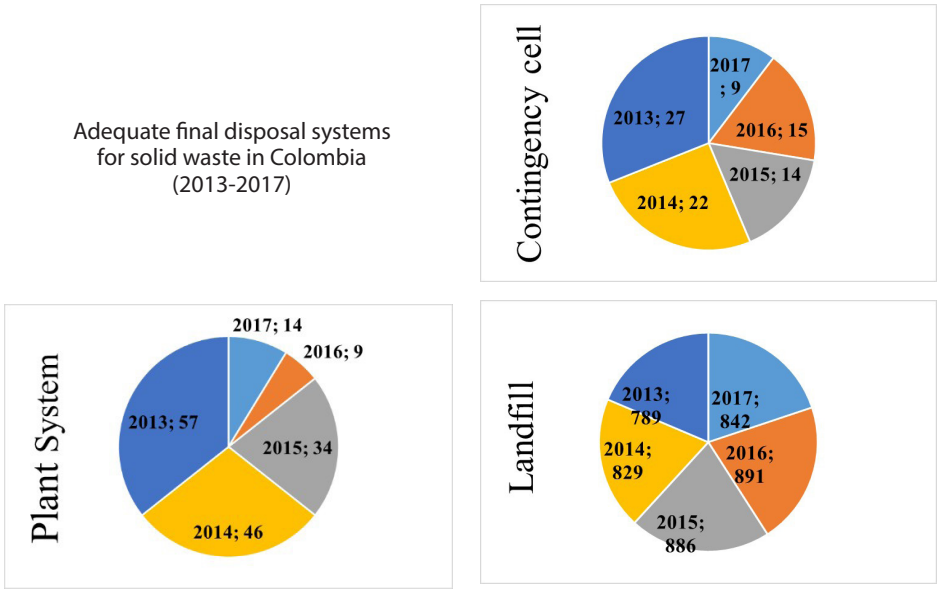


Figure 11. Adequate final disposal systems for solid waste in Colombia (2013-2017). Data analysis of publications from National Report on Final Solid Waste Disposal (SSPD)

Figure 12 shows important data on some of Colombia's major sanitary landfills in Bogotá, Medellín, Cali, and Barranquilla. With 59 hectares (Concejo de Bogotá, 2018) (1,463 acres), Doña Juana in Bogotá has been operating since 1998. It receives an average of 188.384 tons of waste per month and it only has 4 years of useful life, as it must close by 2020. La Pradera in Don Matías, Antioquia, is where waste from Medellín and other Useful Life Remaining locations is deposited. It is 354 hectares (INTERASEO, 2018) (874 acres), has been operating since 2003, has a useful life of 10 more years and receives an average of 79.469 tons of waste each month. In Cali, Guabal has been operating since 2008. It is 363 hectares (897 acres), receives 70.543 tons per month and its useful life is 14 years. Pocitos in Barranquilla is 135 hectares (333 acres), receives 47.432 tons and has a useful life of 21 years. Sanitary landfills in Colombia are inter-municipal, which means that strategies are needed to implement green logistics and a circular economy to this form of waste disposal, as the land for these systems is running out of its projected useful life faster than expected.

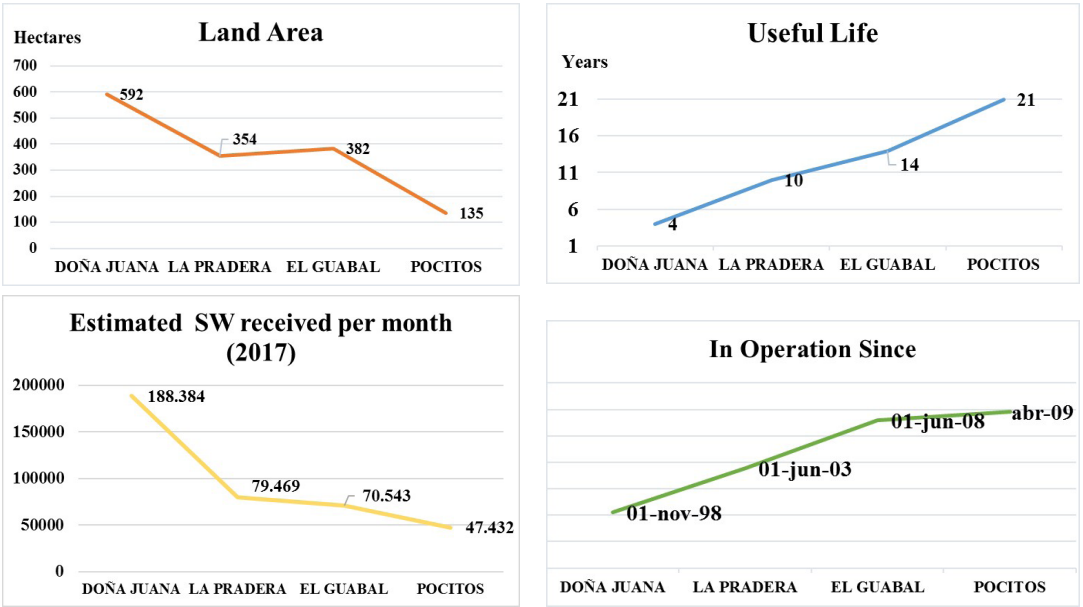


Figure 12. Sanitary Landfills 2017. Bogotá, Medellín, Cali, Barranquilla. Data analysis of National Report on Final Solid Waste Disposal (SSPD)
Source: Superintendencia de Servicios Públicos Domiciliarios (2018)

Figure 13 is an overview of the distances and route times of 2015 routes from 9 locations to a sanitary landfill in Ciudad Bolívar, which is settled south of Bogotá, as well as the respective fuel that is used and CO2 that is produced for each route (García; Padilla, 2014). Calculations show the following results: the town of Gutiérrez is 101.7 km away from the landfill with a 155.94 minute route; Choachí is 54.7 km away with an average 83.87 minute route; Quetame is 53.7 km away with an 82.34 minute route; Ubaque is 53.2 km away with an 81.57 minute route; Caqueza is 36.1 km away with a 55.35 minute route; Bogotá is 26.7 km away with a 40.94 minute route; Chipaque is 20.4 km away with a 31.28 minute route; Bosa is 15.7 km away with a 24.07 minute route; and Usme is just 3.4 km away with a 5.21 minute route. The ratio of fuel and CO_2 production is measured by the liters of fuel that is needed to take the route, given in kilograms of greenhouse gases. The results show that the route from the town of Usme to the landfill takes 0.54 liters of fuel, producing 0.2 kg of CO_2 per trip; and the route from Gutiérrez (which is the town furthest from the landfill) takes 16.27 liters of fuel, producing 5.97 kg of CO_2 per trip. One of the most important aspects of developing a waste management logistics plan is the CO_2 that is produced as a result of fossil fuel use, as making a change in the fuel that is used to alternatives, such as natural gas or electric cars, can greatly reduce pollution levels in the environment.

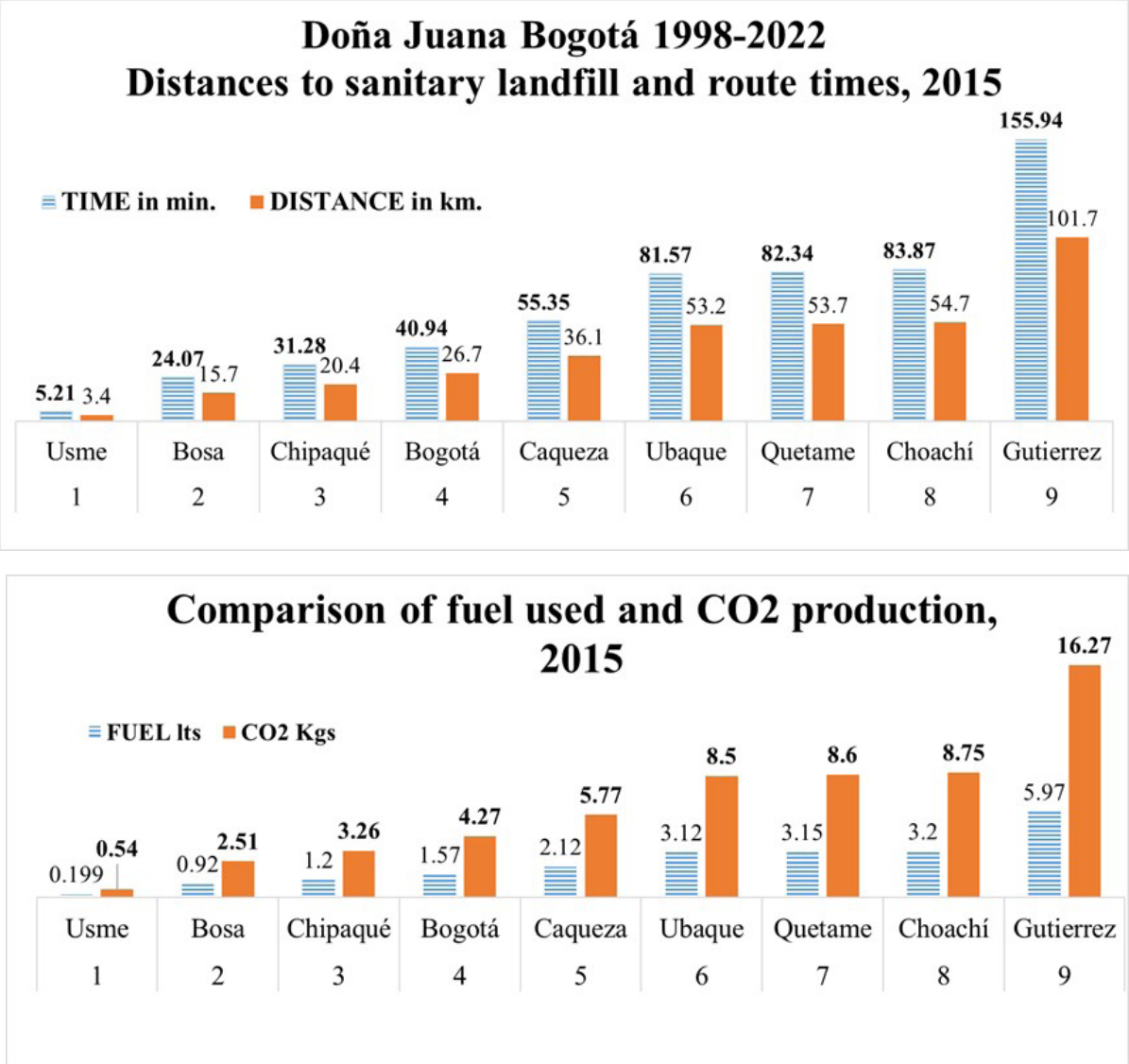


Figure 13. Doña Juana Bogotá 1998 - 2022. Data analyzed according to Colombia's Unified Information System (Sistema Único de Información, SUI). Distance calculated with Google maps. Calculations of fuel use, CO_2 produced, and route times are author calculations
Source: García; Padilla (2014)

According to the Intergovernmental Panel on Climate Change (IPCC) from Table 1, activities that cause GEI are grouped into four categories or sectors: AFOLU (Agriculture, forestry and other land uses), ENERGY, IPPU (Industrial processes and use of products) and WASTE, with the calculations made for the year 2014 of the INGEI (greenhouse gas inventory) for the Second Biennial Update Report of Colombia to the UNFCCC made by the IDEAM of 2014. The first AFOLU sector with a 55 % share in GHG emissions is composed of 7 subsectors: Forest lands 17 %; Grassland 14 %; Enteral fermentation 9 %; N2O of managed soils 8 %; Farmland 4 %, Other 2 %, Manure management, and other 2 %. The second sector: energy with 35 %, composed of Transportation 12 %; Energy industries 10 %; Manufacturing and construction industry 6 %; Fugitive coal, gas and oil 3 %; Other sectors 3 %. The third component is IPPU with 6 % and its subsectors: Cement production 2 % and Other IPPU; Use of substitutes SAO 1 % and other IPPU 1 %. In the fourth place with a 4 % stake is the waste sector, which has the following elements: Managed sites for waste disposal 3 %; Domestic wastewater 1 %; industrial wastewater 2 % and other waste 0 % (Ministerio de Ambiente y Desarrollo Sostenible; PNUD; IDEAM, 2018).

Table 1.
Sectoral stakeholder participation GEI 2014

SECTORAL PARTICIPATION GEI 2014 EMITTERS		
Sector	**Percentage**	**Subsector**
AFOLU	**55 %**	Forest land 17 % Grassland 14 % Enteric fermentation 9 % N_2O of soil managed 8 % Farmland 4 % Others 2 % Manure management and others 2 %
ENERGY	**35 %**	Transport 12 % Energy industry 10 % Manufacturing and construction industry 6 % Coal, gas, and oil 3 % Other sectors 3 %
IPPU	**6 %**	Cement production 2 % and other IPPU Substitutes use SAO 1 % Others IPPU 1 %
WASTE	**4 %**	Waste disposal management sites 3 % Domestic sewage water 1 % Industrial sewage water 2 % Other wastes 0 %

Source: García & Padilla (2014)

Although the WASTE sector is the one that contributes less to the generation of GHG, it is important that the systems of final disposal of solid waste have the adequate treatment for taking advantage of the gases produced due to the decomposition of the organic waste. These wastes in different periods of time generate CH_4 in a higher proportion, while CO_2 and N_2O are given to a lesser extent, (Camargo; Vélez, 2009). In the same way, other gases, whose proportion of contribution GHGs are minimal, can be generated. However, with proper management, pollution in this sector can be reduced, as most of the solid waste in Colombia is organic, which generates a high percentage of GHG (Andrade; Restrepo; Tibaquirá, 2018). Waste management has also to include the use of better vehicles for the collection of wastes, as they mostly use diesel as combustible instead of gasoline. The design of programs for optimal waste management has been presented in the software Agenda 21 in four areas:

- Promotion of treatment and final disposal.
- Expansion of collection coverage.
- Minimization of waste generation.
- Maximization of reuse and environmentally adequate recycling.
  (Rondón; Szantó; Pacheco; Contreras; Gálvez, 2016).

Conclusions

Logistics is a valuable tool necessary for monitoring each stage of system processes whether these are commercial, productive or related to management. The purpose of logistics is to estimate costs, time and resources that are needed minimize as much as possible their use while aiming for maximum performance. Logistics, however, depends on several factors for it to function smoothly. Some of these factors include having the right logistics systems, trained personnel and road networks that allow for safe travel and limit the number of accidents during commutes. Colombia has made progress in terms of its logistics; in order for its infrastructure to be competitive, however, is needs to improve. With the investments that it is making, it is expected to improve its results in the short term. Logistics in the management of C&D in Colombia has made significant progress in recent decades, especially in areas involving its waste collection system, one of the most effective systems of the Latin American and Caribbean region. While it is 98% effective in urban areas, a figure that is less than 30% in rural areas, the figures for Colombia's waste collection systems are superior if compared to certain countries in Africa. It is also important to mention that Colombia's logistics systems for solid waste management have mainly been developed in its primary cities. While these have been effective, due to the demand for them, it remains clear that the entire nation requires an effective system that can use solid waste adequately.

The growing trend for the governments of different nations to further their efforts and investments in this area is reflected in the results of publications that specialize in logistics studies (LPI and GCI). These reports help demonstrate that there is much to be done in this area at a logistical level, which impacts logistic management systems, for which there are already several successful models in Europe.

1. Latin America

Currently, the separation of waste at its source in Latin America and the Caribbean is in the beginning stage, as well as its logistics systems. Analysis from the PERLOG logistics report further demonstrates this, as it reveals the shortcomings of some countries in the region in terms of their ports, airports, roads, transportation systems (land, rail, river, air) and multimodal interconnectivity in general. Latin American and Caribbean countries have also clearly focused their investments on their primary cities, neglecting the road connectivity of their own territories. This poses a challenge to the logistics of waste management systems, which require roads that can access rural areas to shorten route times. In another vein, despite having adopted legislation, regulations are also ignored either because of poor policy and implementation strategies by urban waste collection service providers or because of a lack of environmental awareness on behalf of both providers and users. Throughout the region, studies on waste management models are just becoming common, yet they already exist in European and Asian countries.

While significant progress has been made in this area, users education remains a top priority on how to dispose of waste correctly. This includes educating users on how a circular economy can be applied to reuse, reduce and recycle most of the waste possible – making users familiar with how reducing the tons that go to landfills can lengthen their useful life. Such efforts are beneficial to society and could offer an opportunity for subsidies or discounts and also allow for waste from different activities to be given different uses. The importance of including recycled materials should be shown not only at an industrial level but also in the area of construction, explaining the characteristics of these materials as well as their cost benefit so they are attractive to builders. To expand the coverage of waste collection service companies, investments in secondary and tertiary roads that give access to remote areas are also important.

2. Colombia

Nationally, a successful waste logistics system has been implemented for Colombia's, especially in main cities such as Medellín, Bogotá, Cali, and Barranquilla. Its coverage is extensive, and the frequency of its collection is an average of three days a week for the collection of solid waste in municipalities and cities; an average that is less in its rural areas. Construction and Demolition waste (C&D) management needs programs that can educate people about the importance of the proper use of waste. For waste to be separated at the source, it is important to demonstrate the benefits this can have on the environment and natural landscape, but also its economic, social and cultural aspects. Separating waste at the source is key to disposing of C&D waste correctly, as this is the starting point for classifying waste. By ensuring that this waste does not become mixed (contaminated), it can then be treated appropriately to reuse, reduce or ultimately, recycle it. This waste classification also helps to increase the percentage of C&D waste that that can be used again.

3. Circular Economy

The role of a circular economy is really valuable to address society's consumer behavior. When combined with logistics, it plays a key role. This combination helps to do the least possible damage on the environment as well as makes it possible to act act following the objectives of reducing the degradation of natural resources to the maximum, which leads to lower gas emissions. The linear economy model, where it is assumed that there is an unlimited supply of natural resources and that the environment has an unlimited capacity to absorb waste and pollution, is now dismissed. Instead, a circular economy model is proposed, where the throughput of energy and raw materials is reduced, (Murray; Skene; Hayanez, 2015). In Colombia, several efforts are made to mitigate the impact of solid waste on the environment such as the recovery of hazardous waste (Loaiza; Cifuentes; Colorado, 2017; Loaiza; Colorado, 2018; Colorado; Singh, 2014; Colorado; Colorado, 2016), the recovery of rubber waste (Agudelo; Cifuentes; Colorado, 2019; Revelo; Correa; Aguilar; Colorado, 2019) and studies on circular economies (Rua-Restrepo; Echeverri; Colorado, 2019).

Acknowledgments

The authors of this article would like to thank the Universidad Autónoma Latinoamericana and Universidad de Antioquia for the partial financing of this work.

References

Agudelo, Guilliana; Cifuentes, Sergio; Colorado, Henry (2019). Ground tire rubber and bitumen with wax and its application in a real highway. *Journal of Cleaner Production, 228*, 1048-1061. https://doi.org/10.1016/j.jclepro.2019.04.353

Al-Hamamre, Zayed; Saidan, Motasem; Hararah, Muhanned; Rawajfeh, Khaled; Alkhasawneh, Hussam; Al-Shannag, Mohammad (2017). Wastes and biomass materials as sustainable-renewable energy resources for Jordan. *Renewable and Sustainable Energy Reviews, 67*, 295-314. https://doi.org/10.1016/j.rser.2016.09.035

Álvarez, Víctor; Valenzuela, Santiago (10 de enero de 2016). Cobertura en servicio de basuras es mínima en zonas rurales. *El Colombiano*. Retrieved from: https://www.elcolombiano.com/especiales/que-hacer-con-la-basura/cobertura-en-servicio-de-basuras-es-minima-en-zonas-rurales-CD3410958

Andrade, A.; Restrepo, A.; Tibaquirá, J. E. (2018). Estimación de biogás de relleno sanitario, caso de estudio: Colombia. *Entre Ciencia e Ingeniería, 12*(23), 40-47. https://doi.org/10.31908/19098367.3701

Ballesteros-García, Julieth. (2016). *Cómo la logística contribuye al desarrollo de la competitividad de una* empresa (tesis de grado). Fundación Universitaria Los Libertadores, Bogotá, Colombia. Retrieved from: https://repository.libertadores.edu.co/handle/11371/948

Betanzo-Quezada, Eduardo; Torres-Gurrola, Miguel; Romero-Navarrete, José; Obregón-Biosca, Saúl (2016). Evaluación de rutas de recolección de residuos sólidos urbanos con apoyo de dispositivos de rastreo satelital: análisis e implicaciones. *Revista internacional de contaminación ambiental, 32*(3), 323-337. https://doi.org/10.20937/RICA.2016.32.03.07

Cámara Colombiana de la Infraestructura. (2016). *Encuesta Nacional Logística 2015* (Boletín económico- Febrero 2016). Retrieved from: https://www.infraestructura.org.co/filef_contenido.php?IDe=889

Camargo, Y.; Vélez, A. (septiembre de 2009). Emisiones de Biogás Producidas en Rellenos Sanitarios. En *II Simposio Iberoamericano de Ingeniería de Residuos*, Red de Ingeniería en Saneamiento Ambiental, Barranquilla, Colombia. 1-12. Retrieved from: http://www.redisa.net/doc/artSim2009/TratamientoYValorizacion/Emisiones%20de%20biog%C3%A1s%20producidas%20en%20rellenos%20sanitarios.pdf

Chen, Lihong; Rong-Gang, Cong; Bangrong, Shu; Mi, Zhifu (2017). A sustainable biogas model in China: The case study of Beijing Deqingyuan biogas project. *Renewable and Sustainable Energy Reviews, 78*, 773-779. https://doi.org/10.1016/j.rser.2017.05.027

Colorado, Henry; Colorado, Sergio (2016). Portland Cement with Battery Waste Contents. En Kirchain, Randolph; Blanpain, Bart; Meskers, Christina; Olivetti, Elsa; Apelian, Diran; Howarter, John; Kvithyld, Anne; Mishra, Brajendra; Neelameggham, Neale; Spangenberger, Jeff (Eds.), *Rewas 2016: Towards Materials Resource Sustainability* (pp. 57-63). Springer. https://doi.org/10.1002/9781119275039.ch9

Colorado, Henry; Singh, Dileep (2014). High-sodium waste streams stabilized with inorganic acid–base phosphate ceramics fabricated at room temperature. *Ceramics International, 40*(7), 10621-10631. https://doi.org/10.1016/j.ceramint.2014.03.045

Comisión Europea. (2016). *Protocolo de gestión de residuos de construcción y demolición en la UE* (Septiembre de 2016). Retrieved from: https://ec.europa.eu/docsroom/documents/20509/attachments/1/translations/es/renditions/pdf

Concejo de Bogotá. (2018). *concejodeBogotá*. Retrieved from: http://concejodeBogotá.gov.co: http://concejodeBogotá.gov.co

Consejo privado de Competitividad. (2017). *Informe Nacional de Competitividad*. Retrieved from: https://compite.com.co/informe/informe-nacional-de-competitividad-2016-2017/

Cortés-Villafradez, Raúl (2018). ¿Qué tan competitivos son los países miembros de la Alianza del Pacífico en infraestructura de transporte?. *Revista Escuela de Administración de Negocios,* (85), 143-162. https://doi.org/10.21158/01208160.n85.2018.2055

Departamento Nacional de Planeación. (2015). *Encuesta Nacional Logística 2015.* Retrieved from: http://onl.dnp.gov.co/es/Publicaciones/Paginas/Encuesta-Nacional-Log%C3%ADstica-2015.aspx

Duarte-Díaz, Felipe (2008). *Caracterización de los desechos sólidos del municipio San Antonio la Paz, Departamento de el progreso y la propuesta para relleno sanitario.* Universidad de San Carlos de Guatemala, Guatemala. Retrieved from: http://biblioteca.usac.edu.gt/tesis/08/08_3031_C.pdf

European Environment Agency. (2013). *eea europa*. Retrieved from: https://www.eea.europa.eu: http://reports.weforum.org

Farromeque-Quiroz, Rafael (2015). Integración Logística en América Latina. Reflexión sobre la Logística Regional. *Banco de Desarrollo de América Latina*. Retrieved from: https://www.mintransporte.gov.co/descargar.php?id=4763

Farromeque-Quiroz, Rafael (2016a). *Pefil logístico de América Latina (PERLOG-Panamá)*. Panamá: CAF. Retrieved from: http://scioteca.caf.com/bitstream/handle/123456789/1023/CAF_PERLOG%20Panamá.pdf?sequence=65&isAllowed=y

Farromeque-Quiroz, Rafael (2016b). *Pefil logístico de América Latina (PERLOG-Bolivia)*. Bolivia: CAF. Retrieved from: http://scioteca.caf.com/bitstream/handle/123456789/1023/CAF_%20PERLOG%20BOLIVIA.pdf?sequence=62&isAllowed=y

Farromeque-Quiroz, Rafael (2016c). *Pefil logístico de América Latina (PERLOG- Colombia)*. Colombia: CAF. Retrieved from: http://scioteca.caf.com/bitstream/handle/123456789/1023/CAF_%20PERLOG%20COLOMBIA.pdf?sequence=63&isAllowed=y

Farromeque-Quiroz, Rafael (2016d). *Pefil logístico de América Latina (PERLOG-México)*. México: CAF. Retrieved from: http://scioteca.caf.com/bitstream/handle/123456789/1023/CAF_%20PERLOG%20%20México.pdf?sequence=58&isAllowed=y

Farromeque-Quiroz, Rafael (2017). *PERLOG-LATAM: Perfil logístico de América Latina*. Bogotá: CAF. Retrieved from: http://scioteca.caf.com/handle/123456789/1022

Francisca, Franco; Montoro, Marco; Glatstein, Daniel (2017). Technical and economic evaluation of biogas capture and treatment for the Piedras Blancas landfill in Córdoba, Argentina. *Journal of the Air & Waste Management Association, 67*(5), 537-549. https://doi.org/10.1080/10962247.2016.1243594

Franco, Julio (2016). *Diseño de planta de tratamiento de desechos sólidos para la ciudad de Babahoyo* (tesis de pregrado). Universidad de Guayaquil, Guayaquil, Ecuador. Retrieved from: http://repositorio.ug.edu.ec/handle/redug/9411

Freitas, F. F.; De Souza, S. S.; Ferreira, L. R.; Otto, R.B.; Alessio, F. J.; De Souza, S. N.; Venturini, O.J.; Ando Junior, O. H. (2019). The Brazilian market of distributed biogas generation: Overview, technological development and case study. *Renewable and Sustainable Energy Reviews, 101*, 146-157. https://doi.org/10.1016/j.rser.2018.11.007

Frérot, Antoine. (3 de noviembre de 2014). *Fondation Robert Schuman.* Cuestiones europeas: Economía circular y eficacia en el uso de los recursos: un motor de crecimiento económico para Europa, 331. Retrieved from: https://www.robert-schuman.eu/es/cuestiones-europeas/0331-economia-circular-y-eficacia-en-el-empleo-de-los-recursos-un-motor-de-crecimiento-economico-para

Fundación CEDDET (Eds.). (2015). *Gestión de rellenos sanitarios en América Latina.* Retrieved from: https://www.ceddet.org/wp-content/uploads/2018/02/RESIDUOS-003.pdf

García, Jeimmy; Padilla, Yeleny (2014). Retos de la administración distrital en la recolección y disposición de residuos sólidos. *Econografos, (63)*. Retrieved from: http://www.fcenew.unal.edu.co/publicaciones/images/documentos-econografos-economia-63.pdf

Gellens, Veerle; Boelens, Jan; Verstraete, Willy (1995). Source separation, selective collection and in reactor digestion of biowaste. *Journal of Microbiology, 67*(1), 79-89. https://doi.org/10.1007/BF00872196

Instituto nacional de vías (2018). *invias.gov*. Retrieved from: https://hermes.invias.gov.co

INTERASEO. (2018). *www.interaseo.com.co*. Retrieved from: https://www.interaseo.com.co

Loaiza, Alexandra; Cifuentes, Sergio; Colorado, Henry (2017). Asphalt modified with superfine electric arc furnace steel dust (EAF dust) with high zinc oxide content. *Construction and Building Materials, 145*, 538-547. https://doi.org/10.1016/j.conbuildmat.2017.04.050

Loaiza, Alexandra; Colorado, Henry (2018). Marshall stability and flow tests for asphalt concrete containing electric arc furnace dust waste with high ZnO contents from the steel making process. *Construction and Building Materials, 166*, 769-778. https://doi.org/10.1016/j.conbuildmat.2018.02.012

Ministerio de Ambiente y Desarrollo Sostenible; Programa de las Naciones Unidas para el Desarrollo; PNUD; Instituto de Hidrología, Meteorología y Estudios Ambientales. (2018). *Segundo Informe Bienal de Actualización de Colombia ante la CMNUCC (2O Informe)*. Retrieved from: http://www.ideam.gov.co/documents/24277/77448440/PNUD-IDEAM_2RBA.pdf/ff1af137-2149-4516-9923-6423ee4d4b54

Ministerio del medio ambiente, vivienda y desarrollo territorial. (23 de marzo de 2005a). *Por el cual se modifica el Decreto 1713 de 2002 sobre disposición final de residuos sólidos y se dictan otras disposiciones.* [Decreto 0838 de 2005]. Retrieved from: http://www.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/Normativa/Decretos/dec_0838_230305.pdf

Ministerio de Ambiente, Vivienda y Desarrollo Territorial (27 de septiembre de 2005b). P*or la cual se establecen directrices y pautas para el cierre, clausura y restauración o transformación técnica a rellenos sanitarios de los sitios de disposición final a que hace referencia el artículo 13 de la Resolución 1045 de 2003 que no cumplan las obligaciones indicadas en el término establecido en la misma.* [Resolución 1390 de 2005]. Retrieved from: http://www.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/Normativa/Resoluciones/res_1390_270905.pdf

Ministerio de Medio Ambiente de Colombia, Organización Panamericana de la Salud. (1996). *Análisis Sectorial de Residuos Sólidos en Colombia.* Retrieved from: http://www.bvsde.ops-oms.org/eswww/fulltext/analisis/colombia/colombia.html

Ministerio de vivienda, ciudad y territorio. (2015). Plan de Gestión Integral de Residuos Sólidos. Retrieved from: http://www.minvivienda.gov.co/Documents/ViceministerioAgua/PGIRS/PGIRS%20de%20Segunda%20Generaci%C3%B3n/Gu%C3%ADa%20para%20la%20formulaci%C3%B3n,%20implementaci%C3%B3n,%20evaluaci%C3%B3n,%20seguimiento,%20control%20y%20actualizaci%C3%B3n%20de%20los%20PGIRS.pdf

Murray, Alan; Skene, Keith; Hayanez, Kathryn (2015). The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context. *Journal of Business Ethics*, *40*(3), 369-380. https://doi.org/10.1007/s10551-015-2693-2

Pinzón-Uribe, Luis (2010). Influencia de los rellenos sanitarios en el cambio climático. *Revista Gestión Integral en Ingeniería Neogranadina,* 2(1). Retrieved from: http://www.umng.edu.co/documents/10162/745277/V2N1_8.pdf

Revelo, Carlos; Correa, Mauricio; Aguilar, Claudio; Colorado, Henry (2019). Waste tire rubber powders based composite materials. En Gaustad, Gabrielle; Fleuriault, Camille; Gokelma, Mertol; Howarter, John; Ma, Kaka; Meskers, Christina; Neelameggham, Neale; Olivetti, Elsa; Powell, Adam; Tesfaye, Fiseha; Verhulst, Dirk; Zhang, Mingming (Eds.), *REWAS 2019 Manufacturing the Circular Materials Economy*. The Minerals, Metals & Materials Series. Springer, Cham. https://doi.org/10.1007/978-3-030-10386-6_50

Rojas, Juan; Salazar, Raul; Sepúlveda, Miguel; Sepúlveda, Moisés; Santelices, Iván (2006). Residuos sólidos domiciliarios: logística, una herramienta moderna para enfrentarse a este antiguo problema. *Revista Ingeniería Industrial, 5*(1), 77-78. Retrieved from: http://revistas.ubiobio.cl/index.php/RI/article/view/130

Romero-Moreira, Roxana (2017). *Análisis económico del reciclaje y el cuidado del medio ambiente en el Ecuador* (tesis de pregrado). Universidad de Guayaquil, Guayaquil, Ecuador. Retrieved from: http://repositorio.ug.edu.ec/handle/redug/23220

Rondón, Estefani; Szantó, Marcel; Pacheco, Juan; Contreras, Eduardo; Gálvez, Alejandro (2016). *Guía general para la gestión de residuos sólidos domiciliarios.* Comisión Económica para América Latina y el Caribe, CEPAL: Chile. Retrieved from: https://www.cepal.org/es/publicaciones/40407-guia-general-la-gestion-residuos-solidos-domiciliarios

Rua-Restrepo, José; Echeverri, Gloria; Colorado, Henry (2019). Towards a solid waste economy in Colombia: an analysis with respect to other leading economies and Latin America. En Gaustad, Gabrielle; Fleuriault, Camille; Gokelma, Mertol; Howarter, John; Ma, Kaka; Meskers, Christina; Neelameggham, Neale; Olivetti, Elsa; Powell, Adam; Tesfaye, Fiseha; Verhulst, Dirk; Zhang, Mingming (Eds.), *REWAS 2019 Manufacturing the Circular Materials Economy*. 337-354. The Minerals, Metals & Materials Series. Springer, Cham. https://doi.org/10.1007/978-3-030-10386-6_41

Sosa-Marín, Jehison. (2014). *El análisis de datos el marco de un proyecto ambiental de manejo de residuos sólidos* (tesis de maestría). Universidad Nacional de Colombia, Bogotá, Colombia. Retrieved from: http://www.bdigital.unal.edu.co/48921/

Superintendencia de Servicios Públicos Domiciliarios (2018). *Informe de Disposición Final de Residuos Sólidos – 2017* (2018). Retrieved from: https://www.superservicios.gov.co/sites/default/archivos/Publicaciones/Publicaciones/2018/Dic/2._disposicion_final_de_residuos_solidos_-_informe_2017.pdf

The World Bank. (2018). *world bank.* LPI Home. Retrieved from: https://lpi.worldbank.org/

Troncoso, Pablo. (2018). *Gestión de la Economía Circular en la producción de mezcla asfáltica en Chile* (tesis de maestría). Universidad Politécnica de Valencia, Valencia, España. Retrieved from: http://hdl.handle.net/10251/106485

Vargas, Pablo (2015). *Diseño y ejecución de la planta de manejo integral de residuos sólidos (PMIRS) del municipio de Restrepo, Valle del Cauca* (tesis especialización). Universidad Nacional Abierta y a Distancia, Cali, Colombia. Retrieved from: https://repository.unad.edu.co/handle/10596/6147

Word Economic Forum. (26 de september de 2018). *The Global Competitiveness Report 2017-2018.* Retrieved from: http://reports.weforum.org/global-competitiveness-index-2017-2018/