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The impact of the cost of road transport on the price of Brazilian soybean: the case of Mato Grosso do Sul and the practice of collaborative logistics

O impacto do custo médio do transporte rodoviário no preço da soja sul-mato-grossense para exportação e a adoção da prática da logística colaborativa

El impacto del costo medio del transporte por carretera en el precio de la soja de Mato Grosso do Sul para exportación y la adopción de la logística colaborativa

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Abstract
Of vital importance to the economy of Mato Grosso do Sul, soybean held the second position in the overview of the products exported in 2020, however, the state is distant from the main export terminals and with high dependence on the road modal. In view of this, the present study sought to evaluate the impact of the average cost of transportation on the price of Mato Grosso do Sul state soybean and the adoption of the practice of collaborative logistics as an alternative to reduce transportation costs. In order to calculate the average cost of road transport, the criteria established in the National Policy of Minimum Costs of Road Cargo Transport (PNPM – TRC) were followed as a guide. Analyzes were made for the vehicle compositions with 7 axles and 9 axles, originating in the municipalities of Maracaju, Ponta Porã and São Gabriel do Oeste and as destinations the port of Santos, Paranaguá and São Francisco do Sul. The results indicate that the vehicle compositions with 9 axles presented the lowest cost per ton transported for all routes analyzed and that, in the comparison between the current scenario and the ideal scenario that considers the adoption of the practice of collaborative logistics with the aggregate of routes Santos (route 1a), Paranaguá (route 1b) and São Francisco do Sul (route 1d) the reduction in the total financial cost for 7-axle compositions was R$ 49,936,261.64, representing a reduction of 5.24% and for 9-axle compositions the reduction in the total financial cost between the current scenario and the ideal scenario of the same aggregate route was R$ 43,462,818.45, representing also a reduction of 5.24%.
Keywords: Cost minimization; Decision making; Routing; Collaboration; Freight-return.

Resumo
De vital importância para a economia do Mato Grosso do Sul, a soja ocupou a segunda posição na visão geral dos produtos exportados em 2020, contudo, o estado está distante dos principais terminais de exportação e com alta dependência do modal rodoviário. Diante disso, o presente estudo buscou avaliar o impacto do custo médio do transporte no preço da soja sul-mato-grossense e a adoção da prática da logística colaborativa como alternativa para reduzir os custos de transporte. Para calcular o custo médio do transporte rodoviário, seguiu-se como roteiro os critérios estabelecidos na Política Nacional de Pisos Mínimos do Transporte Rodoviário de Cargas (PNPM – TRC). Foram feitas análises para as composições veiculares com 7 eixos e 9 eixos, com origem nos municípios de Maracaju, Ponta Porã e São Gabriel do Oeste e como destinos o porto de Santos, Paranaguá e São Francisco do Sul. Os resultados apontam que as composições veiculares com 9 eixos foram as que apresentaram menor custo por tonelada transportada para todas as rotas analisadas e que, no comparativo entre o cenário atual e o cenário ideal que considera a adoção da prática da logística colaborativa tendo como destino o agregado de rotas Santos (rota 1a), Paranaguá (rota 1b) e São Francisco do Sul (rota 1d) a redução no custo financeiro total para composições de 7 eixos foi de R$ 49.936.261,64, representando uma redução de 5,24% e para as composições de 9 eixos a redução no custo financeiro total entre o cenário atual e o cenário ideal dessa mesma rota agregada foi de R$ 43.462.818,45, representando uma redução também de 5,24%.
Palavras-chave: Minimização de custo; Tomada de decisão; Roteirização; Colaboração; Frete-retorno.

Resumen
De vital importancia para la economía de Mato Grosso do Sul, la soja ocupó el segundo lugar en el panorama de productos exportados en 2020, sin embargo, el estado está alejado de las principales terminales de exportación y tiene una alta dependencia del transporte por carretera. Por lo tanto, el presente estudio buscó evaluar el impacto del costo medio de transporte en el precio de la soja de Mato Grosso do Sul y la adopción de la logística colaborativa como alternativa para reducir los costos de transporte. Para el cálculo del costo promedio del transporte por carretera se siguieron los criterios establecidos en la Política Nacional de Pisos Mínimos para el Transporte de Carga por Carretera (PNPM – TRC). Se realizaron análisis para las composiciones de vehículos de 7 y 9 ejes, con origen en los municipios de Maracaju, Ponta Porã y São Gabriel do Oeste y como destino el puerto de Santos, Paranaguá y São Francisco do Sul. Los resultados muestran que las composiciones vehiculares de 9 ejes fueron las que presentaron menor costo por tonelada transportada para todas las rutas analizadas y que, en la comparación entre el escenario actual y el escenario ideal que considera la adopción de la práctica logística colaborativa con el destino del agregado de las rutas Santos (ruta 1a), Paranaguá (ruta 1b) y São Francisco do Sul (ruta 1d), la reducción en el costo financiero total para trenes de 7 ejes fue de R$ 49.936.261,64, lo que representa una reducción de 5, 24% y para los trenes de 9 ejes, la reducción del costo financiero total entre el escenario actual y el escenario ideal de esa misma ruta agregada fue de R$ 43.462.818,45, representando también una reducción del 5,24%.
Palabras clave: Minimización de costos; Toma de decisiones; Secuencias de comandos; Colaboración; Envío de devolución.

1. Introduction

Establishing itself as the main player for the production and export of soya beans on the international market, the country accounted for 82.978 million tons of soya beans worldwide in 2020, with China as one of the main destinations (SECINT & SEPEC, 2021). According to Conab (2021) the main Brazilian production region is the Center-West, concentrating 48.62% of the national production, and the most distant from the port terminals and with high dependence on road transport, as it is the case with Mato Grosso do Sul. The state has a geographical position distant from the main terminals for exporting commodities, being approximately 1,104km from the port of Santos, 1,126km from the port of Paranaguá and 1,205km from the port of São Francisco do Sul. Today, the main alternative for grains transportation focuses on the use of a precarious road structure (Kussano, 2010).

This reality is a Brazilian portrait because the highways have been the main means for the internal movement of cargo in the country. According to data from the Statistical Bulletin – CNT – June 2021, the modal road was responsible for 64.86% of the annual cargo movement in the country, totaling 1,548 billion NTK (net ton kilometer) (CNT, 2021). Another important factor is related to the highways quality. According to The Global Competitiveness Report elaborated in the World Economic Forum the country occupies the 116th position of the total ranking of 141 analyzed economies (Schwab, 2019).

In addition, CNT traveled in 2019 a total of 108,863 km between state and federal highways and the data collected were published in the CNT Research Bulletin of Highways 2019. The results showed that of the total traveled, 64,198 kilometers presented some type of problem in the general state of the highways when analyzed jointly the characteristics of the pavement, the signaling and the track geometry (CNT, 2019). According to the bulletin, the low quality of the highways directly influences the increase in the risk of accidents, demands a higher volume of investments and results in an increase in the operational cost, directly impacting the price of freight transport services.

Considering that transportation represents a significant portion of the operational costs, the present study aimed to evaluate the impact of the average cost of road transport on the price of Mato Grosso do Sul state soybean for export and the adoption of the practice of collaborative logistics to reduce costs.

2. Methodology

In order to calculate the average cost of road transport, the present study followed as a guide the criteria established in the National Policy of Minimum Costs of Road Cargo Transport (PNPM – TRC) established in Law number 13703 of August

8, 2018 (Brasil, 2018). For the calculation of the minimum costs, the methodological procedures and coefficients indicated in Resolution number 5867 of January 14th, 2020 (ANTT, 2020) that establishes "...the methodology and coefficients of the minimum costs, referring to the kilometer traveled in the performance of the freight-paid road transport service, per loaded axle". The analyzes took into account vehicle compositions of 7 and 9 axles and regarding the type of cargo, solid in bulk. According to Chapter I, Article 2, Section V of the said resolution, this type of cargo is "shipped and transported without any type of packaging, without identification mark and without counting of units."

For the calculation of fixed costs, the values were extracted from Administrative Rule number 322, of July 15, 2021 of the ANTT (2021) considering the following premises:

Cargo motor vehicle depreciation cost (Cdep_c): two analyzes were carried out, the first with a Volvo FM460 (6x4) vehicle with a purchase value (VAc) of R$ 543,189.46 for a 7-axle vehicle composition car and the second with a Scania R450 (6x4) vehicle with a Vac of R$ 590,671.12 for a 9-axle vehicle composition. For the resale value (VRc), the percentage equivalent to 46.1% of VAC and the economic life of the vehicle composition (VEc) of 84 months was adopted. The monthly cost formula is equal to

$$Cdep\_c = ((VAc - VRc) / VEc); \quad (1)$$

Cost of depreciation of the road cargo implement (Cdep_i): The analyzes took into consideration the implement for a category of products of the Solid Bulk + Hazardous (Solid Bulk) type for vehicle compositions with 7 with an implement acquisition value (VAi) of R$ 150,347.08 and 9 axes with VAi of R$ 210,162.59. For the implement resale value (VRi), the percentage equivalent to 46.1% of VAi and economic life of the implement (Vei) of 84 months was adopted. The monthly cost formula is equal to

$$Cdep\_i = ((VAi - Vri) / Vei); \quad (2)$$

Cost of remuneration for the capital of the cargo motor vehicle (Crcap_c): the percentage of 0.13125% for the variable rate of return on capital per month (i) was adopted, and the monthly cost formula equal to

$$Crcap\_c = ((Vac + VRc) / 2) * I; \quad (3)$$

Cost of remuneration for the capital of the implement (Crcap_i): the percentage of 0.13125% for the variable rate of return on capital per month (i) was adopted, and the monthly cost formula equal to

$$Crcap\_i = ((VAi + VRi) / 2) * i; \quad (4)$$

Labor cost of drivers (Cmo): for the calculation, the following values were adopted:

Drivers' minimum wage (S) the value of R$ 2,202.21;

A 96.75% increase in labor expenditure on labor and labor charges (ES);

Total number of drivers operating the vehicle composition (Nmo);

The formula for the monthly cost equal to:

$$Cmo = [S * (1 + ES) * Nmo] \quad (5)$$

Cost of taxes and car composition rates (Ctax): for the calculation, the following values were adopted:

IPVA: rate of 1.0% per year;

LIC: Licensing value of R$ 360.00 per year;

DPVAT: Mandatory insurance amount of R$ 5.78 per year;

TAC: Inspection rate of the tachograph of the motor cargo vehicle of R$ 145.42 per year;

The formula for the monthly cost equal to:

$$Ctax = ((IPVA * ((VAc + VRc) / 2)) + LIC + DPVAT + TAC) / 12 \quad (6)$$

Cost of accident insurance and car composition theft (Cseg):

VS: for the insurance cost factor, the percentage of 1.45% per year was adopted (Silva et al., 2011);

The formula for the cost of insurance equal to:

Cseg = ((((VAc + VRc) / 2) + (((VAi + Vri) / 2) * VS) / 12 (7)

Additional cost of Hazardous cargos (CPER): not applicable;

Day rate cost (Cdia): value of R$ 1,607.84 per month.

Working time of the vehicle composition (TT): 181.00 hours per month.

Finally, the fixed cost coefficient (CCF) is obtained by the formula:

CCF = (ΣjCFj / TT) = (Cdep_c + Cdep_i + Crcap_c + Crac_i + Cmo + Ctax + Cseg + Cper + Cdia) / TT (8)

For the calculation of variable costs, the values were extracted from the ministerial orders no. 496, of October 19th, 2021 and number 322, of July 15th, 2021 of the ANTT (2021) considering the following premises:

Fuel cost (Ccomb): The following values have been adopted for the calculation of fuel cost:

Fuel price (Pcomb): R$ 5.033 per liter (ministerial order number 496/2021);

Average Fuel Yield (Rdcomb): 2.00 km/l for composition of 7 axles and 1.725km/l for composition of 9 axles;

The formula is equal to:

Ccomb = Pcomb / RDcomb (9)

Cost with Arla (Carla): arla is the name given to an essential reducing agent whose objective is to reduce the emission of pollutants and for its calculation the values were adopted:

Arla Market Price (Parla): R$ 2.96 per liter;

Average yield of arla additive (RDarla): 40.00km/l for composition of 7 axles and 34.50km/l for composition of 9 axles;

The formula is equal to:

Carla = Parla / Rdarla (10)

Cost of tires and tires repairs (Cpne): as indicated in Annex I – methodology for calculating minimum costs, B. Variable Costs, III – Cost of tires and repairs, no repair procedures were considered for directional tires, which are those used on the steered axle(s) of the vehicle. The rear tires, however, are all tires used on the other axles of both the motor vehicle and the road implement of the vehicle composition. The values adopted were:

Directional tires unit price (Ppned): R$ 1,869.91 per tire for both 7-axle and 9-axle composition;

Rear Tire Unit Price (Ppnet): R$ 2,069.29 per tire for both 7-axle and 9-axle composition;

Tire repair price (Prec): R$ 635.87 per repair;

Number of repairs (Nrec): 1 tire repair for both the composition of 7 axles and 9 axles;

Directional tires life (VUpned): 100,000 km per directional tire;

Rear tire life with repair (VUpnet): 130,000 km per rear tire;

Number of directional tires of motor vehicle (Npned): 2 units per motor vehicle;

Number of rear tires of the vehicle composition (Npnet): 24 units for the composition of 7 axles and 32 units for the composition of 9 axles;

The formula is equal to:

Cpne = ((Ppned / VUpned) * Npned) + (((Ppnet + (Prec * Nrec)) / Vupnet) * Npnet) (11)

Maintenance cost (Cman): R$ 0.313 per km for both the composition of 7 axles and 9 axles;

Cost of Engine Lubricants (Club):

Volume of engine oil used in the motor vehicle (Llubm): 41 liters for both the composition of 7 axles and 9 axles;

Unit price of engine oil (Plubm): R$ 15.63 per liter;

Engine oil change interval (Im): 15,000 km

Volume of transmission oil used in the motor vehicle (Llubt): 16 liters for both the composition of 7 axles and 9 axles;

Unit price of transmission oil (Plubt): R$ 19.40 per liter;

Transmission oil change interval (It): 80,000 km

The formula is equal to:

Club = ((Llubm * Plubm) / (Im)) + ((Llubt * Plubt) / (It)) (12)

Cost of washes and greases (Clav):

Wash and grease application expense (Dlav): R$ 323.33 per wash for both the composition of 7 axles and 9 axles;

Interval between washes and grease applications (Ilav): 9,000 km for product class of the other cargos type, both for the composition of 7 axles and 9 axles;

Finally, the total cost of transport (CTce) is obtained by the formula:

Ctce = Tp * CCFce + Tv * CCFce + d * CCVce (13)

Where,

Total yard time (Tp) = 5 hours. Time the composition stands still waiting for loading and unloading;

Total travel time (Tv): it is the division between the distance to be traveled (route) and the average transport speed of 55 km/h for both the 7-axle and 9-axle composition.

It should be noted that resolution ANTT number 5867/2020 chapter II art. 3rd § 1st indicates that the variables profit and toll do not integrate the minimum costs calculation. In continuity, in the same Article 3rd § 3rd of the resolution, "the toll value, when present, must be added to the minimum costs, and payment must be made in the form of Law number 10209 of March 23rd, 2001, and current regulations." According to this law, the compulsory toll-card becomes the responsibility of the shipper or the equivalent (owner originating from the cargo), and the same must be paid in advance (Brasil, 2001).

Thus, the toll cost information was collected for the 7-axle and 9-axle compositions, originating in the municipalities of Maracaju, Ponta Porã and São Gabriel do Oeste and as destinations the ports of Santos, Paranaguá and São Francisco do Sul. The values were subsequently added to the CTce to obtain the total cost of freight for the two vehicle compositions analyzed.

Data were collected from the Ministry of Industry, Foreign Trade and Services Database (MDIC, 2021) to identify soybean export flows, with the state of MS and the three ports evaluated as their origin. For fertilizer import flow, the information collected considered the three recipient ports analyzed for MS as their origin.

Regarding the freight-return, two scenarios were analyzed, and for the first one (current scenario) the present study was based on the percentages adopted by Soliani, Innocentini and Carmo (2019), who applied 96 questionnaires with truck drivers from a shipping company operating in the ports of Santos and Paranaguá in March 2018 and who identified that about 61.5% of the trips back from the port of Santos and 76.4% of the Port of Paranaguá were fertilizers. The port of São Francisco do Sul was not analyzed in the analysis performed by Soliani, Innocentini and Carmo (2019) therefore, for the present study, the percentage of 68.95% representing the average between the two percentages was adopted. The second scenario (ideal scenario) took into account that 100% of the trips back would return with fertilizers to the analyzed municipalities, which would be the result of the application of collaborative logistics.

Regarding the soybean and fertilizer prices, the data were collected from Agrolink portal and the Esalq-USP freight information system (Sifreca) and considered the period from September 06th to September 12th, 2021 for both soybean and fertilizer.

In this research the monetary value of the equivalent of the real to the US dollar was R$ 1 = US$ 0.1772, on the date

of 29 of october 2021 (Ipeadata, 2021).

3. Results and Discussion

For the analysis of the results, the routes originated in the municipalities of Maracaju, Ponta Porã and São Gabriel do Oeste and destination in the ports of Santos, Paranaguá and São Francisco do Sul were collected. Figure 1 shows the routes considered to originate in the municipality of Maracaju.

Figure 1: Routes analyzed between Maracaju and the Ports of Santos, Paranaguá and São Francisco do Sul.

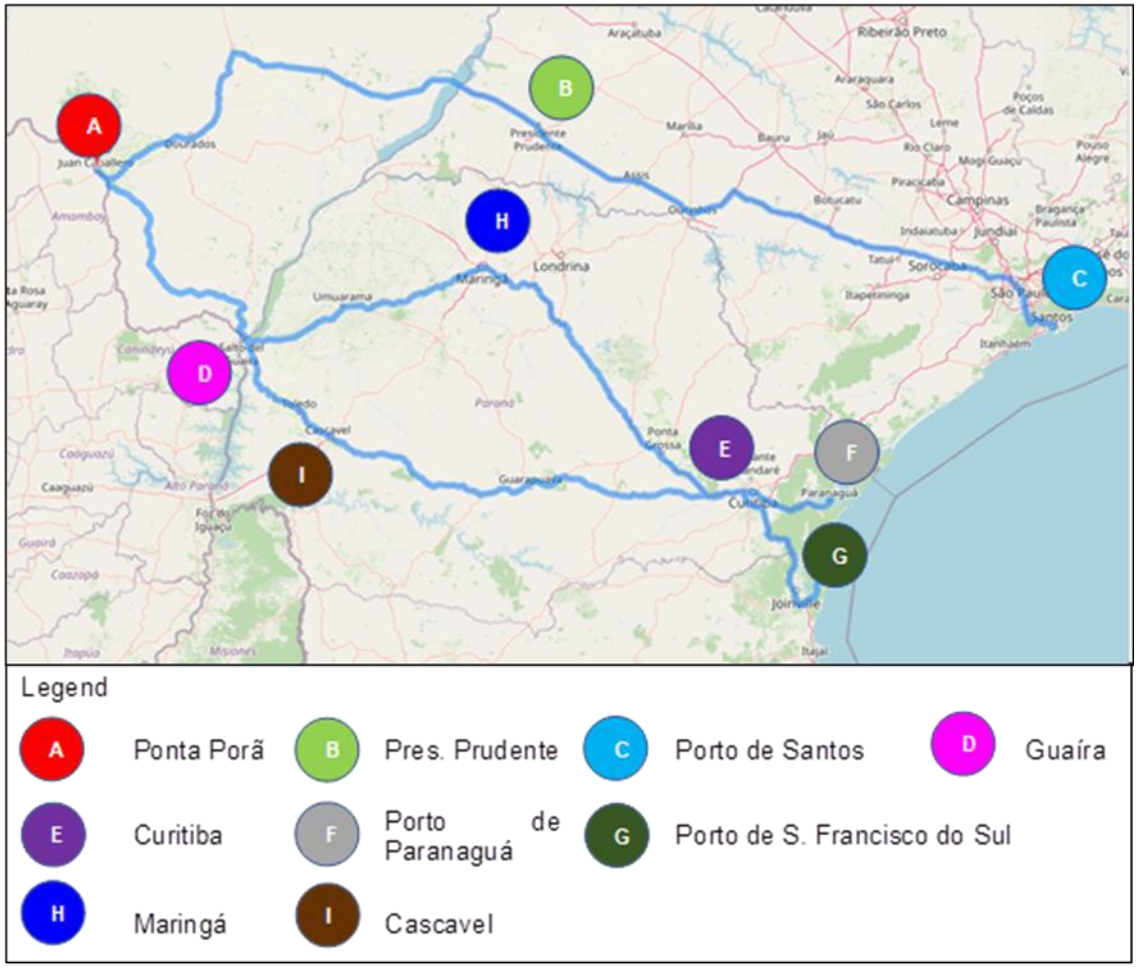
Source: Google maps and authors.

The details of the routes presented in Figure 1 were elaborated as follows:

- Route 1a (points A, B, C);
- Route 1b (points A, B, E, F);
- Route 1c (points A, D, E, F);
- Route 1d (points A, B, E, G);
- Route 1e (points A, D, E, G).

In continuity, the analyzed routes originated in the municipality of Ponta Porã, as shown in Figure 2, were identified.

Figure 2: Routes analyzed between Ponta Porã and the Ports of Santos, Paranaguá and São Francisco do Sul.



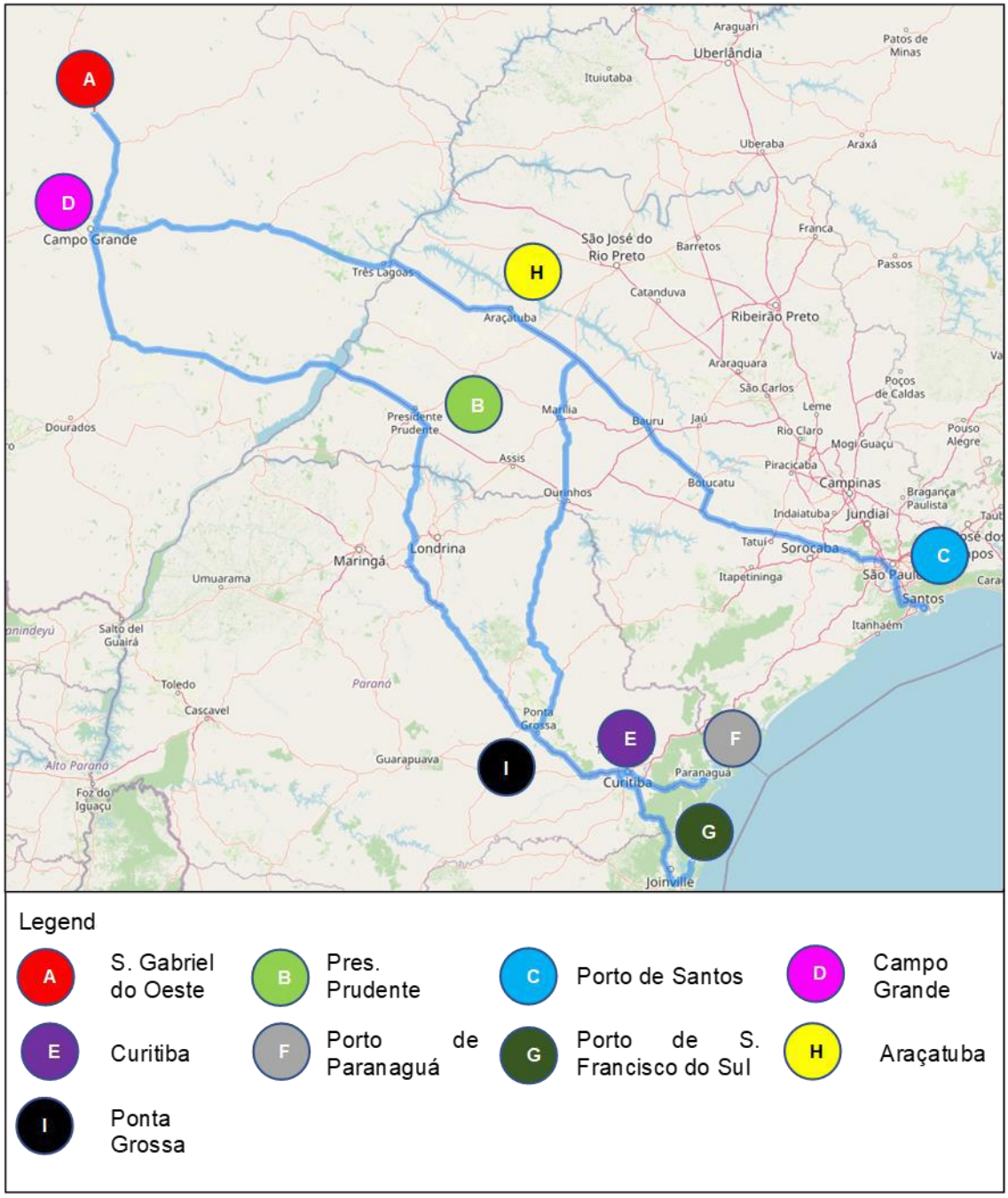
Source: Google maps and authors.

The details of the routes indicated in Figure 2 have been elaborated as follows:

- Route 2a (points A, B, C);
- Route 2b (points A, D, H, E, F);
- Route 2c (points A, D, I, E, F);
- Route 2d (points A, D, H, E, G).
- Route 2e (points A, D, I, E, G).

In continuity, the analyzed routes originated in the municipality of Ponta Porã, as shown in Figure 3, were identified.

Figure 3: Routes analyzed between São Gabriel do Oeste and the Ports of Santos, Paranaguá and São Francisco do Sul.



Source: Google maps and authors.

The details of the routes indicated in Figure 3 have been elaborated as follows:

- Route 3a (points A, D, H, C);
- Route 3b (points A, D, H, I, E, F);
- Route 3c (points A, D, B, I, E, F);
- Route 3d (points A, D, H, I, E, G).
- Route 3e (points A, D, B, I, E, G).

The distances for the routes analyzed and the toll values according to their vehicle composition were also gathered as shown in Table 1 below:

Table 1: Details of the routes analyzed – route, origin, destination, distance and toll value

Routes	Origin	Destination	Distance (km)	Toll value	
				7 axles	9 axles
Route 1a	Maracaju	Santos	1,082.5	R$ 1,188.60	R$ 1,528.20
Route 1b	Maracaju	Paranaguá	1,093.6	R$ 699.30	R$ 899.10
Route 1c	Maracaju	Paranaguá	1,094.8	R$ 884.80	R$ 1,137.60
Route 1d	Maracaju	S. F. do Sul	1,176.5	R$ 620.20	R$ 797.40
Route 1e	Maracaju	S. F. do Sul	1,177.7	R$ 805.70	R$ 1,035.90
Route 2a	Ponta Porã	Santos	1,188.1	R$ 1,238.30	R$ 1,592.10
Route 2b	Ponta Porã	Paranaguá	1,026.3	R$ 786.80	R$ 1,011.60
Route 2c	Ponta Porã	Paranaguá	1,079.5	R$ 602.70	R$ 774.90
Route 2d	Ponta Porã	S. F. do Sul	1,109.2	R$ 707.70	R$ 909.90
Route 2e	Ponta Porã	S. F. do Sul	1,162.4	R$ 523.60	R$ 673.20
Route 3a	S. G. do Oeste	Santos	1,217.2	R$ 1,327.20	R$ 1,706.40
Route 3b	S. G. do Oeste	Paranaguá	1,228.0	R$ 837.90	R$ 1,077.30
Route 3c	S. G. do Oeste	Paranaguá	1,349.3	R$ 997.50	R$ 1,282.50
Route 3d	S. G. do Oeste	S. F. do Sul	1,310.9	R$ 758.80	R$ 975.60
Route 3e	S. G. do Oeste	S. F. do Sul	1,432.3	R$ 918.40	R$ 1,180.80

Source: Search data.

Once the routes and their distances and the corresponding toll values have been identified, the fixed cost coefficients (CCFce) and the variable cost per kilometer traveled (CCV) for the type of solid bulk cargo and vehicle compositions with 7 and 9 axes were calculated. The results are shown in Table 2.

Table 2: Fixed cost coefficients (CCFce) and variable cost coefficients (CCVce) for solid bulk cargo type and vehicle compositions with 7 and 9 axes

Quantity of axles	Motor Vehicle	CCFce	CCV (R$/km)
7	VO/FM 460 (6X4)	R$ 412.65	R$ 3.52
9	SC/R450 (6X4)	R$ 437.92	R$ 4.10

Source: Search data.

It should be noted that, according to resolution ANTT number 5867/2020, the values obtained from the coefficients in Table 2 do not include the toll price. Once the fixed and variable cost coefficients have been defined, the total transport costs (CTce) have been calculated by adding the toll costs for each route analyzed.

In continuity and considering that the tare (weight of the set without cargo) of the vehicle composition weighs on average 19 tons for composition of 7 axles and 24 tons for composition with 9 axles, resulting in a cargo capacity of 38 tons in the combination with 7 axles and 50 tons with 9 axles. Taking into account the total costs obtained, it is useful to identify the costs per tonne transported. Therefore, considering that Resolution 211 of November 13, 2006 of the National Traffic Council (Contran, 2006) indicates the combined total gross weight (PBTC) of the vehicle composition with 7 axles of 57 tons and the composition with 9 axles of 74 tons. Thus, the total cost and the cost per ton transported for the 7 and 9 axle trains were calculated. The results are shown in Table 3.

Table 3: Total cost of transport (CTce) included toll and total cost per ton transported.

Routes	Total cost of transport (CTce)		Total cost per ton transport	
	7 axles	9 axles	7 axles	9 axles
Route 1a	R$ 7,062.25	R$ 8,156.09	R$ 185.84	R$ 163.12
Route 1b	R$ 6,612.02	R$ 7,572.50	R$ 174.00	R$ 151.44
Route 1c	R$ 6,801.74	R$ 7,815.92	R$ 178.99	R$ 156.31
Route 1d	R$ 6,824.73	R$ 7,810.69	R$ 179.59	R$ 156.21
Route 1e	R$ 7,014.45	R$ 8,054.07	R$ 184.59	R$ 161.08
Route 2a	R$ 7,483.66	R$ 8,652.91	R$ 196.93	R$ 173.05
Route 2b	R$ 6,462.62	R$ 7,409.03	R$ 170.06	R$ 148.18
Route 2c	R$ 6,465.79	R$ 7,390.45	R$ 170.15	R$ 147.80
Route 2d	R$ 6,675.33	R$ 7,647.22	R$ 175.66	R$ 152.94
Route 2e	R$ 6,678.49	R$ 7,628.64	R$ 175.74	R$ 152.57
Route 3a	R$ 7,674.99	R$ 8,886.52	R$ 201.97	R$ 177.73
Route 3b	R$ 7,223.71	R$ 8,301.70	R$ 190.09	R$ 166.03
Route 3c	R$ 7,810.28	R$ 9,004.23	R$ 205.53	R$ 180.08
Route 3d	R$ 7,436.41	R$ 8,539.89	R$ 195.69	R$ 170.79
Route 3e	R$ 8,023.34	R$ 9,242.83	R$ 211.14	R$ 184.85

Source: Search data.

The results obtained in Table 3 show that the 7-axle vehicle compositions options presented the lowest total cost for all the routes analyzed. With origin in Maracaju and destination in the port of Paranaguá, route 1b showed the lowest total cost in the two car compositions. In the analysis from Ponta Porã, the best option was route 2b for the vehicle composition with 7 axes and route 2c for the composition with 9 axes, both to the port of Paranaguá.

The same can also be observed for routes to the port of São Francisco do Sul (routes 2d and 2e). Even though there are differences in toll costs, the costs have been very close, which may indicate an alternative route option for the shipping company. In the analysis based on the city of São Gabriel do Oeste, the results obtained showed that route 3b was the one that presented the lowest total cost in the two vehicle compositions. Still considering the same origin, another alternative would be the route 3d that has as its destination the port of São Francisco do Sul and that presented a cost of about 2.94% higher than the route 3b.

The results presented in Table 3 show that of all the options presented with origin in the municipality of Maracaju, the one that presented the lowest total cost per ton was the vehicle composition with 9 axes for route 1b, which has as destination the port of Paranaguá, this may indicate a significant gain potential for the producer. Taking into account that the municipality of Maracaju exported about 152,173.25 tons of soya in 2020 (MDIC, 2021), the difference between the lowest cost option and the highest cost option (route 1a with 7 axles composition) was R$ 34.40 per ton (22.71%), which would amount to R$ 5,234,759.80.

In the analysis based on the municipality of Ponta Porã, the results showed that the route 2c for vehicle composition with 9 axles presented the lowest total cost per ton. Route 2b also presented a cost similar to that of route 2c, approximately R$ 0.38 higher (0.25%), indicating another possibility for the transportation of soybean from the municipality. It is urged to point out that both routes (2b and 2c) have a destination in the port of Paranaguá.

Considering that the difference between the lowest cost option and the highest cost option was R$ 49.13 per ton (33.24%) and that 2020 the municipality exported only 2,084.67 tons which would result in an economy of R$ 102,419.84. According to IBGE data (2021), the city produced about 930,000 tons of soya in 2020, which indicates that most of the volume produced is consumed internally or supplies the other municipalities in the state.

In continuity, the total cost per ton transported was calculated based on the municipality of São Gabriel do Oeste, and the results showed that the 9-axle vehicle composition option to the port of Paranaguá (route 3b). The lowest cost per ton transported was R$ 45.11 (27.16%) lower than the highest cost option, which was in the composition of 7 axles for the port of São Francisco do Sul (route 3e).

Considering that in 2020 the municipality exported around 89,832.74 tons the difference between the lowest cost option and the highest cost option would amount to R$ 4,052,354.90. Another important figure refers to the percentage of the total cost of transport in relation to the price paid by soya, which is an important index for the producer to assess the impact of this cost factor on the cost of its production. Data on the price of the 60 kg of soya sack were collected from the Agrolink portal based on November 12th, 2021, as shown in Table 4.

Table 4: Price of 60 kg of soya bean sack

Origin	Price of sack 60 kg	Price of ton
Maracaju	R$ 143.50	R$ 2,391.67
Ponta Porã	R$ 143.50	R$ 2,391.67
São Gabriel do Oeste	R$ 140.50	R$ 2,341.67

Source: Agrolink (2021) and Sifreca (2021).

Once the prices of the 60 kg soya bean sack were identified in the municipalities studied, it was possible to calculate the impact of the cost of transport on the price of soya bean and the results are shown in Table 5.

Table 5: Impact of the cost of transport on the soya price.

Routes	Vehicle composition with 7 axles	Vehicle composition with 9 axles
Route 1a	7.77%	6.82%
Route 1b	7.27%	6.33%
Route 1c	7.48%	6.53%
Route 1d	7.50%	6.53%
Route 1e	7.71%	6.73%
Route 2a	8.23%	7.23%
Route 2b	7.11%	6.19%
Route 2c	7.11%	6.17%
Route 2d	7.34%	6.39%
Route 2e	7.34%	6.37%
Route 3a	8.62%	7.58%
Route 3b	8.11%	7.09%
Route 3c	8.77%	7.69%
Route 3d	8.35%	7.29%
Route 3e	9.01%	7.89%

Source: Search data.

Considering the origin in the municipality of Maracaju, the results presented in Table 5 showed that the lowest percentage is obtained in the vehicle composition of 9 axles for the port of Paranaguá (route 1b), representing about 6.33% of the price paid for soya. In the analysis of the origin in Ponta Porã, the lowest percentage is obtained for the composition of 9 axles to the port of Paranaguá (route 2c), showing 6.17%. Originating in São Gabriel do Oeste, the lowest percentage is obtained for the composition of 9 axles to the port of Paranaguá (route 3b), showing 7.09%. In the sequence, the representativeness of the volumes imported from fertilizers compared to the volumes exported from the state of MS to the ports studied was analyzed, as shown in Table 6.

Table 6: Representativeness of fertilizer volumes in relation to soybean exports by port terminal.

Port Terminal	Importation of Fertilizers (ton)	Exportation of soy beans (ton)	Representativeness
Santos	2,737.50	757,724.29	0.36%
Paranaguá	1,193,017.42	2,108,287.02	56.59%
São Francisco do Sul	13,455.78	1,305,385.87	1.03%

Source: Search data.

The results of the research show that the adoption of the practice of collaborative logistics between soybean exports and fertilizer imports to the state of MS can integrate 0.36% in the port of Santos, 56.59% in the port of Paranaguá and 1.03% in the port of São Francisco do Sul. Once export and import flows have been defined, the total financial cost was calculated according to the vehicle compositions and routes studied. The average freight value took into account the results obtained for the 7 and 9-axle compositions for the municipality of Maracaju because it is the main city in the state soybean production volume according to IBGE data (2021). The calculation took into account the compositions of vehicles with 7 and 9 axles and as routes the ports of Santos (route 1a), Paranaguá (routes 1b and 1c) and São Francisco do Sul (routes 1d and 1e). The results obtained are shown in Table 7.

Table 7: Total financial cost for 7 and 9-axle trainsets in soybean and fertilizer operations in 2020.

Routes	Product	Average volume (ton)	Average Freight (ton)		Financial Cost	
			7 axles	9 axles	7 axles	9 axles
Route 1a	Soy bean	757,724.29	R$ 185.84	R$ 163.12	R$ 140,815,482.05	R$ 123,599,986.18
	Fertilizer	2,737.50	R$ 185.84	R$ 163.12	R$ 508,737.00	R$ 446,541.00
Route 1b	Soy bean	2,108.287.03	R$ 174.00	R$ 151.44	R$ 366,841,941.48	R$ 319,278,986.31
	Fertilizer	1,193,017.43	R$ 174.00	R$ 151.44	R$ 207,585.031.08	R$ 180,670,558.08
Route 1c	Soy bean	2,108.287.03	R$ 178.99	R$ 156.31	R$ 377,362,293.71	R$ 329,546,344.10
	Fertilizer	1,193,017.43	R$ 178.99	R$ 156.31	R$ 213,538,188.01	R$ 186,480,552.92
Route 1d	Soy bean	1,305.385.88	R$ 179.59	R$ 156.21	R$ 234,434,248.39	R$ 203,914,326.75
	Fertilizer	13,455.79	R$ 179.59	R$ 156.21	R$ 2,416,523.53	R$ 2,101,927.39
Route 1e	Soy bean	1,305,385.88	R$ 184.59	R$ 161.08	R$ 240,961,177.74	R$ 210,271,555.94
	Fertilizer	13,455.79	R$ 184.59	R$ 161.08	R$ 2,483,802.43	R$ 2,167,457.04

Source: Adapted from MDIC (2021) and research (2021).

The results in Table 7 showed that the total financial cost for the composition of vehicles with 7 axles was R$ 141,324,219.05 for the port of Santos (route 1a), R$ 574,426,972.56 for the port of Paranaguá (route 1b) and R$ 590,900,481.72 for route 1c, R$ 236,850,771.92 for the port of São Francisco do Sul (route 1d) and R$ 243,444,980.17 on route 1e. For vehicle compositions with 9 axles, the results showed that the total financial cost was R$ 124,046,527.18 for the port of Santos (route 1a), R$ 499,949,544.39 for the port of Paranaguá (route 1b) and R$ 516,026,897.02 for route 1c, R$ 206,016,254.15 for the port of São Francisco do Sul (route 1d) and R$ 212,439,012.98 for route 1e.

In the comparison of the results between vehicle compositions, with the option of the vehicle composition of 9 axles, the reduction in financial costs was in the order of R$ 17,277,691.87 (13.92%) for the port of Santos (route 1a), R$ 74,477,428.17 (14.89%) for the port of Paranaguá (route 1b) and R$ 74,873,584.70 (14.50%) to route 1c, R$ 30,834,517.78 (14.96%) to port of São Francisco do Sul (route 1d) and R$ 31,005,967.19 (14.59%) to route 1e. In the sequence, the freight-return percentages indicated by Soliani, Innocentini and Carmo were applied (2019), considering 61.5% for the trips that returned from the port of Santos, of 76.4%. For the port of São Francisco do Sul, the percentage adopted was 68.95%, which represents the average between the first two ports. The average freight value took into account the results obtained for the 7 and 9-axle compositions. The results are shown in Table 8.

Table 8: Total financial cost for 7 and 9-axle compositions in soybean and fertilizer operations in 2020

Routes	Product	Average volume (ton)	Average Freight (ton)		Financial Cost	
			7 axles	9 axles	7 axles	9 axles
Route 1a	Soy bean	757,724.29	R$ 185.84	R$ 163.12	R$ 140,815,482.05	R$ 123,599,986.18
	Fertilizer	2,737.50	R$ 185.84	R$ 163.12	R$ 312,873.26	R$ 274,622.72
Route 1b	Soy bean	2,108.287.03	R$ 174.00	R$ 151.44	R$ 366,841,941.48	R$ 319,278,986.31
	Fertilizer	1,193,017.43	R$ 174.00	R$ 151.44	R$ 158,594,963.75	R$ 138,032,306.38
Route 1c	Soy bean	2,108.287.03	R$ 178.99	R$ 156.31	R$ 377,362,293.71	R$ 329,546,344.10
	Fertilizer	1,193,017.43	R$ 178.99	R$ 156.31	R$ 163,143,175.64	R$ 142,471,142.43
Route 1d	Soy bean	1,305.385.88	R$ 179.59	R$ 156.21	R$ 234,434,248.39	R$ 203,914,326.75
	Fertilizer	13,455.79	R$ 179.59	R$ 156.21	R$ 1,666,192.97	R$ 1,449,278.94
Route 1e	Soy bean	1,305,385.88	R$ 184.59	R$ 161.08	R$ 240,961,177.74	R$ 210,271,555.94
	Fertilizer	13,455.79	R$ 184.59	R$ 161.08	R$ 1,712,581.78	R$ 1,494,461.63

Source: Adapted from MDIC (2021) and research (2021).

The results in Table 8 showed that for the composition of vehicles with 7 axles, the total financial cost was R$ 141,128,355.31 for the port of Santos (route 1a), R$ 525,436,905.23 for the port of Paranaguá (route 1b) and R$ 540,505,469.35 for route 1c, R$ 236,100,441.37 for the port of São Francisco do Sul (route 1d) and R$ 242,673,759.52 for route 1e. In the comparative analysis between the tables 7 and 8 which consider the current scenario and the ideal scenario for the vehicles compositions of 7 axles, the results indicate a cost reduction of R$ 195,863.75 (0.14%) for the port of Santos (route 1a), R$ 48,990,067.33 (9.32%) for the port of Paranaguá (route 1b) and R$ 50,395,012.37 (9.32%) to route 1c, R$ 750,330.56 (0.32%) to port of São Francisco do Sul (route 1d) and R$ 771,220.65 (0.32%) to route 1e. Based on the results of Table 8, it is possible to conclude that route 1c is the one that presented the greatest potential for cost reduction, indicating that it is the best option for the adoption of the practice of collaborative logistics, in the analysis of the vehicle composition with 7

axles.

Subsequently, the results for the composition of the vehicle with 9 axles showed that the total financial cost was R$ 123,874,608.90 for the port of Santos (route 1a), R$ 457,311,292.69 for the port of Paranaguá (route 1b) and R$ 472,017,486.53 for route 1c, R$ 205,363,605.69 for the port of São Francisco do Sul (route 1d) and R$ 211,766,017.57 for route 1e. In the comparative analysis between the tables 7 and 8 for the vehicles compositions of 9 axles, the results indicate a cost reduction of R$ 171,918.28 (0.14%) for the port of Santos (route 1a), R$ 42,638,251.71 (9.32%) for the port of Paranaguá (route 1b) and R$ 44,009,410.49 (9.32%) to route 1c, R$ 652,648.46 (0.32%) to port of São Francisco do Sul (route 1d) and R$ 672,995.41 (0.32%) to route 1e. Based on the results of Table 8, it is possible to conclude that route 1c is the one that presented the greatest potential for cost reduction, indicating that it is the best option for the adoption of the practice of collaborative logistics both for the composition of 7 axles and for the composition with 9 axles.

For aggregate analysis, the total financial costs obtained in the current scenario and ideal scenario considered the adoption of the collaborative logistics practice were raised. The analysis took into account two options, the first being the ports of Santos (1a), Paranaguá (route 1b) and São Francisco do Sul (route 1d) and the second being the ports of Santos (route 1a), Paranaguá (route 1c) and São Francisco do Sul (route 1e). The results are shown in Table 9.

Table 9: Analysis of the total financial cost between the current scenario and the ideal scenario for 7-axle and 9-axle compositions in soybean and fertilizer operations in 2020

Aggregate of Routes	Vehicle composition	Current Scenario	Ideal Scenario	Cost Difference
Routes 1a, 1b e 1d	7-axle	R$ 952,601,963.54	R$ 902,665,701.90	R$ 49,936,261.64
Routes 1a, 1c e 1e		R$ 975,669,680.94	R$ 924,307,584.17	R$ 51,362,096.77
Routes 1a, 1b e 1d	9-axle	R$ 830,012,325.72	R$ 786,549,507.28	R$ 43,462,818.45
Routes 1a, 1c e 1e		R$ 852,512,437.18	R$ 807,658,113.00	R$ 44,854,324.19

Source: Search data.

In the aggregate of routes, the results obtained for compositions with 7 axles indicate that the lowest financial cost is obtained in the aggregate of Santos (1a), Paranaguá (route 1c) and São Francisco do Sul (route 1d) routes. Another important factor is that the reduction in the total financial cost between the current scenario and the ideal scenario of this same aggregate route was R$ 49,936,261.64, representing a 5.24% reduction, which shows that the practice of collaborative logistics can contribute to the reduction of transportation costs.

As for the trains with 9 axes, the results in Table 9 indicate that the lowest financial cost is also obtained in the aggregate of the Santos (route 1a), Paranaguá (route 1b) and São Francisco do Sul (route 1d) routes. Where as in the reduction in the total financial cost between the current scenario and the ideal scenario of this same aggregate route was R$ 43,462,818.45, representing a reduction of 5.24% as well. Finally, when comparing the results of able 9, it is possible to observe that with the option of the vehicle composition of 9 axles for the aggregate of routes Santos (route 1a), Paranaguá (route 1b) and São Francisco do Sul (route 1d) was the one that obtained the lowest total financial cost between the two vehicle compositions analyzed, totaling R$ 786,549,507.28, thus consolidating the practice of collaborative logistics as an important alternative for minimizing transportation costs according to Tacla (2003) already indicated.

4. Conclusion

Due to the objective of this Article, which was to evaluate the impact of the average cost of transportation and the

adoption of the collaborative logistics practice as an alternative for reducing transportation costs, it can be concluded that the proposed objective was achieved.

The results indicate that the vehicle compositions with 9 axles were those with the lowest cost per ton transported for all the routes analyzed. By analyzing the impact of the cost of transportation on the price of soya bean, it was possible to observe that the transport represents about 6.33% in the price of soya for the vehicle composition of 9 axles originating in Maracaju and to the port of Paranaguá (route 1b), about 6.17% for composition of 9-axle vehicle from Ponta Porã to the port of Paranaguá (route 2c) and about 7.09% to the 9-axle vehicle composition and destination to port of Paranaguá (route 3b).

It can also be observed that, in the comparison between the current scenario and the ideal scenario that considers the adoption of the practice of collaborative logistics with the aggregate of routes Santos (route 1a), Paranaguá (route 1b) and São Francisco do Sul (route 1d) the reduction in the total financial cost for 7-axle compositions was R$ 49,936,261.64, representing a reduction of 5.24% and for 9-axle compositions the reduction in the total financial cost between the current scenario and the ideal scenario of the same aggregate route was R$ 43,462,818.45, it also represents a reduction of 5.24%.

Finally, the results of this research consolidate the practice of collaborative logistics as an important alternative for minimizing transportation costs. It is suggested for future studies to expand the sample of cities studied. In addition, a new port terminal has emerged as a channel for the flow of soybeans and imports of fertilizers, the Porto Murtinho terminal and the development of a study contemplating this channel could further contribute to consolidating collaborative logistics in the state of MS. With these lines of studies, it will be possible to compare the results obtained with other regions that face the same difficulties related to their geographical position in relation to export terminals.

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