Logistics and Transportation in Brazilian Agribusiness: The Flow of Grain Production

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***Abstract*—Soy and corn are the most representative crops in national agricultural production. Logistics activities are directly related to the competitiveness of agricultural commodities on the foreign market, so that the favorable characteristics of the productive segment only become competitive advantages for the country if there is an efficient logistics system. In this sense, the present study aimed to investigate transportation in the context of Brazilian agribusiness, focusing on the soy and corn production chains. Thus, from a bibliographic search and interviews conducted with executives from the logistics sector, the investigation was oriented to identify and analyze the main logistical aspects related to the flow of Brazilian grain production. For agricultural commodities, logistical costs have a greater influence on competitiveness, as they are goods with low added value and are generally transported in large volumes. This fact makes the waterway and railway modes more appropriate for the transportation of these products, due to the ability to move large volumes while consuming little fuel, that is, greater energy and economic efficiency in long distance journeys. Among the main aspects of infrastructure and operation identified, the poor state of repair of the Brazilian road network stands out, with only 12.4% of its roads paved; the low density of the tracks of the railroad and waterway systems when compared to other countries; the small participation of waterways (20%) and railways (15%) in the national transport matrix; and the greater use of Arco Norte in the flow of production. In order to be able to monitor the development of its agricultural production, the country needs to invest relatively more in the structuring logistics infrastructure, destined to rail, waterway and cabotage services, and to increase the productivity of the existing assets.**

***Index Terms*—Agribusiness, transportation, logistics management, transportation costs, agricultural commodities.**

I. Introduction

Logistics is the set of activities that integrate and rationalize systemic functions from the supply of inputs to the production and distribution of goods, facilitating the flow of products and information related to them. In this sense, transportation, product availability and order processing are essential activities of the logistics segment [1].

The costs associated with logistical activities are broken down as logistical costs. Like any other cost, they are computed to determine the price of the good or service, so that the higher it is, the greater its share in the final value of production. Thus, its impact is more significant in sectors whose products are of low added value [2].

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Agricultural commodities, such as soybeans and corn, due to their characteristics, are a good example of this relationship. The Brazilian agricultural sector produces large volumes that need to be moved from producing areas to consumption, processing or export centers. The movement of this large quantity of goods over long distances, in Brazil, makes the total cost of the transport service to be high [3].

The fact that the commodity has low added value also translates into another difficulty. In the domestic market, where there is power to set prices for commodities, the addition of logistics expenses results in an increase in the price and loss of competitiveness of products in a region compared to production from locations closer to the consumer market and with greater availability of products. logistics infrastructure [2]. For goods destined for export, these costs are reflected in the decrease in the amount received by the producer [4]. This is because it is not possible to embed logistics costs in the final price of the product, since it is formed on the Chicago Stock Exchange [3].

In this sense, logistical activities are directly related to the competitiveness of agricultural products in the country, so that the favorable characteristics observed in the productive segment only become competitive advantages if there is an efficient logistics system, which does not nullify productivity differentials. Thus, the utilization of the Brazilian agricultural potential, which is notably high, is directly related to the availability and quality of the existing logistics infrastructure and the resulting costs. And, in this regard, Brazilian production is penalized due to existing logistical bottlenecks [3].

Brazil's logistical problems are associated with the lack and poor quality of the infrastructure, an inadequate modal distribution, the lack of incentive for inter or multimodality and the geographic concentration of the available structures, which leads to the saturation of the flow capacity of certain regions. As a result, the comparative advantages observed in the productive aspects are suppressed by the costs derived from the country's logistical inefficiency [5].

Thus, from a bibliographic search and interviews conducted with executives from the logistics sector, the investigation was oriented to identify and analyze the main logistical aspects related to the flow of Brazilian grain production.

II. Grain Distribution Logistics

The flow of grain production in Brazil occurs in two stages. The first of these comprises the transport of the products, after harvesting, directly from the fields to the warehouse on the rural property or to the public, cooperative

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or trading warehouses, carried out by road. It is a pulverized transport, of generally high cost due to the lack of paving in most of the Brazilian rural roads [6].

The second stage involves transporting warehouses, by road, to the processing industry, from which the derivatives are destined for the domestic market, also by road, or to the foreign market, by road, railroad or waterway. In the case of the export of unprocessed grains, production proceeds from the warehouse to the ports, being transported by highways, railways, waterways or combinations of these modes [7]. In this case, the displacement is usually characterized by the long distances covered and the longer transit time, mainly due to the concentration of production in areas far from the export ports, such as the production originated in the Center-West of the country, drained by the ports in the South and Southeast [8].

Sometimes, due to the lack of warehouses or at the option of the producer or shipper (given the conditions of supply and demand in the market), the harvested crop can proceed directly from the rural property to the port of destination; or even, for the processing industry, which generally maintains its stock in the vicinity of its facilities [9]. Fig. 1 shows the logistical flow of distribution of agricultural production, from the points of origin (rural properties) to the ports or processing industries.

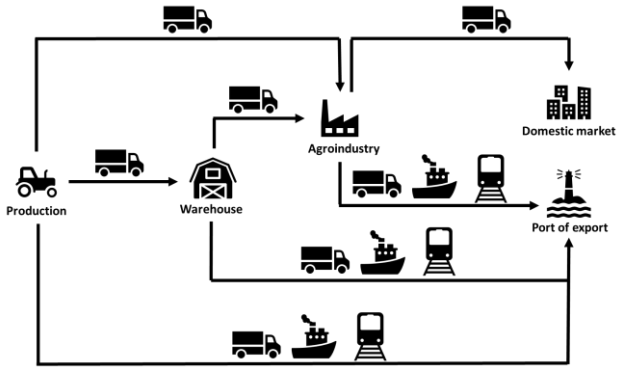

Fig. 1. Grain distribution logistics in Brazil. Source: [10].

For the logistical flow of distribution to work properly, points of interconnection and connectivity between modes of transport are essential, from the origin to the destination of the displacements. This role is played, above all, by the transshipment terminals, warehouses and port terminals. Such infrastructures can be public or private, operated by the shippers themselves or by third parties. Larger companies or cooperatives, in general, own and operate this type of infrastructure [7].

As seen in Fig. 1, given the specificities of the products, the transportation of soybeans and corn from the point of origin to the port is carried out by three different modes: road, rail and waterway. In terms of efficiency, the waterway and railway modes are more suitable for these types of products, due to the high capacity and the lower costs incurred in the great distances traveled, especially in the export routes, destined for the ports [11].

The road mode, in turn, has less favorable characteristics for the displacement of bulk cargo over long distances, a situation in which it is currently used. This fact is due to the lower load capacity per vehicle, which, in the sum of the movement, results in lower energy efficiency and higher costs [12]. With competitive advantages on shorter journeys, road transport is more advantageous, compared to rail and waterway, in cases where the origin and destination of the cargo are at close distances [13].

A. Flow of Brazilian Grain Production

Soy and corn are the most representative crops in the national production of grains. The 2019/20 Brazilian grain harvest closed with a historical record of 257.8 million tons, representing a gain of 11 million tons compared to the previous harvest (2018/2019), and a growth of 4.5 %. The production of soybeans was 124.8 million tons and that of corn, more than 102 million tons. Of this total, 84% went to the foreign market, being exported, predominantly, in the form of grain, bran and degummed oil, mainly to China. In the domestic market, the largest consumer of soy is the animal feed industry [14].

All this volume produced, however, exerts a very strong pressure on the country's transport infrastructure. Brazil stands out in comparison to other agricultural producing countries in terms of greater availability of land, favorable climate, qualified human resources, marketing structure, potential in bioenergy, management capacity and technological development. On the other hand, the tax burden, the logistical infrastructure, the exchange rate and trade barriers are considered the main obstacles to the development of agribusiness, according to a survey conducted with companies in the sector [15].

The growth of agricultural production for the interior regions and the continuous evolution of the quantity produced by the Brazilian agricultural sector, added to the increase in commodity exports in recent years, made the marketing and logistics agents to invest in new route alternatives for the harvest flow to national ports with low operational use [16].

According to the National Waterway Transport Agency [17], there was a great increase in the movement of soy and corn through the ports of Arco Norte. This is the new route for the transportation of grains in the country. Considering the participation of the ports of the North Exit in the total Brazilian movement of corn and soybeans, there was, in relation to 2010, an evolution of 482% until 2020.

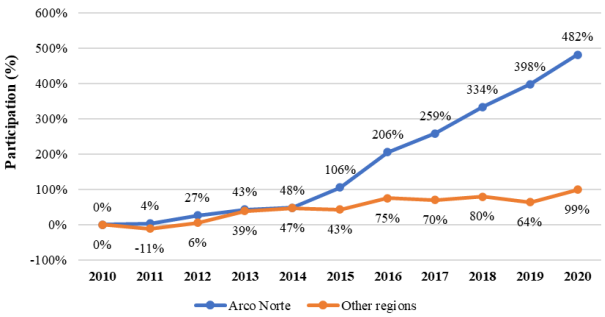

Fig. 2. Comparison of grain movement in Brazilian ports in relation to 2010. Source: [17].

In the 2019/2020 harvest, the main public ports in which soy and corn are shipped to the foreign market through the North Exit were those of Santarém, in Pará, and Itaqui, in Maranhão, with respectively 3.5 and 5.8 million tons. Among the private ports, the main facilities were the Vila do Conde Terminal, with 2.9 million tons; Itacoatiara

(Hermasa), with 2.7 million tons; and Ponta da Montanha, with 2.4 million tons disposed of [17].

The South Exit, which includes the ports of Santos (17 million tons drained), Paranaguá (9.5 million tons), São Francisco do Sul and Rio Grande, each with 3.5 million tons, accounted for 68 % of the flow of Brazilian soy and corn to the foreign market, totaling 43.3 million tons of the two goods in the first half of this year [17].

Also, according to a study by ANTAQ [17], the participation of the so-called Arco Norte in the flow of soy and corn to international consumer markets has practically doubled in ten years, from 24% of the total exported in 2010 to 49% in 2020.

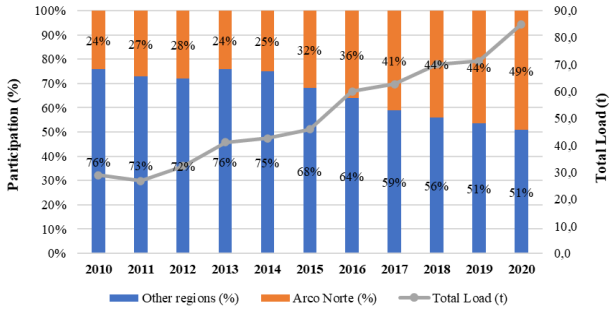

Fig. 3. Historical series of the participation of ports in the Brazilian movement of corn and soybeans (2010-2020). Source: ANTAQ [17].

As can be seen in Fig. 3, the increase in the participation of the North Exit has intensified as of 2015. That year, it reached 32%, and surpassed 40% in 2017. As for the ports in the other regions, the "South Exit" (Santos, Paranaguá, and others), more than 45 million tons were shipped for export in 2020 [17].

Logistic infrastructure projects were implemented in the multimodal corridors of Arco Norte, a name characterized by a set of ports located above the 16 parallel. This new set of exporting platforms allows the adoption of alternatives of transport axes necessary for the flow and loading of vessels destined for international markets [16].

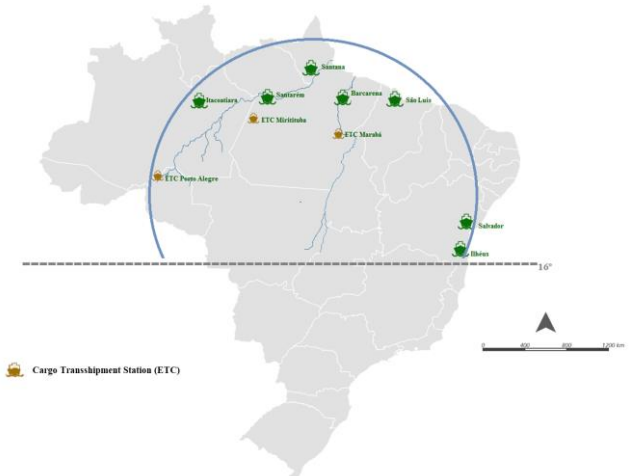

Fig. 4. Geographic location of Arco Norte ports. Source: [18].

The Arco Norte system is formed by several multimodal corridors, illustrated in Fig. 4, which ensure the accessibility of agricultural production to the following ports: Itacoatiara, located in the state of Amazonas; Santarém, Barcarena and Vila do Conde, in Pará; São Luís, located in Maranhão; and Santana, in Amapá. The port support platforms and operational support available in the multimodal corridors are: Porto Velho, in Rondônia; and Miritituba, located in Pará [16].

The internal logistics to reach these ports in Arco Norte have gained more attention. A recent example was the completion of the paving of the BR-163, which was one of the main demands to facilitate the flow through the ports in the region and which had an immediate impact on road freight to reach Miritituba in Pará [19].

The work was delivered at the end of 2019 and, in January 2020, freight between Sorriso (MT) and Miritituba (PA) has already benefited, dropping in relation to the average of previous years, in a period when the soybean harvest enters the market, when generally freight prices advance.

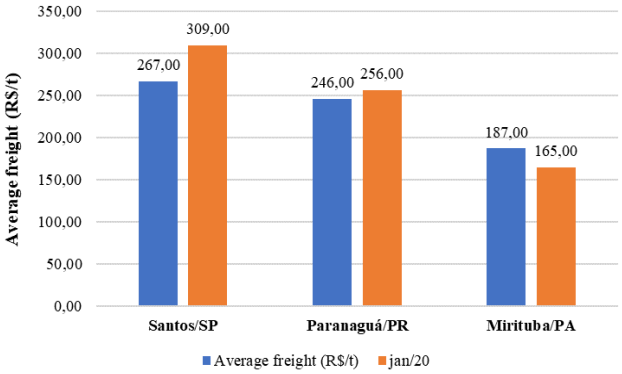

Fig. 5. Comparison of grain freight from the city of Sorriso / MT in January 2020. Source: [20].

Conab [19] points out that this gain is linked to the improvement of infrastructure in the region, in particular by the end of the paving of BR 163, which reduced the time and cost of freight to the port of Miritituba, in Pará. Brazil still concentrates cargo transportation on highways, with more than 60% of everything that is moving internally using this option [21]. However, investments in multimodal options with the combination of highway and waterway, as well as highway and railway have gained space and contributed to making internal logistics more competitive.

Thus, the Arco Norte will have its representativeness and importance in the process of transporting production from the Midwest region to export. It consists of a combination of road, rail and waterway modes directed to the ports of the North. However, despite being geographically presented as a strategic and advantageous alternative in terms of speed and costs, it needs attention and investments in infrastructure to overcome the challenges.

III. Methodology

Based on its objective, this research is characterized as exploratory and descriptive, as it provides a detailed view on the logistics and transport of Brazilian grain production, through a bibliographic review that brings thoughts of several authors on the subject. In addition, the research works with data collected from reality without manipulating them, that is, the researcher makes only observations, recording, analyzing and correlating situations of the theme

[22].

Also, according to Yin [22], the research is exploratory, as it is a study that aims to increase the researcher's familiarity with the theme of the proposed problem. The research is also classified as descriptive, as it is a study of the characteristics, problems and facts known to the sector.

According to Gil [23], exploratory research involves:

• Literature study;

• Interviews with people who have practical experience with the researched problem;

• Analysis of examples that encourage understanding.

The bibliographic study was carried out from the survey of theoretical references published in the databases Scopus, ISI, Scielo and CAPES Periodicals, in addition to the specialized complementary bibliographic survey, with emphasis on studies developed by the National Supply Company (Conab), Ministry of Agriculture (MAPA), National Waterway Transport Agency (ANTAQ), National Land Transport Agency (ANTT), National Association of Railroad Carriers (ANTF) and National Transport Confederation (CNT).

The interviews, based on a semi-structured script, built from the literature review, aimed to validate information from the agro-industrial logistics sector, addressing issues related to the main routes for the flow of grain production, the quality of the infrastructure used, the main logistical obstacles encountered and projects considered as priorities for the efficiency of the sector. The interviewees were defined by accessibility; however, the researcher was careful to check the representativeness in relation to the universe of companies operating in the Brazilian market and in relation to the executives' professional experience.

The interviews were conducted between the months of September and November 2020 by filling out an electronic form, made available by e-mail, and telephone conversations. The Logistics Manager, the Transport Coordinator, the Senior Logistics Analyst and the Senior Trader of an agricultural commodities trading company participated in the process, which in 2019 handled 4.8 million tons of soybeans and 3.3 million in Brazil in 2019 tons of corn, ending the year in sixth place in the ranking of the largest grain exporters in the country. Its decision-making center for the purchase and sale of grains and the contracting of freight by road, rail or sea is located at the main office in São Paulo, where the interviewees operate. The company has five regional offices headquartered in important agribusiness hubs: Sorriso (MT), Passo Fundo (RS), Londrina (PR), Rio Verde (GO) and Luís Eduardo Magalhães (BA).

The analysis and treatment of the data were supported in a qualitative way and presented through discursive language. With regard to treatment, the content analysis method was applied, in which a comparative reading of the citations of the research subjects was carried out [24]. The results obtained with the interview were evaluated in parallel with the bibliographic research.

IV. Results and Discussion

Transport and logistics services act as vectors of territorial, economic and social cohesion, given that they have the capacity to improve connectivity, reduce logistics costs and improve the mobility of production factors. However, in order to enjoy these benefits, it is essential that these services are efficient and effective [25].

In the Brazilian case, the imbalance of the cargo transport matrix, with the existence of few railway and waterway alternatives, and the lack of complementarity between the modes of transport, increases the costs of internal supply and hinders exports [5]. With a focus on the flow process of the Brazilian grain harvest, the main aspects of infrastructure and operation of each mode of transport used in the flow of grain production in Brazil were analyzed.

A. The Dynamics of Grain Transport

Transport is the most important component of a logistics system and also the most representative logistics cost for handling grain. In the agricultural segment, as a whole, the costs associated with the distribution of products correspond to approximately one third of the sector's added value [10].

Historically, Brazil opted for a transportation system for the production flow based on the use of highways. The main reason was the geographical expansion of agriculture in regions lacking logistical infrastructure. It is common for countries of small territorial extension to guide their transport in the road modal. Comparing with the transport matrix of other countries of similar sizes, we can see how unbalanced the use of different modes for transporting cargo in the country is [26].

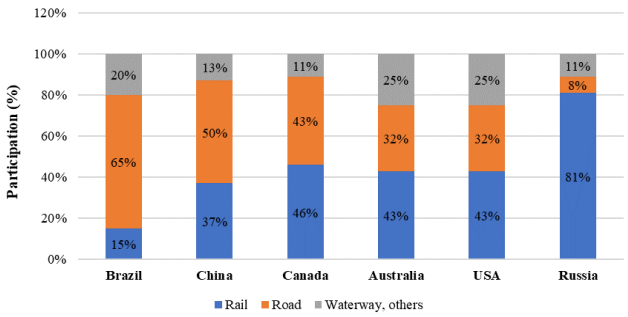

Fig. 6. Comparison of the Brazilian cargo transport matrix with countries of similar territorial dimensions (2018). Source: [21].

The Brazilian cargo transportation matrix is currently based on 65% of transport by road, 15% by rail and 14% by water. Other countries of similar dimensions, such as the United States, China, Russia, Canada and Australia, have chosen to transport their goods by waterways and railways. The only mode in which Brazil stands out is, in fact, the road mode, in which the country reaches rates much higher than countries such as China (50%), Canada (43%), Australia and the USA (32%), and Russia (8%).

Due to the internalization of production, the average costs of transporting the grains produced in the national territory, especially to the exporting ports, increased substantially. This is because the main factor that influences the cost of transportation is the distance traveled from the origin (rural property or warehouse) to the final destination (port terminal) [27]. For purposes of example, the National Supply Company [28] estimated that, in 2016, the freight from Sorriso, in Mato Grosso, to the port of Paranaguá, in Paraná, represented 50% of the sale price, in the port, of the corn and 23% of the value of soybeans, as shown in Fig. 7.

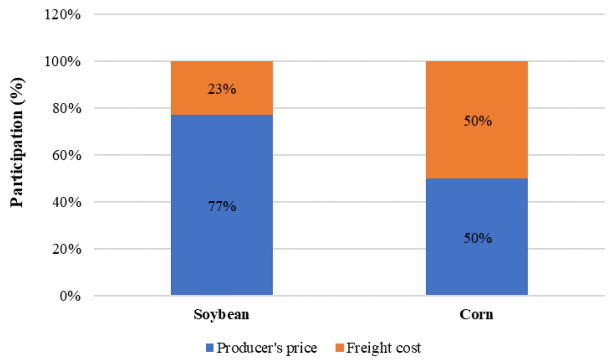

Fig. 7. Freight share on the final value of soybeans and Brazilian corn (2016). Source: [28].

Also affecting the costs of transporting grains, in the Brazilian case, the lack of mechanisms to better distribute the flow of production, which occurs in a concentrated manner; the poor conditions of the existing logistics infrastructure, both in terms of capacity and quality; the absence of return freight on alternative routes; in addition to other characteristics specific to each mode of transport [29].

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B. Road Transport

It was identified in the applied questionnaire that the vehicles used to provide the service of the studied company are large trucks, composed of tractor units and semi-trailers. According to the report of the interviewed logistics manager, with the growth of production and, consequently, of the volume to be transported by these trucks, many transporters opted for new types of vehicles, such as bitrens (total gross weight of 57 tons) and rodotrens (total gross weight of 74 tonnes), which allow the transport of a greater volume of cargo through the use of additional trailers or semi-trailers. The manager affirms that with the use of these combinations, there is a reduction in transport costs per ton by increasing productivity, that is, the volume transported per trip, since the use of additional mechanical horses and drivers is dispensed with.

According to data from the CNT Highway Survey [30], based on standards from the National Department of Transport Infrastructure (DNIT), it is shown that of the 1.72 million kilometers of federal, state and municipal highways existing in Brazil, only 12.4% are paved, and are mostly located in the South and Southeast regions of Brazil. This percentage is 18 times lower than China and 14 times lower than the USA. The state of conservation of Brazilian roads aggravates the situation, making it difficult for agricultural production to flow.

The poor condition of the Brazilian highways was a factor highlighted by the interviewed logistics coordinator. This aspect reduces road safety and increases the cost of maintaining vehicles, in addition to the excessive consumption of fuel, lubricants and other inputs, impacting the negotiation of tariffs with transporters.

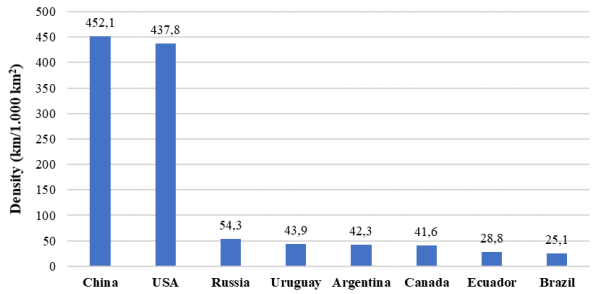

Fig. 8. Density of the paved road network by country (km of paved road / 1,000 km^2). Source: [30].

In 2019, a total of 108,863 kilometers of highways were assessed by the CNT [30] across the country, 64,198 kilometers (59.0%) presented some type of problem in the General State, being classified as regular 37,628 kilometers, bad 19,039 kilometers and poor 7,531 km. For the assessment of the General State, a joint analysis of the characteristics of the Signaling Pavement and of the Road Geometry is made (CNT, 2019b).

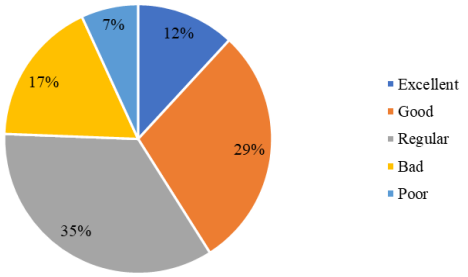

Fig. 9. General condition of Brazilian highways (2019). Source: [30].

In this ranking, the region most affected is the North, with a 34.6% increase in freight costs, followed by the Midwest with 24.5%. When the focus is on the transport of grains (soybeans and corn), 65% of which are by road, the situation is aggravated, especially by the inadequate pavement, which results in a 30.5% higher operating cost. As a consequence, transport costs increase, in the following progression: low productivity, reliability and average speed, high fuel consumption, fleet wear, and high accident rate. It is estimated that there would be savings of R $ 3.8 billion per year, if the bottlenecks that burden transportation were eliminated [10].

For example, when considering grain production in Mato Grosso, specifically in the municipality of Sorriso (MT), the average cost to send one ton to the port of Santos or Paranaguá is approximately R $ 300.00 / t. The use of the route, BR-163 to Miritituba (PA), with a transfer at the ports of Belém (PA), would cost approximately R $ 170.00 / t, providing a reduction of approximately 56% in freight [31].

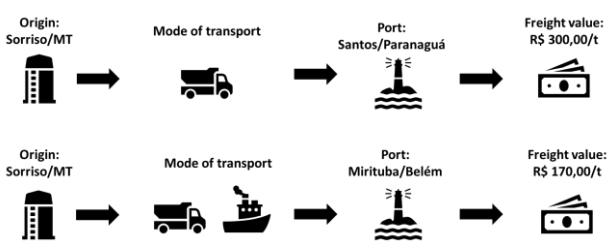

Fig. 10. Comparison of transport costs between ports in the southern and northern regions. Source: [31].

The road transport has characteristics of capacity and cost that make it more suitable for transporting small or medium volumes, over short or medium distances. It also has attributes of flexibility to act from the beginning to the end of the production chain, wide coverage (allowing access to places not reached by railways and waterways) and practicality, compatible with different types of loads and origins and destinations of the movement [27].

Within the scope of export logistic chains and / or long-distance journeys, as is the case with the transportation of a large part of Brazilian agricultural production, road transport should act in displacing production from its origins to the transfers to more efficient modes for this type of cargo or in shorter connections within the logistics system. If we consider the main products exported by Brazil (iron ore, soybeans, corn and sugar), we observe large volumes and low added value, which brings the need for more efficient logistics, which seeks to combine the potential of different modes of transport [25].

C. Rail Transport

The railway mode is indicated for the transport of large volumes of cargo over long distances. It is also considered safer, more economical and less polluting, compared to the road mode. Thus, the Brazilian geographic profile, which generates the need for travel over long distances, and the high participation of commodity production in the country's economic structure would be advantageous factors for the development of the railways [32]. However, rail transport is still a modality that is rarely used in Brazil.

According to the National Bank for Economic and Social Development [33], the Brazilian cargo rail system has the ninth longest network in the world, with 29,817 km, and the sixth largest in production, with 307 billion RTK in 2015. On the other hand, the productivity of this network, measured in TKU / km, as well as other performance indicators, is quite different from world peers. In addition, the density of the Brazilian network, measured by the ratio between the extension (km) and the surface (km2), which is relatively lower than that of other countries, as well as the insertion of rail transport in the Brazilian transport matrix, currently of 15% [21].

In Fig. 11, we can see that Brazil has a density of 3.4 kilometers / thousand km2, while in the United States the density is 29.8 kilometers / thousand km2, that is, almost nine times lower [21]. These bottlenecks restrict the ability to move, increase operating costs and the risk of accidents.

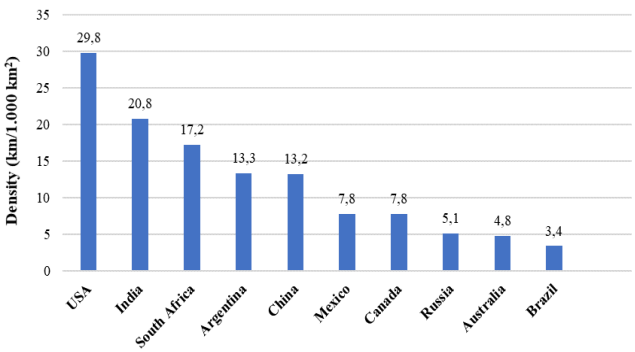

Fig. 11. Density of railway networks by countries (km of railway infrastructure / 1,000 km^2). Source: [21].

The available railway infrastructure, in addition to being relatively dense, also presents quality problems. Based on information from the report of the 2019 World Economic Forum [34], which assesses the quality of the infrastructure available for this modal, Brazil was behind its main global competitors in the export of soybeans and corn.

The expansion of the Brazilian railway is not limited to the purchase of rolling stock and the construction of new routes. Respondents point out that there are a number of physical and operational bottlenecks that need to be removed, with emphasis on invasions of the right-of-way and passages at critical levels. The domain strip is a strip of land of small width in relation to the length, in which the railways are located; level crossings are an expression to refer to a railroad crossing with a road, a street or a pedestrian crossing [35].

These obstacles cause several damages to the modal, causing the trains to reduce their operational speeds. The average speed of operation of trains, in Brazil, is around 29 km / h, whereas in the United States the average is 39 km / h, a difference of almost 35% [36]. This implies greater wear and tear on locomotives, increases fuel consumption and pollutant emissions, decreases operational safety, promotes accidents and facilitates cargo theft [10].

The modal is also characterized by market concentration (natural monopoly), which results in a reduced service offer, high transport rates and low reliability of terms and contract execution, mainly for commodities. This is because in railway concessions in Brazil, the structure adopted by the federal government was the vertical model [37].

In the current concession model, the concessionaire is responsible for the infrastructure, operation and sale of rail transport services [37]. This type of contract, in addition to not stimulating a sufficient volume of investments, also does not provide better use of the railway network, in all its extension, nor does it allow for adequate competition between concessionaires [38].

According to the logistics manager of the studied company, during harvest periods, the value of the railway fare has often been close to the cost of road transport. The value of the average rail fare, practiced between Rondonópolis (MT) and Santos (SP) in 2015, was R $ 195.00 / t. That is, 3% less than paid for road transport. The tariff, according to the calculations of the National Transport Agency (ANTT), should be R $ 160.00 / t [39].

According to Marchetti *et al.* [40], the Brazilian railway sector is mainly focused on the transport of agricultural and mineral commodities (95%), its primary function. However, not necessarily the only one. It lacks comprehensive objectives and targets that include the transportation of general cargo, 87% handled by road (only 4% of general cargo handled by rail), as well as liquid bulk (only 1% on railways).

As an illustration, according to a study by the Planning and Logistics Company [41], if about 1/3 of the internal displacements of general cargo (1.292 billion RTK) migrate from road to rail, with positive effects on cost in the transport operations of several economic agents (industry, retail, services) and in the global emission of GHGs in the transport industry, the participation of the railway in the Brazilian modal matrix would double, going from the

current 15% to 30%. A cost reduction / associated TKU of approximately US $ 30 billion / year is estimated.

The role of the railway sector is expected to gain relevance in the coming years. This is because, Brazil should produce 44.2 million tons more of grains, jumping from 257.8 million tons in the 2019/20 harvest to around 302 million tons in the 2027/2028 harvest. The estimate is part of the study Agribusiness Projections, produced by the Ministry of Agriculture, Livestock [42].

Brazil has the EF-170 project, also known as Ferrogrão, which will have an extension of 933 kilometers, connecting the grain-producing region of the Midwest to the state of Pará, ending at the Port of Miritituba. When completed (forecast for 2029), the railway will have high transport capacity and competitiveness in the flow of production through the Arco Norte, a role that, today, is played by the BR-163 highway. The corridor to be consolidated by the EF-170 and the BR-163 highway will constitute a new route for the export of soy and corn in the country. The undertaking will alleviate traffic conditions on this highway, with the objective of reducing the flow of heavy trucks, GHG emissions and costs with conservation and maintenance [43].

Despite the dispersion of information existing in several countries, the participation of the railway modal in countries with continental dimensions is, on average, 48%, about three times greater than the Brazilian (15%), which indicates a high potential for transformation and reduction of logistic costs with greater use of this modal in Brazil [40].

D. Water Transport

Brazil has a natural vocation for water transport. There are 8 thousand kilometers of coastline (10 thousand kilometers, considering the length of the Amazon River to Manaus) and 41.6 thousand kilometers of waterways, although only about 50% of them are economically viable. Although its potential is not fully explored, waterway transport is one of the main logistical modes in the country, mainly in the northern states, but it can also be better used in other regions of the country [44].

The modal constituted by inland roads accounted for 83.8 million tons of cargo transported in 2016. The so-called inland navigation corresponded to 33% of this total and has the potential to grow [45]. However, to increase the use of rivers as transport routes, it will be necessary to overcome several challenges over the next few years.

1) Cabotage

Currently, road transport accounts for almost 65% of cargo transported in the country. Even with the significant growth that coastal shipping (transportation between Brazilian ports) has achieved in recent years, it now holds a relative share of less than 11% of the total modes of transportation [21]. Despite its potential, coastal shipping in Brazil is very restricted to the movement of few products, especially the transportation of oil between offshore platforms and the continent, as a result of the country being a major offshore oil producer. Between 2010 and 2016, oil represented 75% of the total cargo handled [46].

The logistics manager interviewed points out that the large operational capacity for handling cargo from coastal shipping would generate economies of scale that would result in economic advantages, such as: lower fuel consumption per tonne transported, lower cost per tonne-kilometer transported, reduced registration of accidents. According to Teixeira *et al*. [47], to transport the same amount of cargo from a six-thousand-ton vessel, there would be a need for 172 thirty-five-ton trucks or 86 seventy-ton wagons. In addition, the lower fuel consumption per tonne-kilometer transported will result in a lower emission of pollutants, an environmental benefit.

TABLE I: COMPARISON BETWEEN TRANSPORT MODES

Indicator	Mode of transport		
	Cabotage	**Rail**	**Road**
Equivalent units	6.000 ton vessel	2.9 Hopper trains (86 70-ton wagons)	172 35-ton trucks
Average fuel consumption (t/1.000km)	4,1 L	5,7 L	15,4 L
CO_2 Emission (gCO_2/TKU)	20,0	23,3	101,2
Average transport cost, general cargo per 1,000 km (R$/t)	R$ 50,74	R$ 67,54	R$ 239,74

Source: [47].

The interviewee adds by stating that, in the agricultural sector, the high price of coastal freight is one of the reasons why wheat, corn and rice produced in the south of the country are unable to compete with the imported product in the markets of the Northeast region, now demanding the granting of government subsidies, now forcing exports to the detriment of domestic supply. These characteristics of the Brazilian merchant fleet affect the competitiveness of the national framework, especially in the case of coastal shipping. As a comparison, freight between Rosario (Argentina) and Recife (PE), with approximately 5,200 kilometers of distance, between different countries and over a long distance, costs less than freight between Paranaguá (PR) and Recife (PE), whose route is 2,800 kilometers [39].

Coastal shipping represents a great opportunity for Brazil to make its transport system more efficient, both economically and environmentally. Due to its great operational potential, it can be seen as a relevant opportunity to remove the main bottlenecks in the movement of goods in the country. Waterway transport would also provide a reduction in the number of accidents on the roads, and less environmental impact, with less CO_2 emissions throughout the chain and a reduction in the need for investments to maintain roads and roads.

2) Waterways

The main advantages of inland transport are the low cost of the ton transported per unit of distance and the great capacity for handling cargo. Due to these characteristics, the modality is suitable for transporting homogeneous products with low added value, such as agricultural commodities, soy and corn. However, the modal has low speed and, in the Brazilian case, reduced availability and frequency, which restricts its use to non-perishable (or barely perishable) products and reduces its competitiveness compared to other available transport modes [47].

The potential for navigability in fluviolacustrine surface waters in Brazil is 63 thousand kilometers and the national

hydrographic network is subdivided into nine basins, formed by 44 thousand kilometers of rivers, of which 21 thousand kilometers are naturally available, without the need for realization. dredging or transposition works, and only 13 thousand kilometers used economically [48]. It is little compared to the other grain exporting countries.

In Fig. 12, we can see a comparison between the main grain exporting countries, noting that Brazil has a density of 2.6 kilometers / thousand km^2, while in the United States the density is 60% higher. As a comparison, China was considered to represent the main buyer of Brazilian soy.

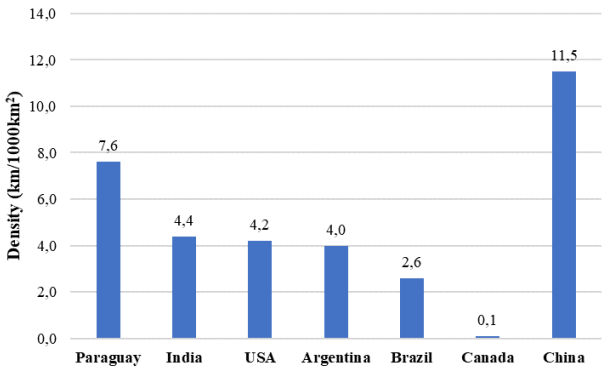

Fig. 12. Density of waterways by grain exporting countries (km of waterway infrastructure / 1000 km^2). Source: [39].

The vocation of the Brazilian waterways is the transport of commodities (such as grains, ores and inputs), fertilizers and fuels. Due to the low value of agricultural products, logistical costs impact the final price of the products. This fact facilitates the formation of commercial and industrial hubs located on its banks, acting in an integrated manner with the other modes that will complement river transport [49].

Inland transport is carried out by sets of barges and pushers, called trains. Compared to countries where navigation is intensively used, the capacity for moving Brazilian trains is limited. As an example, while in Tietê-Paraná, trains have a capacity of up to 6 thousand tons, in Mississippi (United States), they transport between 18 thousand and 60 thousand tons [44].

This low efficiency is a consequence of the lack of interventions to expand the capacity of Brazilian waterway handling and the inadequacy of structures located on waterways, such as locks. Its dimensions established at the time of its implementation limit the size of the trains that currently use them or make it necessary to carry out train dismemberments [49].

TABLE II: COMPARISON BETWEEN BRAZILIAN TRANSPORT MODES

Factors	Road	Rail	Waterway
Average cost of implantation (US$/km)	440.000	1.400.000	34.000
Average cost of operation (US$ / t/km)	34	21	12
Fuel consumption (l/t/1.000 km)	96	10	5
CO_2 Emission (km/t/1.000 km)	0,164	0,0481	0,0334
Infrastructure life span	Low	High	High
Maintenance cost	High	Low	Low

Source: [39].

Table II presents the results of a study by the Confederation of Agriculture and Livestock of Brazil [39], which shows that waterways are the best mode of transport for large amounts of cargo, with the best cost-benefit ratio. Its massive use would contribute to the reduction of the final prices of the goods traded by Brazil, especially with regard to its exports, where competitiveness is increasingly fierce. Regarding fuel economy, waterways are also the best way to transport cargo [50].

The waterway modal is responsible for the lower emission of greenhouse gases. The advantage is also wide when it comes to the costs of implementing the roads. It is known that a standard barge of 1,200 tons is equivalent to 18 wagons and 44 trucks, which represents a reduction in transportation costs. Another important factor in this assessment is the fuel efficiency. In road transport, a liter of fuel transports a ton of product for 25 kilometers; by rail, one liter transports one tonne over 85 kilometers and, by waterway, the same parameters serve to transport up to 217 kilometers [39].

The interviewees reinforce that in Brazil the recent investment in waterway operations has been made by the private sector (terminals and fleet) and, in some cases, also those related to the signaling and marking of the river. After 2000, the private sector consolidated operations on the Madeira River, between Porto Velho (RO) and Itacoatiara (AM), associated with agricultural expansion in western Mato Grosso, with a turnover of 7 million t / year. More recently, on the Tapajós-Amazonas waterway, between Miritituba and Vila do Conde (PA). The so-called north exit is an operation developed by the private sector (fleet, operation and port terminals) and is associated with the agricultural expansion of central-northern Mato Grosso, with an expected movement of 20 million t / year [40].

The essential elements for successful inland waterway transport, internationally recognized, are: well-maintained waterways, with sufficient and adequate cargo to be transported by barges, a governmental structure that supports the modal and an adequately equipped, safe and standardized transport system, within a favorable socio-environmental structure [51].

In this respect, the operation of intermodal terminals has a peculiar role. The terminal represents a potentially facilitating link in the use of more appropriate modalities for the movement of large quantities over long distances, but which do not have the "capillarity" attribute in their favor, that is, they do not necessarily arrive close to the points where production takes place. They can strategically position themselves at intermediate points to capture pulverized production, gather large volumes and ship them to the destination ports. If operated efficiently and at low costs, the intermodal terminal can act as a catalyst, providing lower cost operations by giving the opportunity to access a modality with greater load capacity [52].

In order to be able to follow the development of Brazilian agricultural production, the country needs to invest relatively more in the structuring logistics infrastructure, destined to rail, waterway and coastal services, and to increase the productivity of the existing assets. Special attention should also be given to the intermodal connection of transport systems, such as the connection of highways with railways and waterways and inter-highway connections,

in addition to the installation of integration and transshipment terminals, enhancing intermodality [53].

As seen throughout the research, despite the characteristics that are not very favorable to its isolated use in the transportation of agricultural commodities, highways are predominant in the flow matrix of Brazilian production. They favor the majority use of the road mode, in the Brazilian case, due to the low density of the railway network and the little use of waterways, due to the lack of interventions that guarantee the navigability of the rivers in the country.

V. Conclusion

The competitive potential of Brazilian agriculture has enabled, in recent years, the expansion of Brazil's participation in the international commodities market and has given prominent positions to the nation in supplying the world demand for food. The Brazilian agricultural sector is one of the most dynamic in the national economy. This has been growing for some decades at rates, in most years, higher than the average growth of the Brazilian economy as a whole. In this process of growth, agricultural production has gradually expanded to the interior of the country, occupying areas that are increasingly distant from the main consumer centers and exporting ports.

However, this scenario was not followed in terms of expansion and improvement of the country's logistics infrastructure, so that, today, there is a gap between the grain production capacity and the flow of these through Brazilian roads. In this sense, the sector faces one of the biggest obstacles to its development. It is not new today that the Brazilian transport infrastructure is deficient, and, as exposed throughout this work, it is deficient in several aspects: poor state of repair of the road network, as highlighted by the only 12.4% of paved roads; low density of rail and waterways when compared to other countries; small participation of waterways (20%) and railways (15%) in the transport matrix, which results in a low efficiency transport system; lack of integration between transport modes, among others. The result of this deficit is high costs, making grain transportation in Brazil more expensive and inefficient than its international competitors. An undeniable advance is the greater use of the so-called Arco Norte, but the output of the products is still concentrated far from the production centers, in the ports of the South and Southeast regions.

For agricultural commodities, logistical costs have a greater influence on competitiveness, as grains are low value-added goods and are generally transported in large volumes. This fact makes the waterway and railway modes more appropriate for the transportation of these products, due to the ability to move large volumes while consuming little fuel, that is, greater energy and economic efficiency for long distances. The use of navigable and potentially navigable rivers is also a prerequisite for the consolidation of the corridors of Brazilian agricultural production, especially in the North region. The competitive feasibility of the waterway and railroad modes would make it possible to transfer a large volume of cargo that currently travels on the highways, even reducing the cost of maintaining land roads. In addition, rationalizing the use of modes would reduce impacts on the environment, with less emission of polluting gases. Therefore, the transfer from the road mode to the other modes would reduce logistics costs and increase the competitiveness of the Brazilian soy and corn complex.

Conflict of Interest

The author declares no conflict of interest.

Author Contributions

Rodrigo D. Soliani conducted the research and approved the final version.

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