How to improve the logistics issues during crop soybean in Mato Grosso state Brazil?

Rodrigo Carlo Toloi[1,2], João Gilberto Mendes dos Reis[1], Oduvaldo Vendrametto[1], Sivanilza Teixeira Machado[1,3], Enio Fernandes Rodrigues[3]

[1] Paulista University, Postgraduate Program of Engineering Production, São Paulo, Brazil
[2] Federal Institute of Mato Grosso, Rondonopolis, Brazil, [3] Federal Institute of São Paulo, Department of Management and Business, Suzano, Brazil
{toloirodrigo@gmail.com }

Abstract. The soybean transport costs represent the biggest part of the costs that involve the production and commodity operations. This study analyzed the main soybean flow routes for the foreign Market and proposed alternative routes that contribute to reduce costs involving the transport of grains produced by the macro-region of the Mato Grosso state. For this purpose, it was used mathematical modeling with application of linear programming through Excel Solver supplement program, considering six origins (macro-regions of Mato Grosso state) and eight main destination ports. The results present a minimization of the transport costs in US$ 6.59 million, such as the reduction of the amount of routes used from 34 to 13 routes. It was concluded that the reduction of the transport costs was possible due to the inclusion of routes containing stretches of waterways, with the flow through the Port of Manaus/AM and Port of São Luiz/MA.

Keywords: Logistics, Routes, Costs Reduction, Linear Programming.

1 Introduction

More than sixty percent of the Brazilian soybean production is transported by truck from the production areas to the transformation areas or terminals/ports of exportation [1]. The cost of transport, source of many discussions of logistics experts, represent around 60% of the logistics costs [1], [2], becoming a strategic activity for any production chain. For example, in the case of soybeans, the transport costs represent the biggest part of the costs involving the production and the commodity operations [2]. Proposed solutions to reduce costs and offer alternative transport routes for the carriers, especially during the flow of the grains are current challenges faced by the experts [2].

Transportation alternatives are difficult to be adopted by companies during the flow, due to the complexity of variables that involve the infrastructure of the Brazilian grain transport, such as the imbalance in the transport matrix, the ports capacity, loading equipment's, loading capacity, the fleet of trucks, the carriages informalities on the contracts, freight, roads, modality or multimodality, among others [3], [4]. The poor conditions of roads, maintenance and improper use of truck, overloading and inefficiency in grain transshipment are the main causes of losses occurring during transport operations [1], impacting in additional costs to the production chain.

The complexity of the Brazilian logistics infrastructure reach the country, but with bigger impact in the states of North, Northeast and Midwest. Mato Grosso is the main producer of soybeans in Brazil, located in the Midwest and urges for a logistic strategy that contributes to the competitiveness of Brazilian soybeans on the international Market. The logistic infrastructure of Mato Grosso, as well as Brazil in general, did not follow the growth of production becoming a major challenge for producers and to the sector [2].

Soybean production in Mato Grosso is divided into seven macro-regions: Northwest, Northeast, North, East-North, West, South-Central, and Southeast. The East-North macro-region is the most important in soybean production with 35.6%, followed by Southeast macro-region (21.8%), Northeast (14.3%), West (12.8%), South-Central (7.3%), Northwest (6.4%) and North (1.9%) [5].

This study aims to analyses the main soybean flow routes for the external market and based on minimizing transport costs, propose alternative routes for the grain produced by the macro-regions of the Mato Grosso state.

2 Materials and Methods

The study was developed based on the data of Mato Grosso, Brazil. This study considered six macro-regions as origin (i): Northwest, Northeast, Middle-North, West, South-Central, and Southeast. The North macro-region was dismissed of the study, due to the lake of soybean export volume. Furthermore were considered eight flow ports destinations (j): Manaus (Amazonas); São Luiz (Maranhão); Santarém (Pará); Vitória (Espírito Santo); Santos (São Paulo); Paranaguá (Paraná); Rio Grande do Sul (Rio Grande do Sul) and São Francisco do Sul (Santa Catarine) [6].

2.1 Survey and preparation of data for simulation and network design

The variable **soybean volume** (tons): For the survey of the exported soybean volume data by the municipalities that compose the macro-regions of Mato Grosso, it was used the base of the Analysis System of Foreign Trade Information AliceWeb, with the search parameters: 1) Federative Unit (Mato Grosso); 2)Municipalities (divided by macro-regions); 03) Mercosur Common Nomenclature (SH 4 digits position: 1201 - Soybean even grounded); 4) Filter Detailing (Port of flow); and 5) Year period (2013) [6].
The variable cost of transport (real/ton/kilometers): The transport cost was obtained in the road market, by means of quantitation of freight of the road carriers having as origin the macro-regions and the destination the main ports present in Table 1. For the composition of transport cost for the Manaus Port, AM, São Luiz, MA and Santarém, PA, the waterway freight was added in the road cost transport. Thus, the total cost of transport for the load transportation of the Manaus Port, take into account the road cost to the Porto Velho Terminal, RO, adding the waterway cost from Porto Velho, RO to Manaus Port. The same procedure was adopted for the Port of São Luiz, which had the road freight estimated up to the Colinas do Tocantins Terminal, TO, and then the waterway freight up to the Port; as well as to the loads for the Santarém Port it was considered the freight up to the Miritituba Terminal, PA, and later, waterway to the port.
The variable distance (km): The determination of the distance of macro-regions to the ports was obtained by the Interlog simulator website, adopting the origin as the Mato Grosso macro-regions and the destination, the main flow ports. The destination ports (j) that were simulated were: MA = Manaus; SL = São Luiz; ST = Santarém; VT = Vitória; SN = Santos; PR = Paranaguá; RS = Rio Grande do Sul and SF = São Francisco do Sul, Table 1

Table 1: Distance between the macro-regions and the main flow ports, in kilometers

	Portos de escoamento de soja (j = destino)							
Macro-region (i=origin)	MA	SL	ST	VT	SN	PR	RS	SF
Northwest	1937	2510	1683	2294	2289	2487	2805	2563
Northeast	3100	1802	1758	2194	1758	1962	2605	2123
Middle-North	2303	2382	1578	2513	1944	2144	2460	2282
West	1846	2742	1915	2565	2066	2264	2582	2334
South-Central	2167	2629	1845	2262	1795	1993	2311	2031
Southeast	2640	2509	2102	1888	1353	1566	1992	1693

*Sum of the road distance up to Porto Velho Terminal, RO and the waterway distance up to the Manaus Port; +Sum of the road distance up to Colinas do Tocantins Terminal and the waterway distance up to São Luiz Port; # Sum of the road distance up to Miritituba Terminal, PA and the waterway distance up to Santarém Port. Source: [7]

2.2 Modeling of the transport problem

To direct the exportation volume of the macro-regions of the Mato Grosso State in order to minimize transportation costs, it was used the linear programming model of minimum cost, through the Excel Solver tool program. For this purpose, the transportation problem was modeled as follows:

1. Development of the objective function based on the minimization of transportation cost, Eq. 1.

$$Minimize = \sum_{i=1}^{6}\sum_{j=1}^{8} Vij \ x \ Cij \ x \ Dij \quad \text{(Eq. 1)}$$

Where,
i = origin (1, 2, ..., 6); j = destination (1, 2, ...8,); V = export volume to be transported (ton); C = cost in Reais per ton and traveled kilometers (R$/ton/km); D = distance between origin and destination (km)

2. Definition of restrictions seeking to meet the needs of the export Market, as well as to observe the export capacity of each macro-region: a) the export volume of the macro-regions must be equal (=) the demand of destination ports (Qi), to ensure compliance to all (Eq. 2); b) the volume of exportation of each macro-region must be less or equal (≤) to the exportation capacity of the macro-region (Capj), to not affect the amount that is destined to the internal market (Eq. 3); and c) the volume of exportation must be greater or equal (≥) to 0, to ensure the non negativity in the model (Eq. 4).

$$\sum_{j=1}^{8} Vij = Qi \ (i = 1,2,\ldots,6) \quad \text{(Eq. 2)}$$

$$\sum_{i=1}^{6} Vij \leq Capj \ (j = 1,2,\ldots,8) \quad \text{(Eq. 3)}$$

$$Vij \geq 0 \quad \text{(Eq. 4)}$$

3. Data processing by the Solver tool, Excel. After defining the objective function and the constraints, the data were parameterized in the Solver tool, Excel, to obtain the minimization of the transport costs, as proposed.

2.3 Social networking using the software UCINET

Based on the results presented by the Solver system, Excel, a network of relationships was designed between the macro-regions and the main ports, seeking to present the network configuration before and after the redirection of soybean production for the main flow ports. The actors (origin i and destiny j), were taken into consideration to the built of the network for the current scenario and for the simulation made by the Solver as well.
The attributes considered were the transportation values of soybean for each macro-region for the considered ports (j) such as the current situation as for the simulation carried out after the application of Solver. The ties and relationships are shown in Image 1 and 2 that represent the connections between the production areas (I) and the ports (j), to where the production is destined. Use the same setting for the figure caption, but positioned below the figure. Place Tables and Figures in text as close to the reference as possible.

3 Results and Discussion

The Gross Domestic Product – GDP of Mato Grosso agribusiness in 2013 represented 4.8% of Brazil's GDP, being an important productive area for Brazil as a grain supplier to both the domestic and export market [8]. Nowadays, the macro-regions with higher participation in the Brazilian soybean exportation are Middle-North (38.9%), West (17.8%), Southeast (14.4%), Northeast (13.8%), South-Central (13.2%) and Northwest (1.6%) [6]. The flow of the soybean volume exported before the simulation of the proposed transportation problem, points that the Santos Port with 53.6%, follow by Manaus (10.7%), Vitória (10.3%), Paranaguá (7.6%), Santarém (6.8%), São Luiz (4.8%), São Francisco do Sul (4.5%) e Rio Grande do Sul (1.3%) [5]. The results obtained from Solver after the redirection of export volumes of macro-regions, minimized the estimated initial transport cost from US$ 64.342 million to US$57.746 million, Figures 1 and 2.

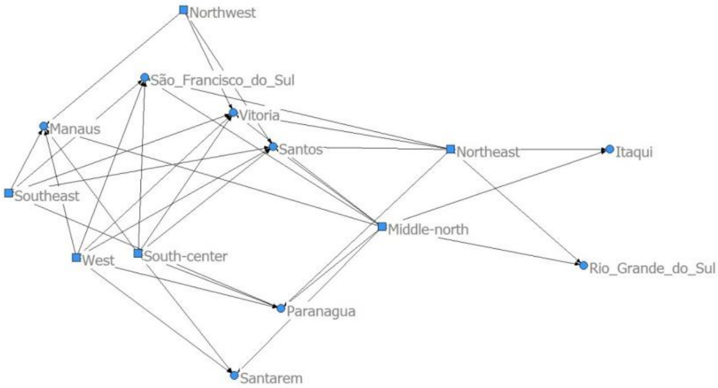

Figure 1: Relationship network between the macro-regions and the main soybean flow ports, current scenario with 34 routes, prior to the simulation.

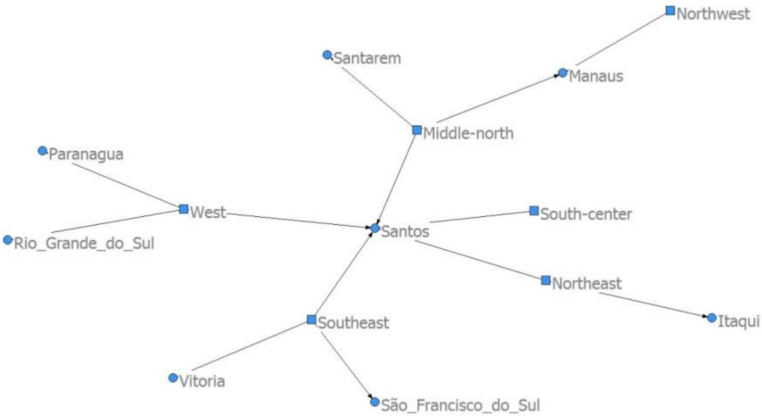

Figure 2: Relationship network between the macro-regions and the main soybean flow ports, alternative scenario with 13 routes, after the simulation.

Observing the before and after scenarios the simulation soybean volume redirection, some comments can be highlighted: Northwest: 100% concentrated in the port of Manaus, AM; Northeast: 69% concentrated in the port of São Luiz, MA and 31% in Santos, SP; Middle-North: 62% concentrated in the Port of Santos, SP; 22% to the port of Manaus, AM and 16% to the port of Santarém, PA; West: 53% concentrated in the port of Santos, SP; 39% in the port of Paranaguá, PR and 8% to the port of Rio Grande do Sul, RS; South-Central: 100% concentrated in the port of Santos, SP; Southeast: 51% concentrated to the port of Vitória, ES, 26% to the Port of Santos, SP and 23% to the Port of São Francisco do Sul/SC.

Besides, it was observed that after the simulation the amount of routes used by the producers and the soybean commercialization companies went from 34 to 13. Alternative routes of grains flow have been suggested by [2], based on investment in transport infrastructure by the Growth Acceleration Plan for the state of Mato Grosso.

3.1 Alternative routes for the macro-regions

Northwest: A transport route was indicated to reduce of soybean flow transportation cost produced on the Mato Grosso Northwest macro-region which was the use of the Manaus Port/AM (**Route 1, average 1.937 km: Northwest/MT-Manaus Port/AM**). For the producer use the Route 1 it should follow by the BR 158 highway up to the city of Barra do Garças/MT, interconnecting with the BR 070 up to the city of Cáceres/MT; from this point, it must follow by the BR 174 up to the city of Vilhena/RO and later on BR

364 up to the city of Porto Velho/RO. Arriving in Porto Velho, the soybean should take the Rio Madeira waterway up to the destiny Manaus Port/AM.

Northeast: For the minimization of the transport costs soybean for the macro-region Northeast, two routes were considered: **Route 2, average 1.802 km** (Northeast/MT- Port of São Luiz/MA) and **Route 3, average 1.758km** (Northeast/MT- Porto of Santos/SP). Route 2 follow through MT 170 up to the road junction of BR 364, next to the storehouses of the Amaggi Group and Bunge Aliments following until MT 246. In MT 246 highway following until it reachs the capital Cuiabá and from this point follow through BR 070 up to the city of Barra do Garça/MT, where will access the BR 158 highway, and must follow up to the city of Redenção/PA. In Redenção, it must follow by the BR 150 up to the city of Marabá/PA and then, by the interconnecting road BR 222 up to the Port of São Luiz/MA. Along the route, the carrier will face simple lane highways, often without roadside, with vertical and horizontal signaling very precarious, without mention the 140 kilometers of the BR158 that still are dirt flooring. Route 3, must follow by the MT 170 up to the road junction of BR364, next to the storehouses of the Amaggi Group and Bunge Aliment following up to MT 246, in this highway it must follow until it reachs the capital Cuiabá, from this point follow by the BR 365 up to Uberlândia/MG, from this last point follow up to the city of São Paulo by the BR 050 and later SP 330 and SP 150 until it reach the Port of Santos/SP.

Middle-North: To flow the production of the macro-region Middle-North the simulation suggested that the harvest were distributed to three distinct routes: **Route 4, average 2.303 kilometers** (Middle-North/MT-Port of Manaus/AM)**, Route 5, average 1.578 kilometers** (Middle-North/MT-Port of Santarém/PA) and **Route 6, average 1.944 kilometers** (Middle-North/MT- Port of Santos/SP). The route 4 must follow through BR 163 up to the city of Nova Mutum/MT with access to MT 235 following up to the city of Porto Velho/RO. From Porto Velho following until Manaus/AM by the Rio Madeira waterway. Regarding the route 5, the production must follow by the BR 163 highway, in the North direction until it reaches Santarém/PA. Route 6 must follow by the BR 163 until the road junction with the city of Cuiabá/MT, from this point following by the BR 365 until Uberlândia/MG and, later, follow up to the city of São Paulo by the BR 050. Arriving in São Paulo should it follow by SP 330 and SP 150 until it reach the Port of Santos/ SP. The results referred to the route 6 agreed with the study of [2].

West: The soybean produced in the West region of Mato Grosso, according to the simulation can be redirect to three distinct routes: **Route 7, average 2.582 kilometers** (West/MT-Port of Rio Grande/RS), **Route 8, average 2.264 kilometers** (West/MT-Port of Paranaguá/PR) and **Route 9, average 2.066 kilometers** (West/MT-Port of Santos/SP). For the use of the route 7, it must follow by the BR 364 up to the city of Comodoro/MT) access the BR 174 following the city of Cáceres/MT and later access the BR 070 up to Serra de São Vicente. From this point enter on the BR 163 cross the state of Mato Grosso, Mato Grosso do Sul, Paraná, Santa Catarina until it reaches the city of Santa Maria/RS. From Santa Maria/RS, enter in the BR 392 and follow up to the Port of Rio Grande/RS. The route 8 suggests the harvest flows following by the BR 364 up to the city of Comodoro/Mt access the BR 174 following the city of Cáceres/MT and later access the BR 070 until the Serra de São Vicente, from this point enter on the BR 163 cross the state of Mato Grosso, Mato Grosso do Sul and follow up to the city of Cascavél/PR, where must access the BR 277 and follow up to the Port of Paranaguá/PR. The route 9 indicate the use of the BR 364 up to the city of Comodoro/MT and access the BR 174 following up to the city of Cáceres/MT and later access the BR 070 up to the Serra de São Vicente. From this point enter on the BR 163 up to the city of Rondonópolis/MT, and it must access the BR364 and follow up to São Simão/GO. In São Simão, it must access the BR 365 following up to Uberlândia/MG, later enter on the BR 050, and follow until the meeting point with the SP 330. After the city of São Paulo/SP access the SP 150 until it reaches the Port of Santos/SP. Considering the study of [2], the route 9 is the one with lower transport cost, after the investments in BR 163.

South-Central: For the flow production of the South-Central macro-region only one route was indicated, for the reduction of the transport costs: **Route 10, average 1.795 kilometers** (South-Central/MT-Port of Santos/SP). The use of the route 10 indicates follow by the BR 163 up to the road junction with the city of Cuiabá/MT, from this point follow by BR 364 until São Simão/GO, where it must follow by the BR 365 until Uberlândia/MG. In Uberlândia must follow up to the city of São Paulo by Br 050 and, later, SP 330 and SP 150 until it reaches the Port of Santos/SP.

Southeast: For harvest flow of the Southeast macro-region the simulation recommends the use of three alternative routes: **Route 11, average 1.888 kilometers** (Southeast/MT-Vitória/ES), **Route 12, average 1.353 kilometers** (Southeast/MT-Santos/SP) and **Route 13, average 1.693 kilometers** (Southeast/MT-São Francisco do Sul/SC). The route 11 will follow by the BR 070 until it reaches Rondonópolis/MT and access the BR 364 that will continue until the road junction with the BR 262, next to the city of

Frutal/MG. In this way, will cross the whole state of Minas Gerais until it reaches the Port of Vitória/ES. The route 12 follow through MT 130 until the road junction in Rondonópolis/MT in the BR 163. From this point following by the BR 364 until São Simão/GO and by the BR 365 until Uberlândia /MG, where will follow until the city of São Paulo by the BR 050. In São Paulo will follow by the SP 330 and SP 150 until it reaches the Port of Santos/SP. Using the route 13 it must follow by the MT 130 until the road junction in Rondonópolis/MT in the BR 163, remained in this highway until cross the whole state of Mato Grosso do Sul and it reaches in the city of Curitiba/PR and the BR 101 until the road junction with the BR 280 and follow up to the Port of São Francisco do Sul.

4 Conclusion

The precarious Brazilian infrastructure still don't allows a better distribution of the grains flow volume between modals hydro, road and railroader, forcing the companies to seek alternative routes to minimize the road freight, the main modal used in the soybean flow. It can be possible to conclude that the inclusion of routes containing waterways stretches, with the flow through the Port of Manuas/AM and Port of São Luiz/MA made possible the reduction of the transport costs of the macro-regions Northwest, Middle-North, and Northeast. The Port of Santarém/PA had a contribution to the reduction on the costs in the Middle-North macro-region. The Port of Santos/SP despite being at an average distance of 1.800 kilometers of the production areas still is the most important for the transportation of soybean from Mato Grosso, helping to reduce the costs of the macro-regions Middle-North, West, South-Central and Southeast.

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