Received: 02/23/2023 | Accepted: 04/3/2023 | Published: 05/2/2023

Problems of transporting solid bulk along the Magdalena River in Colombia

Problemática del transporte de granel sólido por el río Magdalena en Colombia

https://doi.org/10.21803/adgnosis.12.12.611

Ignacio Enrique Cabarcas Puello
https://orcid.org/0009-0009-0737-0577
Magister en Gestión de las organizaciones. General Manager, Naviera Rio Grande. E-mail: ignaciocabarcaspuellootmail.com.

Karen Patricia Peñaranda De Armas
https://orcid.org/0000-0002-5325-2880.
Marketing Specialist. Full-time Professor at Universidad Minuto de Dios. Business Administration Program. Position held and institutional affiliation. Barranquilla - Colombia. E-mail: kppd03@gmail.com.

How to cite this article:

Cabarcas, I. and López, C. (2023). Problems of solid bulk transport on the Magdalena River in Colombia. *Ad-Gnosis, 12*(12). p. 1-13. https://doi.org/10.21803/adgnosis.12.12.611. https://doi.org/10.21803/adgnosis.12.12.611.

Abstract

The Magdalena waterway, due to its navigability and geospatial location, constitutes a space for the articulation of potentialities in the value chain for the economic development of Colombia. For this reason, this article has the objective of executing a balance of the conditions of solid bulk transport by the Magdalena River, supported by a synchromodal network of product mobilization whose scope foresees taking advantage of the advantages offered b y t he fl uvial an d ma ritime po rt in frastructure. It is a bibliographical research, of a hermeneutic, diachronic type, configured from t he d eductive r ationalist approach. He stresses that four determining situations must be overcome: the deepening of the river to allow the navigation of medium-sized ships and joint systems of barges propelled with tugboats; improve bulk storage and handling logistics in river ports; Also, synchronization of multimodal transport systems, finally, i mprove t he operational efficiency of ma nagement to re duce th e co sts of operations. It concludes that techniques for the efficient management of water resources should be addressed in order to take advantage of the multiple opportunities that fluvial c ommunication p resents f or t he t ransport o f products; a situation that allows the social, industrial and commercial development of the country.

Keywords: *Regional development; Social welfare; industrial society; regional economy; Industrial zone.*

Resumen

La hidrovía del Magdalena debido a su navegabilidad y ubicación geoespacial, constituye un espacio de articulación de potencialidades en la cadena de valor para el desarrollo económico de Colombia. Por ello, este artículo tiene el objetivo de ejecutar un balance de las condiciones de transporte de granel sólido por el río Magdalena, soportado por una red sincromodal de movilización de productos cuyo alcance prevé aprovechar las ventajas que ofrecen la infraestructura portuaria fluvial y m arítima. Es una investigación bibliográfica, d e t ipo h ermenéutico, diacrónico, configurado d esde e l e nfoque r acionalista deductivo. Destaca que se deben superar cuatro situaciones determinantes: la profundización del río para que permita la navegación de buques medios y sistemas conjuntos de barcazas propulsados con remolcadores; mejorar la logística de almacenamiento y manipulación de granel en los puertos fluviales; t ambién, s incronización los sistemas multimodales de transporte, por último, mejorar la eficiencia o perativa d e g estión p ara r educir los costos de operaciones. Concluye que deben abocarse técnica de manejo eficiente d e l os r ecursos h ídricos c on el fin d e a provechar l as m últiples o portunidades q ue la comunicación fluvial p resenta p ara e l t ransporte d e productos; situación que permite el desarrollo social, industrial y comercial del país.

Palabras Clave: *: Desarrollo regional; Bienestar social; Sociedad industrial; Economía regional; Zona industrial*[1].

1. Tesauro Unesco (Ciencias Sociales y Humanidades).

Introduction

Bulk cargo can be solid, liquid and in gaseous state, its definition is succinct when describing that cargo that is transported in large quantities or volumes without packaging and packing, where the transportation system itself is the container vessel. Based on this conceptualization and fluvial geospatial conditions in Colombia, the object of this research deals with the problems presented in the transportation of solid bulk using the facilities offered by the Magdalena River as a means of communication. This fluvial arterial system and its basin have a privileged location, since it communicates the central-southern region of the country with the Caribbean; on the other hand, it is one of the areas of greatest demographic, productive and industrial development in Colombia; occupying an area that covers almost a quarter of the national territory (Duque-Escobar, 2021). These conditions favor the transport of bulk and manufactured products, since they reduce logistics costs, favor production and condition competitiveness for export to global markets (Logulo, 2020).

Since river-maritime means are more efficient than land transportation by means of heavy cargo vehicles, there is a great opportunity to massify transportation by the Magdalena waterway to reduce the operating costs of productive, commercializing and exporting companies; which would generate synergy with the riverside municipalities of influence of the river (Corredor and Díaz-Barragán, 2018). However, not everything is assured to undertake navigation and mass transportation projects; some difficulties need to be overcome to create the necessary conditions, such as the problem of erosion-sedimentation of the river, navigability, port logistics, and improving operational management. For this reason, this article seeks to generate an adequate balance of proposals to create conditions for the transport of bulk goods that reduce costs, thus achieving the competitiveness of the transport sector. The methodology used in the study was based on the analysis of official documents, academic studies and indexed articles that propose research and descriptive historiographic data on the conditions of navigability and transport of goods by river. In addition, research was carried out with the different shipping companies engaged in the transport of cargo on the Magdalena River, where an analysis was made of the information they handle on the subject.

Theoretical framework/ Frame of reference

One of the countries in the world that is most closely linked demographically, geopolitically and ecosocially with its river network is Colombia, since its geographical position opens three windows of confluence of the hydrographic network: the Amazon, Pacific and Caribbean basins. The Magdalena-Cauca basin alone covers 24% of the country's territory and is closely related to the socio-productive activities of 11 departments: Atlántico, Antioquia, Magdalena, Santander, Bolívar, Cesar, Boyacá, Cundinamarca, Caldas, Tolima and Huila; these are home to more than 79% of the country's population, 90% of the electricity is produced and it is estimated that during 2019 the productive goods and services it generated to the nation represented almost 85% of the gross domestic product-GDP (Duque-Escobar, 2021, p. 5). This makes these river arteries the organic axis of the nation with a very important economic potential.

For this reason, in 2015 the national government approved Colombia's 2015 River Master Plan, whose objectives were focused on obtaining a competitive, sustainable and beneficial transportation system for social and economic development through governance that would allow solving the problems of navigability, administration, expansion and improvement of river ports (Ministry of Transportation, 2015). The country has five major waterways with intermediate navigability potential: Magdalena river basin, which includes the Magdalena and Canal del Dique, Cauca rivers; Atrato river basin; Orinoco river basin; and Amazon river basin. This plan should be complementary to the nation's socioeconomic development plans and seeks to generate an intermodal cargo communication network, while at the same time interconnecting people to establish links with isolated populations.

Specifically, the Magdalena River basin represents the territorial space with the greatest productive incidence for the country, due to its historiography, demographic accumulation, potential in energy, mining, agricultural and livestock resources and offers a geopolitical perspective of North-South communication that opens the doors for internal and external trade; at the same time, it potentiates human mobility of great significance, which allows connecting the interior with the Caribbean (Anzola-Garavito, 2018). Despite this, productivity, quality of life and problems associated with sedimentation-erosion, pollution and other socio-cultural factors have led to the decline of socio-productive activities, inhibiting territorial vocations, a situation that has slowed spatial economic growth in the Magdalena basin.

One of the aspects to be taken into consideration in the projects for the recovery of the productive vocation of the Magdalena basin is the current environmental diagnosis of the territory, taking as a basis for trade the opportunities offered by the city of Barranquilla together with its port services infrastructure and other port cities such as Cartagena and Santa Marta; therefore, a sustainable approach with social responsibility is required, taking into account the participation of the State-Government and the private economic sector (Arteta-Peña et al., 2015). At the same time, in order to guarantee the social welfare and quality of life of the inhabitants of the Magdalena basin, taking advantage of the enormous natural resources found in the basin, it is important to stimulate business activity with sustainable governance, safeguarding reciprocity in the care of the environment so that growth is clean, safe and the return of resources in the long term is efficient (Maldonado-Pedroza, 2015).

The Magdalena River basin has historically had a fragmented vision of its use as a transportation route and the socio-productive growth of the spatial environment. In fact, the National Planning Department of the Colombian Government states that deforestation in the area reached 42% and 68% of the proximal and distal primary forests of the basin in 2013, respectively. This situation has resulted in accelerated erosion and sedimentation; this has caused the loss of river depth, loss of aquatic species, since the reproductive cycle of fish has been altered, causing a decrease in fish catches (Mora- les-Basanta et al., 2021), which has reduced one of the main productive activities of the local people. These factors have been added to other conditioning factors such as poaching, illegal fishing, failures in the government's surveillance and control capacity, among others, which have led to inefficient management of environmental resources and, consequently, have had an impact on the reduction of the basin's hydrobiological connectivity.

According to the national agricultural census published by DANE for 2014, the Magdalena River basin consists of more than 8,3016,349 hectares of rural area with agricultural and livestock vocation. It co-exists 269,090 productive units, of which almost 83% are of agricultural and livestock activity, which makes the basin a true productive space of more than 4 million hectares with abundant water availability, which can very well be directed towards the planting of pastures, grasses, stubble, vegetables and other agricultural items (Galvis-Aponte and Quintero-Fragozo, 2017) representing an important potential for the production of grains and other transportable products in bulk. These conditions mean that the river offers diverse human opportunities, highlighting the transportation corridor, generating better opportunities for competitiveness, since it brings products from the interior of the country closer to the Caribbean ports of Barranquilla and Cartagena, creating synergies between intermodal transportation systems (Cormag- dalena, 2015).

Thus, in the last two decades, underpinned by the opportunities offered by the port systems, oil derivatives such as asphalt, fuel oil, diluents, gases, diesel fuel, gasoline, lubricants and naphtha have been transported by the Magdalena River; also, other products such as: fertilizers, beverages, mineral coal, cement, iron, steel, wood, manufactures, machinery, metal-mechanics, minerals, fish, groceries, in turn, paper and packaging (Galvis-Aponte and Quin- tero-Fragozo, 2017). The conditions are so complex due to the temporality of navigation through the Magdalena River that the Colombian State issued decree 1640 in 2012 for the purpose of planning, ordination and management of watersheds for the prioritization of na- vegability and its fluvial networks; whose objective was focused on a harmonious and adequate management (Ruano-Garzón, 2017).

It is important to mention that the area of influence of the Magdalena River basin exploits mining products that are easily transported in bulk and packaged with special containers, industrial materials such as coal, limestone, minerals used in construction, gypsum, among others. In addition, semi-precious minerals are produced in the territory. These, despite being polluting materials, are important resources in international trade, a consequence of the current global energy deficit; in fact, 45% of the coal that is exploited nationally is produced in the Magdalena impact area (Mancera-Rodrí- guez and Rodríguez-Sánchez, 2022). However, the exploitation of some of the minerals leads to social and environmental conflicts in areas susceptible to conservation (Sotelo-Suarez, 2022). Therefore, political, technological and educational community strategies associated with exploitation are required to consolidate sustainable productive development in the region.

Despite the fact that the Gran Magdalena basin is the productive heart of Colombia, social welfare has not been in line with economic development; nor has a solution been found to the difficulties of navigability and the strong pressures on the basin due to demographic and productive growth. The area of influence produces more than 80% of the national GDP and 50% of freshwater fisheries. However, the basin is highly threatened due to increased deforestation, the drying up of its marshes, sedimentation and contamination, which have caused 78% of the river to show critical erosion and, therefore, low navigability for mass transportation of goods.

reduction of 62.5% in fish volume in the last 40 years (Paz-Cardona, 2020). As a corollary, one of the largest freshwater reserves in the urbanized intramontane zone of Co- lombia, only contributes barely 11% of the country's potable water resource (Labrador-Hernández et al., 2017).

Methodology

This is a hermeneutic, diachronic research, structured from the qualitative approach of inquiry. The scope of the research is explanatory. Bibliographic research is used as a data collection technique. The deductive rationalist perspective is privileged for data analysis. Ethical considerations take into account the intellectual property of the studies cited; therefore, these are clearly and precisely identified, providing the links that allow verification of the information collected and analyzed.

Results

Productive environment of the Magdalena river basin

In order to describe the navigable nature of the Magdalena River, it is important to contextualize the water flow areas according to the stages of the basin. In this sense, the waterway is classified in the Upper Magdalena, with a length of 565 km; at the beginning it is characterized by a steep slope and high turbulence, it runs from the source of the river in the Magdalena Lagoon, Cauca, located in the Las Papas moor at 3,327 meters above sea level, to the municipality of Honda in Tolima at an altitude of 229 meters above sea level. The Middle Magdalena has a length of 1,100 km to El Banco, at the mouth of the Cesar River. The Lower Magdalena with a length of 428 km to the mouth of the river at Bocas de Ceniza and in the bay of Cartagena, through the Canal del Dique (Galvis-Aponte and Quintero-Fragozo, 2017). The river is navigable only by small vessels from Neiva to Boca de Ceniza in the Caribbean -for the transit of transport-related vessels it is only navigable from Barrancabermeja to Bocas de Ceniza-; its important ports are distributed in the middle and lower Magdalena, these are: Barranquilla, Calamar, Magangué, La Gloria, Gamarra, Capulco, Puerto Wilches, Barrancabermeja, Puerto Be- río, Puerto Salgar and La Dorada (Quintero-González et al., 2020).

The incipient distribution of port logistics and the anthropic pressures suffered by the Magdalena River in the last 100 years, cause its permanent navigability to present great challenges to consolidate the transport of bulk and all types of goods. Therefore, it is necessary to consolidate and execute port works; dredging and channeling are required between Puerto Salgar and Barrancabermeja. In addition, the maintenance of the navigable channel from Barrancabermeja to Barranquilla and Cartagena, to connect the main centers of production and consumption, a situation that will reduce costs and at the same time allow for the consideration of opportunities to increase the capacity of the port.

for the Caribbean (Castro et al., 2015). These comprehensive proposals agreed upon by the government and the private sector should be permanent, in order to develop and strengthen intermodal transportation services. The works should be monitored over time with efficient governance; for this purpose, channel predictability models using neural technological tools should be employed (Javela-Quiñonez and Montealegre-Ruiz, 2021); which will allow undertaking maintenance and navigability management works.

Consequently, the Colombian government has undertaken a series of river and port works that have been timely. There are projects that have not been completed; currently, Ecopetrol, Cormagdalena and the private sector are executing works for the recovery of navigability and port services that favor the increase in the movement capacities of goods to be transported sustainably, as an alternative for domestic and foreign trade of products (Illera-Pabón et al., 2017, p. 47). However, the projects for the recovery of the river's navigability and their possibilities of final realization have generated multiple questions from a social, cultural, environmental and economic perspective (Rodríguez-Becerra, 2015); since, beyond the political proselytism of the works, there is the social development to improve the quality of life of the inhabitants and the mitigation of the environmental impact.

In fact, the Dredging and Maintenance Plan for the Navigability of the Magdalena River involving the municipality of Puerto Salgar, has been a proposal developed since 2014 to improve river and port transportation in favor of improving the socioeconomic conditions of the inhabitants who maintain a community subsistence economy through fishing and always on the riverbank; therefore, it is essential to respect the environment of the basin avoiding its degradation (Amaya-Franco et al., 2022). On the other hand, the recovery project has placed emphasis on the navigability and improvement of port services in Puerto Salgar, which is an intermodal interconnection center and is located 180 km from Bogotá, the capital city; it is the country's main inbound and outbound cargo demander (Sáenz, 2015). This initiative would reduce freight costs, which would lower the cost of mass consumption products that can be transported in bulk.

It is worth mentioning that during the government of Iván Duque the PPP of the Magdalena River was established with an investment of 1.53 trillion pesos, which seeks the recovery of its navigability with the intervention of 668 kilometers between Bocas de Ceniza (Barranquilla) to Barrancabermeja (Santander). The Navelena consortium, made up of the Brazilian Odebrecht and the Colombian Valorcon, has been involved in the project; the expected benefits have not been obtained from the procedures due to flaws in the management and operation of the investments. In view of this, the current government decided to directly make the necessary investments to improve the navigability conditions of the Magdalena, attending to the commercial needs, maintaining the integrity of the ecological niches, helping the communities that inhabit the account to overcome the main needs of coexistence; which requires strict monitoring of the investments by the State's capacity to oversee and control social practices.

One of the most recurrent and differentiated problems of the Magdalena River is the high erosion rate that causes sediment entrainment; therefore, the decrease in depth that impedes the

navigation of medium to large vessels. In studies conducted by Colciencias, private universities with support from NASA, have concluded that the erosion rate between 1970 and 2002 was 710 ton km2 per year, being 4.2 times greater than the Amazon River; 4.5 times greater than the Orinoco River and 16.5 times greater than the Paraná River (Restrepo, 2015). These data are surprising, since the Magdalena is a river of lesser length; the conclusion inferred is that the position in the intertropical convergence zone that causes excess rainfall, added to the fact that the position of the river, places it in a tectonically active zone that causes vertical uplift of the cortical substrate. This leads to conditions in search of an equilibrium profile, causing high erosion, making it one of the areas with the highest sedimentological production in the planet (Ordóñez, 2015).

This intertropical location and differentiated geological-sedimentological conditions cause the depth to decrease rapidly, preventing navigation by larger vessels; an eventuality that requires constant maintenance and dredging. Therefore, the transport of bulk cargo is conditioned by the types of vessels; due to its draft, bulk cargo must be transported in boats, which will be complemented with food and passengers; boats for bulk and food, and flatboats or barges supported by tugboats, which could transport larger volumes of bulk, also hydrocarbons and derivatives, materials and equipment, among others (Quintero-González et al., 2020). These scientific-technical details are required for the effective governance with planning, management and optimal exploitation of this transportation system, seeking to maintain the navigability conditions of the Magdalena River (Quintero-Gonzalez et al., 2020); thus, executing the transportation of bulk cargo and other types of goods in an efficient manner.

Discussion

Competitive advantages of the use of the Magdalena River

In Colombia, until 2015 there were no policies, plans and projects for the development of river transport. For this reason, the Ministry of Transportation, the State body in charge of transport administration in general, within the framework of the National Development Plan-PND and with the support of the National Planning Department-DNP, commissioned the Dutch company ARCADIS Ne- derland BV, with the help of JESYCA S.A.S, to develop the Colombia River Master Plan 2015 (Ministry of Transportation, 2015). The plan includes five main elements: river and port infrastructure, institutional planning, operation, promotion and financing of navigability works with sustainability. With the adjustments, the project plans to increase cargo capacities and volumes on Colombian rivers, which are visibly very low compared to other countries in the region, which use river transport to a greater extent.

An econometric study carried out during 2018, using information provided by importers, exporters and domestic trade companies in the Bogotá metro area and nationally, indicates that the use of the river as a means of transport for the transportation of goods and services, as well as the use of the river as a means of transportation, is a significant source of income for the country's economy.

wants to improve investments in navigability projects on the Magdalena River. Also, to create conditions that reduce costs so that transportation is competitive, involving the use of new or repowered vessels to reduce travel times and, on the other hand, to improve the punctuality of the sailing and docking (Zambrano, 2018). This will require a navigability-production-society integration model that enhances hydrocirculation, with the aim of increasing the production of goods and services, biotrade, ecological agriculture, based on the implementation of technology as an important axis within the proposal (Sil- va-Galvis, 2010); complemented by an efficient administration of services.

There are two extra elements to strengthen the competitiveness of bulk cargo transportation on the Magdalena River. One is the setting of freight rates for cargo services, which should not be a unilateral intervention of the Colombian State, since an adequate environment of competition and market freedom must be guaranteed. Therefore, there must be participation among service providers, producers, traders, buyers and the State; the latter must provide an information system that reaches the entire value chain (Consejo Privado de Competitividad, 2017). The second element to consider is that due to the geographic and demographic conditions of the Magdalena River basin, transportation must be inter-modal -river and land-, where competitiveness is sought, reducing transportation costs. For this, it is necessary to de-monopolize the sector (Camacho-Sarmiento, 2020, p. 4) and also involve all the actors in the modal transport interchange.

In order to compete with export services for bulk goods, the conditions of port and logistics services in Barranquilla, Cartagena and the river ports in the Lower Magdalena must be improved, since these cities represent the face of the development of foreign trade in Colombia, being the most developed port municipalities in the region and the most important cities in the country (Castro et al., 2015). It is important to note that Cormagdalena, with its Action Plan 2022-2024, has been developing important projects together with the private sector as part of its National Strategic Plan, among them: the recovery of the navigability of the Magdalena River, the project for the recovery of the Mompox Arm, the Master Plan for the Integral Management and Sustainable Use of the Magdalena River. At the same time, work is being done on legislation, which needs to be updated in order to promote a clear contractual and financial basis for port and river works with the support of multilateral banks and the Inter-American Development Bank-IDB (Corporación Autónoma Regional del Río Grande del Magdalena-CORMAGDALENA, 2021).

Logistics for bulk solid transportation

The transportation of solid bulk is carried out using the means that guarantee the dry condition of the goods and can be dispatched depending on the type of goods; it can be grain, dry food, minerals extracted in raw form, fertilizers, wood and any other material. For this purpose, ports require adequate logistics for storage, such as silos, cranes, feed hoppers, conveyor belts, sufficient energy to power machinery, etc., to ensure that the goods are in a dry condition and can be shipped depending on the type of merchandise.

and equipment. In this sense, in the last 10 years Colombia has been very slow in adapting the river ports of the Magdalena River for these purposes. Therefore, this is an opportune moment for the country, where the definitive adaptation of the ports must be accelerated; since t h e Free Trade Agreement (FTA) with the United States is underway and the expansion of the Panama Canal has been completed, which generates multiple opportunities that allow for an increase in world trade.

In addition, according to several studies, Colombia is a country that concentrates its major industrial and demographic activity in the interior; river transport on the Magdalena River has the potential to transport 7200 tons of bulk cargo in 6 barges in tow, while the same volume by land requires 206 trucks with high transportation costs (Torres-Muñoz, 2011). Another element to consider in the transport of bulk goods by waterways is the ownership of the goods and their operations during storage, loading, travel and unloading; since they are unpackaged products and their conservation will depend on the physical condition, size, durability during transport times, fluidity, cohesion and final disposition of the product. For this reason, the vessel, barge or bulk cargo ship is optimal, since it is composed of a single deck, has high and low tanks for ballast loading, and hopper tanks are added (Chávez-Turín and Grau-Banda, 2020).

There is no doubt that the transport of goods along the Magdalena River will have to be a synchronized multimodal system; therefore, efficient overland logistics, including the interface, is important to reduce costs. In consideration, in some ports, such as Ba- rrancabermeja, Puerto Berrío and Puerto Salgar, overland road services and loading and unloading handling equipment should be improved in the medium and long term, using technified services, according to the study by Paternina-Iriarte and Ramírez-López (2010); more recent research that confirms the current situation is warranted. It highlights that port logistics with efficient operation and lower costs tends to enhance the participation and competitiveness in domestic and international markets of bulk goods, since an attractive final price for export or domestic sale creates competitiveness and strengthens the supply chain (Londoño-Giraldo and San- ta-Valencia, 2021), promoting an efficient scenario that allows the success of operations.

Port logistics involving cost reduction and travel times are important elements for the transport of bulk goods to displace single land and rail modes, which historically have had greater participation in Colombia than river transport (Corredor and Díaz-Barragán, 2018). Therefore, the logistics for the use of barge chains of up to 6 planks in convoy should be improved to massively increase the volumes to be transported and add elements for cost reduction; an action that is already being executed in the transportation of goods by river.

The use of technology is necessary to facilitate transportation and port logistics so that its impact produces safety, competitiveness; with the purpose of making bulk cargo transportation operations attractive and profitable. To this end, the Colombian government must offer incentives and technological services to promote private enterprises, since economic benefits will be obtained from projects that increase trade through the waterway. The use of real-time telemetry is needed to detect sedimentation and decrease the rate of sedimentation.

depth of the Magdalena River navigation channel, since traffic is continuous and permanent (Núñez-Blanco et al., 2020), thus reducing losses due to accidents and strandings. This would provide an optimal commercial opportunity through the river transport modality in the country (Martínez-Salcedo, 2020), generating significant economic growth in the sector and, therefore, technological development.

Conclusions

The technical-economic feasibility of transporting bulk cargo by river through the Magdalena River from a theoretical perspective offers important competitive advantages; The comparative capacities, according to multiple studies, are 7 times greater by river than by land, being able to generate a potential cargo through the river of 55 million tons/year under optimal navigability conditions, using barges or flatboats with tugboats (Paterni- na-Iriarte and Ramírez-López, 2010). Competitive advantages include lower comparative mobilization rates, adequate handling of goods with a high weight/volume ratio, use of vessels and/or barges that allow lower fuel use with less depreciation of equipment and components, and lower environmental impact. For its part, the National Development Plan establishes the importance of promoting the development of alternative and synchronous modes of transportation, for which the geopolitical position of the Magdalena River and its basin offer alternatives for implementing multimodal transportation strategies.

By virtue of the above, the positional advantages of the Caribbean ports of Barranquilla, Santa Marta and Cartagena through the dike channel could be exploited, as they represent important advantages for the export of products from the industrialized interior of the country. These competitive advantages could contribute to the development and growth of the general bulk transportation system, offering an opportunity for sustainable, social and environmental execution. To this end, some situations that have historically prevented the transport of solid bulk by river in Colombia must be solved, such as: overcoming the inconveniences caused by the high sedimentation rates of the river, which prevents the recurrent navigability of medium-sized vessels, and trans- forming the multimodal transport structure of the country towards a synchromodal perspective. On the other hand, improve the logistics systems for storage, loading and unloading of solid bulk in the existing river ports so that the operational work is efficient and executed in a network with the use of technology (Ramírez-Herrera and Aguilera-Chávez, 2019); these proposals would improve the cost and benefit indicators for the Magdalena waterway.

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