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ANALYSIS ON THE INTEGRATION OF SOYBEAN FLOW FROM SORRISO (MT) TO THE PORT OF SANTOS WITH A MODALOHR MULTIMODAL

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“Intelligence is the ability to adapt to change”

Stephen Howking

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Abstract

This study has the intention to analyze the Brazilian soybean flow from the main producing areas in the state Mato Grosso to the port of Santos. Brazil is currently the second largest producer of soybean in the world and, therefore, promoting adequate handling of the product is essential for leveraging its competitiveness worldwide. This scenario, coupled with the precariousness of the current infrastructure give way for writing this material and proposing new alternatives for the country. Therefore, an analysis was conducted by implementing a new transshipment terminal in the region of Rondonópolis (Mato Grosso), next to the producing farms, in order to promote multimodality in a very efficient manner. Such terminal is projected to have the Modalohr system, a technology that is currently only available in Europe. In order to better understand the suitability and operation of the proposed system, it was made a simulation of several scenarios of operation through a Poisson distribution to represent the arrival of the trucks and forecast line formations. Additionally, a study about the implementation of ITS tools was conducted through the analysis of an Intelligent Transport Maturity Model matrix developed by IBM. Overall, the method proposed had interesting results that support the price decrease in the soybean freight, besides showing significant benefits regarding the environment.

Key words: soybean; multimodal; transport; ITS.

Foreword

This project is intended to be an effort of bringing new technologies to Brazil and is part of a study developed with a multiple-background academic view taking into consideration the Brazilian state of Mato Grosso as the analyzed region.

This thesis has been produced by the leading author and supervised by professors Roberto Maja and Cláudio Marte. This work is the one submitted as *Tesina di Laurea Magistrale at the Politecnico di Milano* and as *Trabalho de Formatura para Engenharia Civil* at the *Escola Politécnica da Universidade de São Paulo*.

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1. Introduction

The Brazilian railway system has approximately 29,706 km, with the first meters of this extensive network, originated in the “Estrada de Ferro Mauá” in 1854. The whole project aims to connect several states, focusing on regions close to the ports in Parati, Angra dos Reis and Santos.

In 1996, there was the privatization of many railways, which accounted for 28,840 kilometers no longer being owned by the government. In the last 10 years R$3.1 billion was invested in the sector, providing the leverage in transport production by 80% and a continuous reduction of the incidents ratio (currently 50% less compared to past Figures). Despite all these improvements, it is still very evident the infrastructure problems in the Brazilian railway system which preclude the raise on productivity levels in order to be comparable to developed regions such as United States and many European countries. These state-of-the-art infrastructures have an average speed of 80 km/h and advanced communication systems allowing constant monitoring of the routes. Whereas in Brazil, the railway has a structure from the 19th and early 20th century, with different gauges and layouts 30% longer than roadways, generating an average speed of 23km/h. Besides the considerably lower speed, the communication system is outdated and not integrated as a unified system across the country.

Continuous improvement in rail transport and logistics in strategic corridors would have a direct influence on the Brazilian trade balance, as these railways carry annually 390 million tons: iron ore and coal accounting for 66%; soybean for 6%, steel products, 4%, agricultural products other than soybean, 1%, and other products, 23%. Out of the total, 78% is originated by imports / exports handling and only 22% refer to the internal market. In this scenario, the proper use of the railway is compulsory to aggregate value to Brazilian products and making it more competitive worldwide.

The Brazilian cargo transport registered only 20% share of the rail transport compared to 60% made by roads, resulting on loss of productive chain due to the current low efficient system.

An average wagon is capable of handling up to three time the cargo of trucks and is also able to operate on a much higher scale, making prices up to six times cheaper on tons / 1,000 kilometers. This reduction is also sensible to greenhouse gases emissions such as carbon dioxide, generating environmental benefits.

Therefore, in order to improve the current system, this study proposes a new technology, currently only available in Europe, to be installed in the tropical country. The referred proposal was the Modalohr system. The idea was the implementation of a transshipment terminal in the municipality of Rondonópolis (Mato Grosso) to add capacity of the already existing terminal that uses the tipping technique.

To conduct this study, several tools were used to better forecast the future operation of the proposed terminal such as the Poisson distribution to analyze the arrival of the trucks in the terminal in order to optimize its efficiency. Moreover, to guarantee state-of-the-art technologies to be available, it was used an Intelligent Transport Maturity Model matrix developed by IBM to cover all aspects of ITS.

Thereby, after detailed analysis made possible due to the data provided by the company that operates the existing terminal (ALL), it was possible to verify that new technologies are critical for the Brazilian competitiveness worldwide. Another very important aspect to mention is the lack of infrastructure projects that the country currently faces and its negative effect in the soybean market.

After the study, it was also possible to understand that the soybean producers are the most affected by high freight prices, once the final price charged by then is directly influenced by the handling cost. Moreover, another analyzed feature was the need of ITS technologies in the new terminal in order to promote all the benefits discussed in the material. Thus, with the correct installing of such items, the proposed terminal can provide a more efficient system.

Furthermore, a very important analysis was made regarding CO^2 emissions. The result showed that it is fundamental to invest in cleaner transport methods, mainly the ones with such a substantial impact due to the high volume of cargo handled.

In short, this material was able to validate the aforementioned intention that the

Modalohr technology would cause a positive impact in the Brazilian infrastructure regarding the soybean market. Therefore, it is very important to mention that further studies toward the infrastructure as whole are sorely recommended in order to promote development and integrate the vast territory in Brazil.

2. Objective

The purpose of this research is to analyze the implementation of a multimodal terminal to outflow soybean from the state of Mato Grosso (main production region) to the port of Santos (main hub for exports).

The idea is to show the impact of the referred terminal on reducing the commodity price in order to make it more competitive in the global market.

3. Context

3.1. General overview

The Brazilian soybean production in the 2013 / 2014 crop was estimated by approximately 86 million tons[*], 30.9% of which was originated in the state of Mato Grosso (largest producer). The importance of the state can also be seen by noting that this crop generated around 42 million tons of soybean in the Center-West region and Mato Grosso had a share of 63.5% of this total. The Figure 1 presents the historical data of soybean production through 2007 – 2012 (Agrianual, 2015).

[*] Estimate by Informa Economics FNP

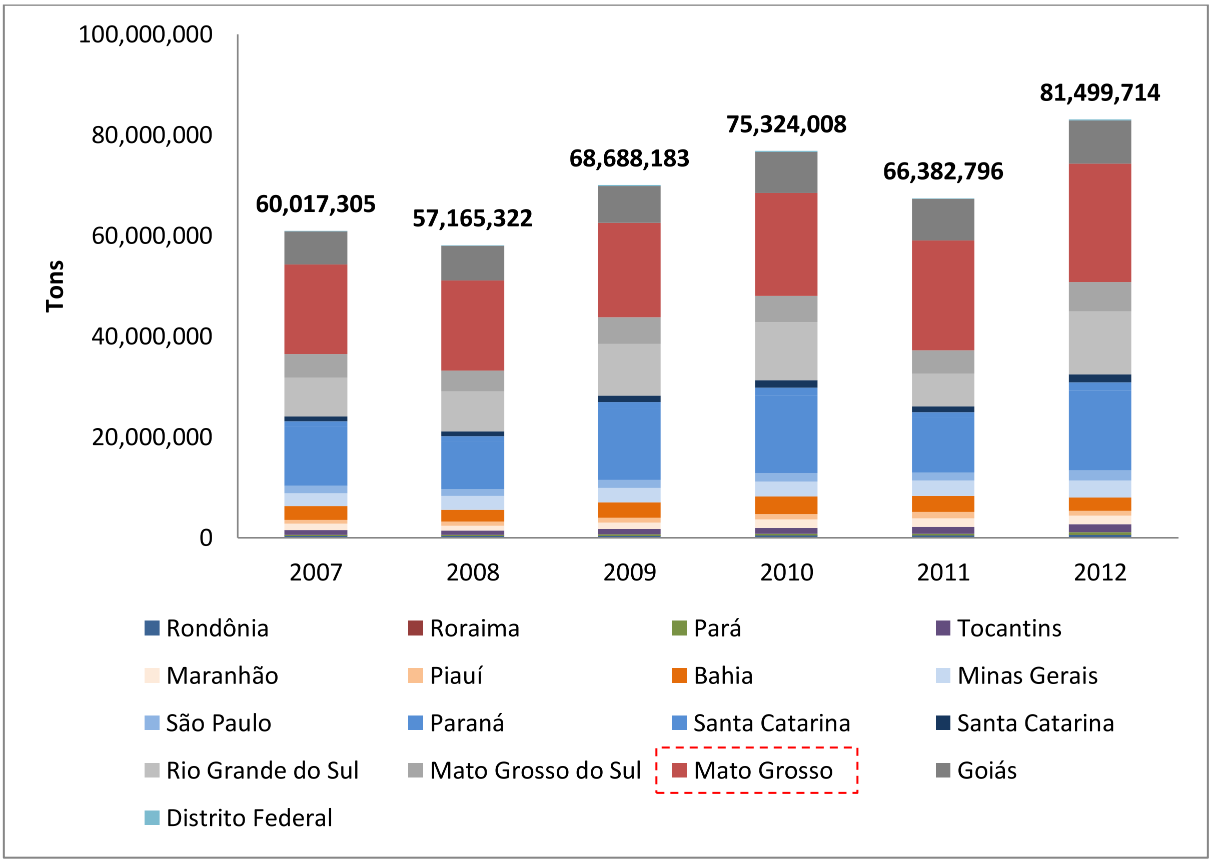

Figure 1. Brazilian soybean production by state
Source: Agrianual (2015)

In this context, it can be noticed that the state of Mato Grosso has one of the highest productiveness ratio of soybean among its peers states with an average of 3,120 Kg/ha*, being placed as 5th in the same crop of 2014 / 2015, according to estimates provided by the Agrianual, 2015 (Figure 2).

* As of August / 2014

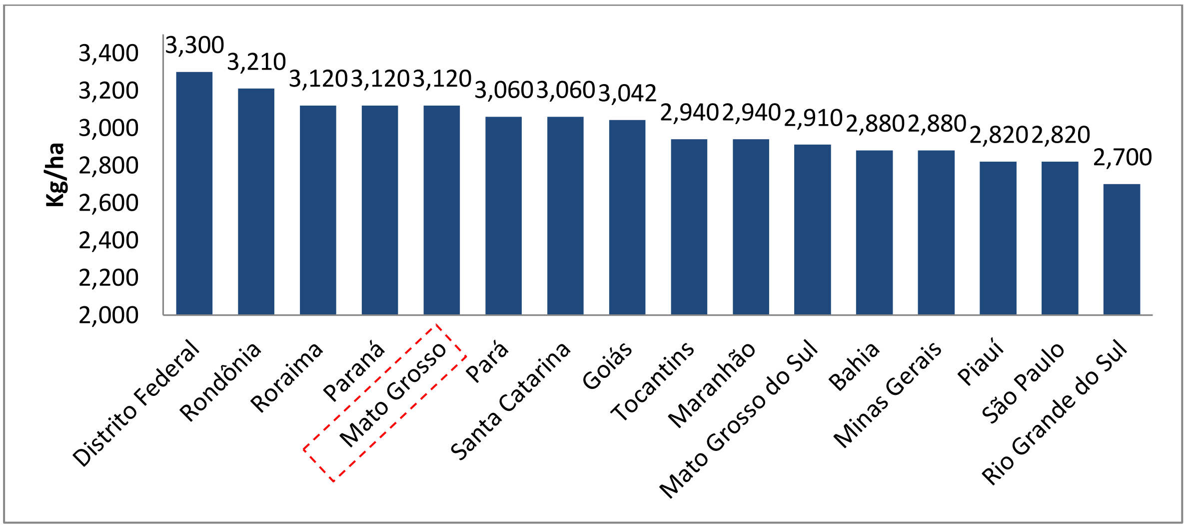

Figure 2. Productivity of the Brazilian states

Source: Agrianual (2015)

Several factors allowed the shift of soybean production to the Center-West from the Southern regions. Among others, it should be featured the low land value in the area compared to the South states between 1960 and 1980; the existence of tax incentives available for opening new agricultural production areas, acquisition of machinery and construction of silos and warehouses; favorable topography for automation; and improvements in the regional production transport system – establishment of new export corridors through road, rail and waterways (EMBRAPA, 2004).

However, despite the many benefits provided to the soybean production in the Brazilian region, the road transportation has been suffering for some time due to the lack of public investments (OJIMA, 2006).

The roadway transportation is the most used system for the soybean flow – especially for the sections of highways BR-163 and BR-364 – to the ports located in the Center-South complex (CAIXETA FILHO, 2010).

With the fiscal crisis in the 1980s, the participation of public investments in the road network was affected, resulting in less competitive advantage among international players for the Center-West soybean (CORREA, 2008).

The weakness in the flow system of agricultural products relies on precarious conditions of the roadways, low efficiency and lack of capacity of railways, clutter and excessive bureaucracy at the ports. These facts lead to increase in truck queues at major ports, long waiting for ships maneuver (berthing and unberthing) and therefore, non-fulfillment of the shipping delivery schedules. Thus, the costs are leveraged and international competitiveness of the Brazilian products is inevitably jeopardized (FLEURY, 2008).

The current railway and waterway infrastructure is insufficient for the grain transportation in Brazil, which motivates the use of roadways for the soybean flow, even for long distances. This scenario shows lack of efficiency, once a train can carry up to 150 times more than a truck and a convoy of barges can reach up to 600 times a truck capacity in a waterway as the one in Rio Madeira (OJIMA, 2006).

The need of reduction on logistic costs for the soybean production is due to the fact that it is produced with low aggregated value and, thus, needs a transportation solution less expensive. It is also important to emphasize that the handling cost is usually paid by the farmers (CAIXETA FILHO, 2010).

The Center-West corridor, with the notable participation of highways BR-163 and BR-364, the railways ALL Malha Norte (former Ferronorte), ALL Malha Oeste (former Novoeste) and ALL Malha Paulista (former Ferroban), have the best infrastructure, in the country, for the soybean flow from Mato Grosso, as well as the best port infrastructure, such as the port of Santos (São Paulo) and Paranaguá (Paraná).

The transport of soybean originated in Mato Grosso towards the port of Santos occurs through several routes. The main option for handling this cargo is through roadways all the way from the producing area to Santos. Moreover, a recent multimodal terminal installed in the city of Rondonópolis (Mato Grosso), allowed producers to have the possibility of transporting the soybean by roads up to the terminal and then, shifting the commodity from the roads to the rail by transferring it through dumpers. The cargo then continues the trip with destination to the port of Santos (Figure 3).

Figure 3 . Location of the multimodal terminal in Rondonópolis
Source: construcaomercado.pini.com.br (2010)

However, despite the good infrastructure of the road network in the state of São Paulo, the intense use of this alternative for the soybean transportation has its consequences and can be noticed by the formation of bottlenecks due to the large amount of surrounding cities and elevated car traffic (LOTO and LOPES, 2005).

In the case of choosing the roadway transportation for the whole route, the most commonly used are highways BR-163 and BR-364. However, the downside of using such infrastructure is its lack of investments and low conditions of use. Furthermore, the existence of toll roads also adds up to the total transportation cost, making it more expensive (LORETI, 2011).

Another alternative for the soybean flow to Santos is via the waterway Tietê-Paraná up to Pederneiras (São Paulo) and then railway transportation through the ALL Malha Paulista network to the port of Santos. Further, less used, alternative, would be using the waterway of São Simão (Goiás) to Panorama (São Paulo) and then, shifting to roadway up to Santos, or even unberth by the waterway in Anhembi (São Paulo) and transport the commodity with the ALL Malha Paulista (ALMEIDA, 2011).

Table 1 shows the percentage distribution of the soybean exported by the Brazilian ports in 2010 and 2013. The main port considering the volume exported is located in Santos (São Paulo), followed by the port of Rio Grande (Rio Grande do Sul), and the port of Paranaguá (Paraná), port of São Francisco do Sul (Santa

Catarina) and port of Itaqui (Maranhão). In this context, the port of Santos accounted for approximately 30% of the Brazilian soybean exported during the data shown.

Table 1. Amount (in tons) of soybean exported through Brazilian ports (2010-2013)

Export ports	2010		2011		2012		2013	
	Tons	%	Tons	%	Tons	%	Tons	%
Santos	8,226,982	28.3%	9,230,508	28.0%	10,396,325	31.6%	12,893,109	30.1%
Rio Grande	4,564,075	15.7%	5,755,691	17.4%	3,540,700	10.8%	8,206,122	19.2%
Paranaguá	5,333,970	18.3%	6,924,388	21.0%	6,954,322	21.1%	7,735,132	18.1%
São Francisco do Sul	3,044,282	10.5%	2,609,398	7.9%	2,880,518	8.8%	4,032,264	9.4%
São Luís - Port	2,063,214	7.1%	2,514,376	7.6%	2,750,687	8.4%	2,974,624	7.0%
Vitória – Port of Itaqui	2,379,156	8.2%	2,452,879	7.4%	2,392,146	7.3%	2,823,224	6.6%
Salvador - Port	1,232,150	4.2%	1,525,901	4.6%	1,721,014	5.2%	1,778,558	4.2%
Manaus - Port	1,283,034	4.4%	1,086,216	3.3%	1,364,627	4.1%	1,278,985	3.0%
Santarém	809,619	2.8%	789,584	2.4%	873,005	2.7%	996,879	2.3%
Ilhéus	130,865	0.5%	89,029	0.3%	37,547	0.1%	71,205	0.2%
Others	5,808	0.0%	7,589	0.0%	5,525	0.0%	6,002	0.0%
Total	**29,073,155**	**100.0%**	**32,985,559**	**100.0%**	**32,916,416**	**100.0%**	**42,796,104**	**100.0%**

Source: Agrianual (2015)

3.2. The Brazilian soybean

From the 1970s, Brazil definitely entered the soybean international market. Until this period, the United States controlled around 95% of the commodity exports. However, in order to meet domestic demand, the North Americans established an export embargo for the product, forcing worldwide prices to artificially raise until it became profitable for producers, even for the most inefficient farmers, paving the way for international competition (SAMPAIO et al., 2012; BROWN-LIMA; COONEY; CLEARY, 2010).

In the 1980s, the Brazilian Agricultural Research Corporation (EMBRAPA*) allowed the development of crops adapted to the Cerrado climate and therefore, expanding the production to the Center-West, featuring the state of Mato Grosso. At this point, there was a displacement of part of the production from the Southern areas, mainly from the states of Rio Grande do Sul and Paraná, to the Cerrado. This migration can be noticed in the Figure 4:

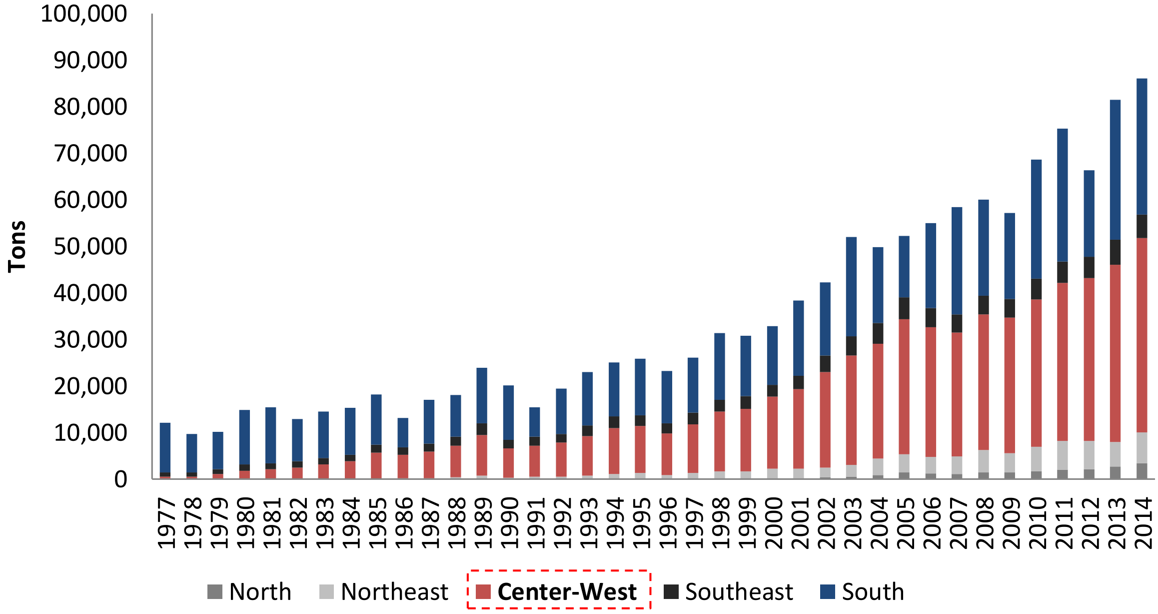

Figure 4. Brazilian soybean production by region (1977 – 2014)
Source: Agrianual (2015)

On the demand side, increasing production followed the national and international trend. On the supply side, the expansion occurred due to: natural conditions of the Brazilian Cerrado; availability of large arable lands in the region; technological development, allowing similar productivity compared to North American farms; automation, enabling operational efficiency; investments, even if restricted, on transport infrastructure (GOLDSMITH, P., 2008; COSTA; ROSSON, 2007).

Meanwhile, this shift of soybean production towards the Cerrado evidenced the infrastructure and the logistics problems as a whole. The increase on distances from production and export hub in the port of Santos, coupled with an inefficient infrastructure in terms of roadways, terminals, railways, ports, warehouses and toll

* Empresa Brasileira de Pesquisa Agropecuária

roads affected significantly the handling costs and, therefore, final competitiveness of the soybean (AFONSO, 2006).

3.3. International panorama

The world production of soybean has undergone expressive changes since the 1060s. Until this period, the world production had as major references the United States as producer and China as importer.

With the entrance of Argentina among the main players in the soybean production segment, mainly around the 1980s, the world soybean market underwent a change from almost a monopoly to a stage with higher competition. In this scenario, Brazil and Argentina became major competitors for the former North American "single player" (SAMPAIO et al., 2012).

In few decades, Brazil has become the world's second largest producer of soybean as shown in Figure 5 (AFONSO, 2006).

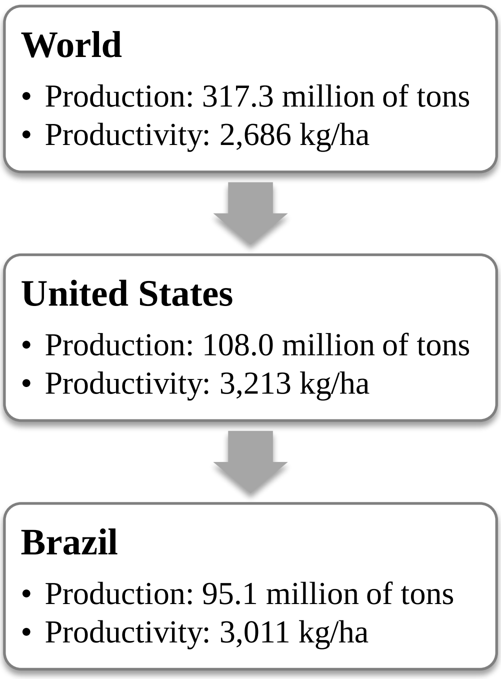

Figure 5. Soybean production (2014/2015 crop) – world and main producers
Source: AFONSO (2006)

Furthermore, the shift on the production scenario of soybean worldwide can be seen in the Figure 6.

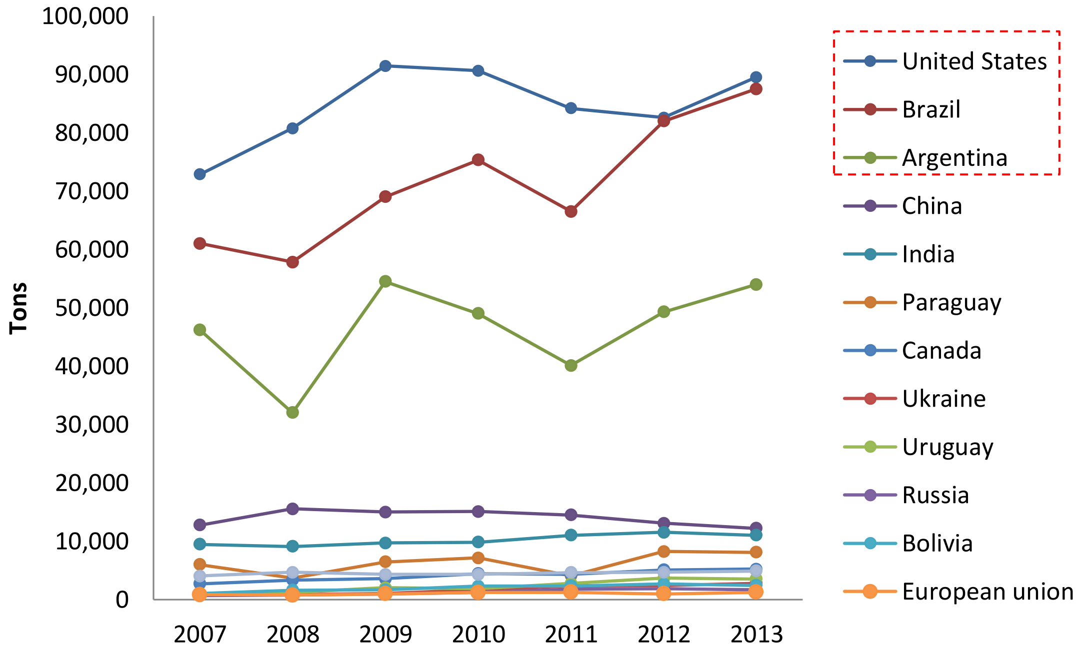

Figure 6. Soybean production worldwide (2007 – 2013)
Source: Agrianual (2015)

Regarding global exports of soybean, the United States hegemony was present until the Brazilian insertion in the 1970s. From this moment, Brazil started to capture market share and appears as a potential competitor in the sector. Moreover, with Argentina also starting as a prospective player, by the end of the 1970s, both Brazil and Argentina began to occupy similar positions in the export framework. Nevertheless, around the mid-1990s, Brazil assumed second position considering the global exports, through an accelerated growth process, which peaked recently, approaching the United States (Figure 7).

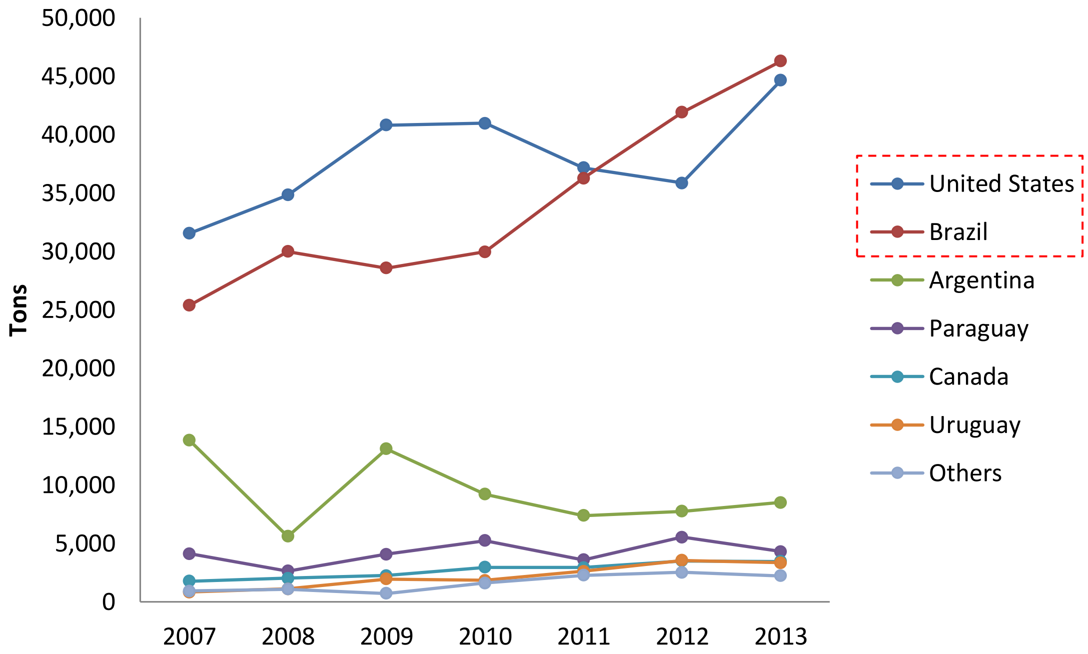

Figure 7. Soybean exports worldwide (2007 - 2013)

Source: Agrianual (2015)

From the importers point of view, China holds a major position as it overcomes more than 14 times the other major countries that import the commodity such as: Netherlands, Japan, Germany, Spain, and Italy. Mexico and Thailand complete the group of the eight largest soy importers (Figure 8).

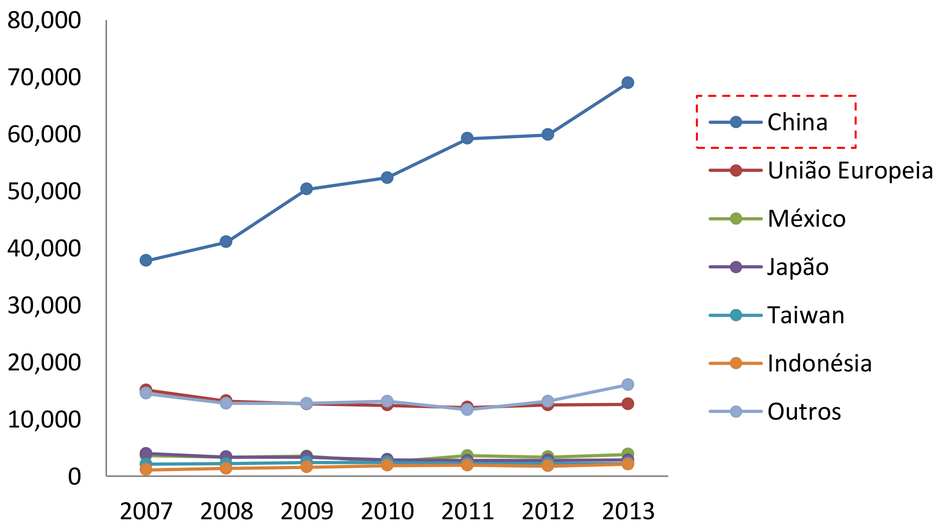

Figure 8. Soybean imports worldwide (2007 – 2013)

Source: Agrianual (2015)

The competitive power of the Brazilian soybean relies on its production costs, usually lower than producers in the United States. In 2010, the production costs were between 57% and 61% of the North American's (USITC, 2012).

The main factors that interfere in the wide gap in production costs between the United States and Brazil are the ones regarding land and seeds. The costs tied to the land are much higher in the United Stated compared to Brazil. Moreover, the high dimensions of rural properties in Brazil help to reduce the soybean unit costs. As for the seeds, the North American costs are also much higher for the use of genetically modified seeds, which increases these costs, once royalty payments are compulsory. This technology is not widespread in the Brazilian soils (USITC, 2012).

On the other hand, minimizing elements of the North American disadvantages are higher prices for fertilizers and chemical products in Brazil. In this discussion, the discrepancy can be explained by the dark red and red-yellow soil encountered in the Center-West, composed by a low pH and lack of nutrients, requiring extra expenditures around 10% of the American fertilizers. Besides that, Brazil imports around 80% of the necessary pesticides and applies higher quantities compared to the U.S. due to the tropical climate (USITC, 2012).

Although production costs are expressively lower compared to the United States, transport costs in Brazil, from the main production zones to the ports, are very high, which reduce significantly the advantage gained in the rural properties. Factors such as lack on transport options with more interesting prices than the roadway; low maintenance of the roads; long distances for the product handling; insufficient capacity of storage in rural properties during crop seasons (to avoid peak freight prices); high diesel prices; among others, sums up to the total cost of the Brazilian soybean, resulting in higher final prices compared to the U.S. soybean.

The transportation costs in the United States are substantially lower than the ones in the Brazilian Center-West. The reason is that in the U.S., the soybean handling is mainly made through barges along the Mississippi river to the Gulf ports. The effect of such modal differences implicates on the participation of transport costs of 8% to 10% on the North American soybean and 25 % to 30% on the commodity originated in Mato Grosso (USITC, 2012).

Although in the U.S. the soybean production is mainly transported by barges, the handling occurs through a multimodal system, combining trucks which carry the product from the rural properties to the nearest grain elevator along the Mississippi river (most common route adopted for the exported soybean). Throughout the route, hundreds of inland terminals can be found to set up the multimodal system (USSEC, 2012).

The United States has a comprehensive channel system, starting from upper reaches of the Mississippi river and its affluents and features four coastal areas: the Gulf of Mexico, the Atlantic Coast, the Pacific Northwest and the Great Lakes. The Gulf of Mexico corresponds to the most relevant hub. However, due to the fact that travel time is lower through the Pacific Northwest in the maritime course, it makes this path important when the demand pressure increases maritime freights, as well as on the Atlantic Coast (USSEC, 2012).

Argentina, on the other hand, possesses shallow rivers in the Panama river connection at the departure area of the port of Rosário; This requires constant dredging to maintain optimal depth for navigation. Nevertheless, delivery of high amounts of soybean is not permitted, unlike its competitors. These conditions increase transport costs in Argentina (HUERTA, 2002).

In the 1970-1990 period, the soybean production in Argentina achieved significant growth through increase on productivity, with soybean yields increasing by 3% annually. Regarding productivity, the better performance involved the use on new lands and the transfer of other cultures to the soybean production. Furthermore, the economic opening of the country, during the 1990s, also played its part, by increasing imports of agricultural supplies and, therefore, encouraging producers to invest in new technologies in order to enhance productivity (DOHLMAN; SCHNEPF; BOLLING, 2001).

The sudden expansion of soybean production in Argentina was also associated to the adoption of genetically modified seeds implemented in the 1990s. The similarity to the North American climate allowed the technology to be transferred rapidly from the U.S. to the country (DOHLMAN; SCHNEPF; BOLLING, 2001).

In addition, most of the soybean in Argentina is exported by ports located in the Paraná river. The epicenter of the most important production region is located around 160 kilometers from the port of Rosário and the ports of San Lorenzo and San Martin. In the United States, the distance from the production farms of the North Central Iowa and a port through the Mississippi river is around 1,000 kilometers, which is considerably greater than the distance in Argentina (LENCE, 2000).

Given the proximity of the main producing areas of soybean in Argentina to the ports, the product is usually handled by roadways, even though more expensive. However, the commodity also uses the waterway system Paraná-Paraguay. It is important to emphasize the existence of warehouses for storage alongside the Paraná river (DOHLMAN; SCHNEPF; BOLLING, 2001).

Likewise the Brazilian soybean production encounter disadvantages in terms of infrastructure when compared to the United States. The less favorable condition is due to the fact that mostly of the production in Brazil is located in the Mato Grosso region, which implicates on distances superior to 1,000 kilometers to reach the main ports. Moreover, when the product arrives at the ports, it can also face long waiting queues of more than 30 kilometers. Adding up to the competitive handicap, the environmental restriction prevails in the tropical soil when compared to its main competitors. It can be verified by the requirement of preserving 30 to 50 meters of the riparian forest depending on the region, whereas, in the U.S. and in Argentina, such specification does not apply (BROWN-LIMA, COONEY; CLEARY, 2010).

3.4. Soybean transport infrastructure in Brazil

Certain aspects of the transport infrastructure for the soybean flow in Brazil will be discussed in this topic in order to portray the thereof deficiencies. Further on that, will be presented the flow routes of the soybean from Mato Grosso.

The soybean price in the global market and the maritime freight are seen as exogenous, given it is a commodity and it is exported from Brazil through ships with foreign flags. Therefore, participants involved in the production activity and in the transport system should be able to minimize the costs in these steps (FILLARDO et al., 2005).

The soybean has the specificity of being a low added value product and of being traded in large volumes. This requires the use of transport that supports such amounts as well as possesses low unit cost (FLEURY, 2008).

From the 1980s, the state fiscal crisis in Brazil resulted in reduction of investments on roadway expansion, maintenance and restoration. This interfered directly in the soybean competitiveness and the inevitable need to use the BR-163 and BR-364 network. The long distances coupled with the infrastructure inefficiency generated losses of around 25 % of the sales revenue, impacting the opportunity cost of the product (CORREA; RAMOS, 2010).

According to Caixeta Filho et al. (1998), comparing several transport options should be seen as a combination of modes in order to handle the cargo from its origin to the final destination. Thus, railway and waterway system should not be considered separately, but as to promote the intermodality.

The roadway option is recommended for short distance transportation once it promotes capillarity for the system. In this case, short distances are considered as being less than 300 kilometers. As for this context, roadways would have the role of transporting the soybean from the producing areas up to the warehouses or railway or waterway terminals, in order to enable cost reduction (HIJJAR, 2004).

The international competitiveness of the Brazilian soybean is affected by the logistic costs due to two factors. Firstly by the excessive use of the roadway option, considered to be inadequate to be used as the only mean of transportation; Second, the precariousness in the roads, due to the already mentioned lack of investments by the public sector since the tax problems from 1980 (CORREA; RAMOS, 2010).

The revitalization of railways in Brazil was not effective due to the emphasis of the roadway system in a moment of scarce investments and due to the automotive industry appeal (CORREA; RAMOS, 2010).

Galvão (1996) argues that the historical inexistence of other transport options was associated to the absence of a strong internal market to economically support the viability for railway and waterway companies.

Regarding each modal, the railway infrastructure is characterized by elevated fixed costs and low variable costs, compared to other means of transport. Moreover, operating efficiently and in large amounts, it is possible to reduce the unit costs. On the other hand, the roadway option is the opposite: low fixed costs and high variable costs. The third option of flowing soybean is by the waterway system, ideal for large amounts of low added value products, low speeds and long distances, presenting the lowest unit costs.

Summing up to this scenario, the Center-West region presents the highest number of sections considered as regular, bad or very bad in Brazil (ALMEIDA et al., 2011).

BR-163 and BR-364, the main highways to the ports in the Center-South complex, are very compromised. The section of BR-174, which connects Cuiabá to Porto Velho, is an important connection channel for the soybean flow from Mato Grosso to the ports of Itacoatiara (Amazonas) and Santarém (Pará), and is considered as regular[*].

As for the perspectives for transport infrastructure development that benefits the exports of the Brazilian soybean, the government program to accelerate the economy[**] is presented as the current intention of planning works related to the development of the country.

The PAC, created in 2007, appeared with the purpose of reinitiating a planning scheme of investments in social, urban, logistics and energetic infrastructure in Brazil. In terms of transports, the PAC was based in the national plan of transport and logistics[***], created in 2006. In 2011, it was releases the PAC 2, which followed the same methodology of the previous program.

From the projected or undergoing constructions, some of them contribute for the soybean flow from the Brazilian Cerrado and correspond to the development in waterways, ports, roadways and railways.

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[*] Rating from the Transport National Federation (CNT), as for 2011

[**] Programa de Aceleração do Crescimento (PAC)

[***] Plano Nacional de Logística e Transportes (PNLT)

The Figure 9 and Figure 10 illustrate the main routes for the soybean flow from the Center-West and South regions.

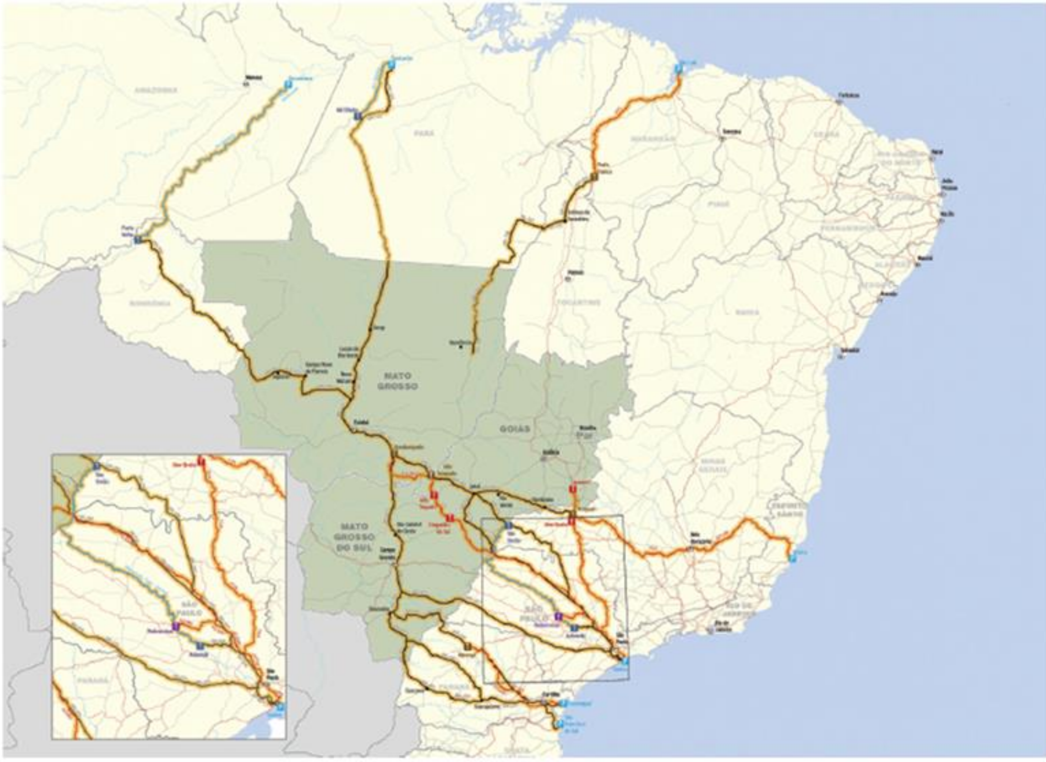


Figure 9. Routes for the soybean flow in the Center-West region
Source: Entraves logísticos ao escoamento de soja e milho (2015)

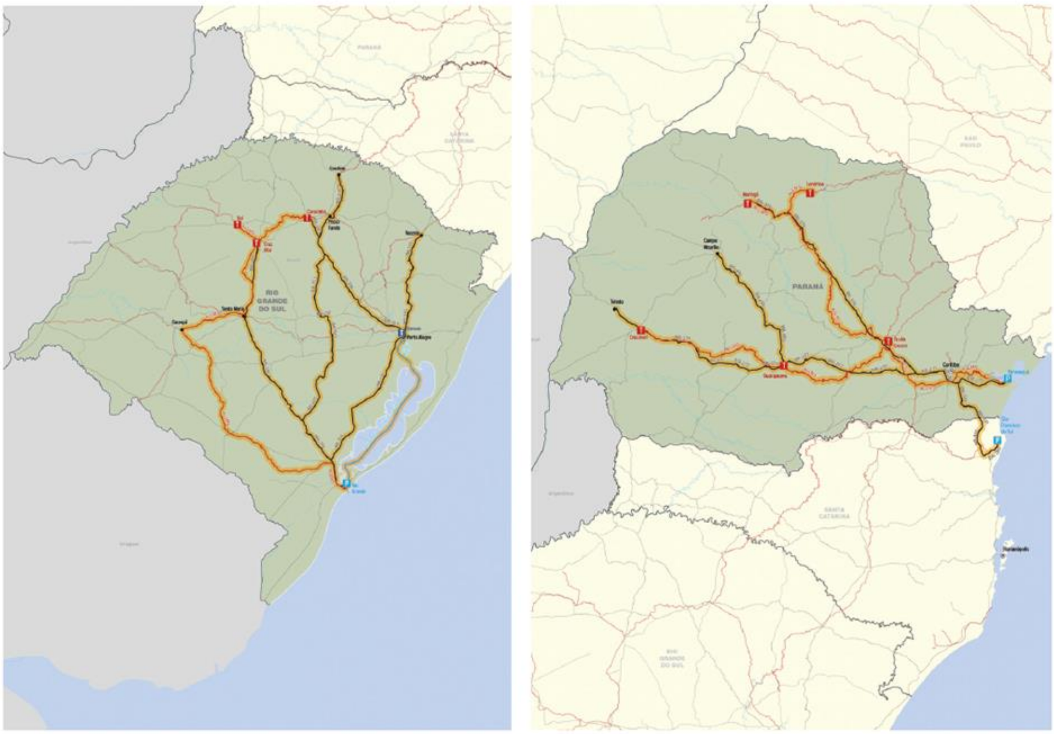


Figure 10. Routes for the soybean flow in Rio Grande do Sul (to the left) and in Paraná (to the right)

Source: Entraves logísticos ao escoamento de soja e milho (2015)

Conditions showed on the previous Figures feature the situation of difficulty handled for flowing the commodity through roadways – by the long distances – and through railways – by the geographic dispersion of the producers in the states. Therefore, what this study intends to evaluate is the relevance of a solution combining the advantage of both modal: roadways and railways, which will be discussed further ahead.

3.5. Brazilian railway system

Since the Regency, the Brazilian government considered the construction of a comprehensive railway system as a strategic investment for the economic growth of the country, especially due to its importance for the coffee industry in the world economy. Thus, at the beginning of the Second Empire, in 1835, a law was enacted enabling concessions of up to 40 years to private investors who were willing to connect several states: Bahia, Minas Gerais, Rio de Janeiro, Rio Grande do Sul and São Paulo. Notwithstanding, the proposal did not attract any potential candidate, and animal traction still prevailed on cargo transportation. Only in 1853, with measures covering tax benefits and more secure return on investments, Irineu Evangelista de Souza*, became the first developer of the Brazilian railways, who was followed by others in subsequent years.

It is important to mention the context in which it appears the construction of the first railways in order to understand better the reasons for their further decline. A century later, roadways became the official option of the Brazilian government, due to several reasons, among: spread of the automobile as individual mean of transport; more operational flexibility associated to the roadway system; the importance of the automotive industry in terms of job generating and country increase on revenue; and the image of the automobile as development symbol.

Besides all these factors, and regarding the cargo handling specifically, the construction of a roadway network with national coverage would allow a productivity integration of the territory, which was impossible to be achieved by a railway system. This unviability was due to its development history, with the coexistence of several infrastructure standards for rails, particularly several different gauges, creating essentially a transport archipelago, as opposed to an interconnected system.

The roadway consequences last until today. Even though the Brazilian infrastructure of all modes is less developed compared to first world countries, it is important to highlight that, on every one thousand square kilometers of surface, there is 17.3 kilometers of paved roadway and only 3.3 kilometers of railway – of which only one third is explored in its full capacity. In terms of modal share in total ton-kilometer transported, although there is some variation in several estimates, the share of road transport is usually estimated at about two-thirds of the total - and the railways, in a fifth. But, in fact, the above Figures are not necessarily very informative. Therefore, some of rail and road characteristics should be mentioned again in more detail.

The construction costs of a railway are usually far superior that the ones linked to roadways – usually around seven times higher. On the other hand, the cargo capacity is usually substantially higher, and the variable costs per ton-kilometer transported are reduced by economies of scale associated to the size of railway

* Usually known as the Baron of Mauá

systems – effectively, in Brazil, by reducing the unit cost up to six times, a difference that could be even higher if the railway were operated more efficiently.

Nevertheless, the roadway option provides unparallel flexibility compared to the rail, once it allows door-to-door services. Moreover, regarding environmental matters, railways are far superior, not causing the level of negative externalities associated to the roadways in general terms (neither to those specifically linked to trucks, such as high particulate emissions).

Considering the above mentioned arguments, it becomes evident that the competitive advantages of the railway transport will occur in situations of high cargo volumes, longer distances, with no need for operational flexibility and capillarity. One would expect that a country with relevant commodity production, characterized with long distanced from the main producing areas to the ports, had a smaller share on road transport. Even though railway is not the only alternative, it would be expected a reduced fraction of the roadway system for a country with such dimensions, as Brazil. Yet, whilst only 20% of the North American production of soybean is handled by roadways, in Brazil this Figure reaches 65%. In addition, the period of fiscal adjustment brings uncertainty regarding the railway investments, and if it really is the best strategic use of resources. Thus, it is possible to say that the prospects of the Brazilian rail transport are not exactly encouraging.

It is important to emphasize that the road-rail transport already exists, even though still limited, in these corridors: Rondonópolis (Mato Grosso), for example, has a transshipment terminal of such modes. However, not only this solution in relatively underexplored, as it will be discussed a specific technology for a multimodal terminal – the so called Modalohr system – with a section dedicated to this subject. Nevertheless, before stepping into the Modalohr technology, an introductory discussion regarding the combined transport, with its advantages and disadvantages, will first be presented. Also the role of information and communication technologies should play in a system in order to assure that proper development will be implemented. Since this study dedicates itself specifically to the soybean flow and the Modalohr system, similar reasoning should be made in further studies regarding the combined handling of cargo in general.

3.6. Final considerations

In short, it can be noticed that the state of Mato Grosso is the largest soybean producer in Brazil with 30.9% of the total production of the country in the 2013 / 2014 crop. It also presented one of the most productive lands with 3,120 kg / ha. On the other hand of the production, the port of Santos is currently the main export hub for the commodity in Brazil, representing 30.1% of exports in 2013. Thus, this scenario settles Brazil as the world`s second largest producer of soybean with 95.1 million of tons registered in the 2014 / 2015 crop.

However, The Brazilian infrastructure is still very limited and sets barriers for the soybean competitively worldwide. Coupled to this situation, the long territory distances between producing farms and export hubs and the underexplored railway system also hinders the country`s soybean market.

4. Proposal

4.1. Combined transport

Concepts related to transportation are usually defined quite vaguely – mobility and accessibility are two well-known examples in this matter. Combined transport is no different. A report from the European Conference of Ministers of Transport states:

> *[...] the combined transport should be understood as a specific mode of transport, which makes the best use of the advantages from several types of ground transportation and cabotage navigation, choosing those that are the most appropriate.*

The same report says that it is a mode which necessarily operates door-to-door, with no changing on the cargo unit – containers, trailers, etc. In the road-rail transportation, the schematic operation frequently consists of: road transport, from the cargo origin to a transshipment terminal; cargo transfer from the truck to the wagon of a train; rail transport from this terminal of transshipment to another; transfer from the load to a truck; road transport to the final destination. Regarding commodities and products for exports, the rail transport can be directed to a port, instead of another terminal. The last situation is the one discussed in this material.

The advantages from the road-rail transport are very clear: use of railway in the longest section allows increase on scale which drastically reduces the overall variable cost per transported unit. Moreover, the combined transport has the advantage of promoting capillarity for the isolated railway system and, therefore, being accessible to the producing farms. In this system, the only additional infrastructure required would be a transshipment terminal, which can be chosen by several different types of constructions – the Modalohr technology as being one of the possible systems – and that are endowed by an elevated operational complexity.

Nevertheless, the combined transport is far from taking the isolated roadway system out of the picture. As it depends on cargo transfer and train loading, it is a handling option that remains "slower" than the exclusive use of trucks. Regarding the speed, it is important to emphasize that the rationale is, in cargo transport, fully equivalent to those used for regular passengers (for example, commercial speed). In fact, as the same European Conference of Ministers of Transport states:

> *The speed should not be extended to absolute terms of kilometer per hour. usually, the client requires: next day delivery, dispatch on day A and delivery on day C, or a similar option. For most services on a national scale [Note: the European national scale, of similar dimensions to the Brazilian states scale], the client usually requires delivery on the following day. When the carrier commissioned by the sender takes the cargo only at 5 p.m., he may face difficulties to reach the terminal before it closes, around 6:30 p.m. Similar problems occur on arrival. If the combined transport unit cannot be forwarded to the destination transshipment terminal before 9 a.m., it may be too late to handle it to the client.*

However, as noted above, this problem refers to relatively small volumes of loads, higher added value and higher importance to time restrictions – opposed to agricultural commodities, that are forwarded to a port, such as Santos (São Paulo).

In our particular case, it is important to consider another possible limitation of the combined transport: the reliability. A road-rail transshipment terminal, mainly those operating with either complete loading or partial loading, has a relatively high operational complexity. Thus, extremely important, for example, to ensure that the loads have the commercial weight agreed – indeed, weighing is an activity that can take a substantial time – and that they are forwarded to the correct trains.

Moreover, given that the railway transport is necessarily made "by batches", small delays in loading can generate a final delay of several hours, resulting in significant economic losses. In the case of cargo transport between the Center-West region to port of Santos, the reliability would be an essential strategic challenge for an operator of a road-rail transshipment terminal. It could be interesting, in this case, to diversify the activities not only for the soybean handling, but also to other productions in the region, including some with more value added.

In this context, the importance of information technology, features of ITS*, becomes evident. Although, taken generally, the combined transport is rather broader than its information technology installed; those functions are the ones responsible for adding to the transshipment terminal the level of reliability that was discussed before, similar or even higher than the roadway system, especially when considering road incidents.

Before proceeding to the presentation of the Modalohr system, a methodological explanation is applicable. In the preceding paragraphs, we compare three modes of transport: road, rail, and road and rail combined. Why not show a decision matrix? The answer is quite simple. Decision arrays are tools that help to clarify the superiority of some options in the presence of trade-offs, but only when this superiority is relatively clear, the imprecision inherent in the assignment of "weights" and "notes" is considerable. Whoever is familiar with transportation planning understand that the decisions of consumers (travelers and cargo shippers) are usually too complex to be modeled in a manner acceptable for this type of

* Information Technoloy Systems

instrument, and not necessarily a transportation mode is inherently superior than others. For that reason alone, it is preferred to explain the type of arbitration that the cargo transport is submitted, the specific advantages and disadvantages of each mode, and the type of situation in which each of them usually prevails.

4.2. Modalohr system

Modalohr is an innovative technology for railway transportation developed by the French company "Lohr industries". Operational for commercial purposes for a few years between France and Italy, the technology concept is patented and licensed and based on the use of wagons that allow the handling of road semi-trailers over an existing railway infrastructure. The first connection made using this system was in Europe, in the segment France – Italy as in the Figure 11 (Aiton – Turin / Orbassano).

Figure 11. Section Aiton - Turin / Orbassano
Source: Lohr Industries (2015)

As being a significantly more efficient system, Modalohr is already operational in several other sections across the old continent, as in France, Spain and Luxembourg. For the end of 2016, it is expected to be concluded the section Turin-London.

At the same time, other projects are under study with the intention of connecting more countries and taking typical 45 tons semi-trailer out of the roads.

Figure 12 below shows the European connection with the aforementioned system.

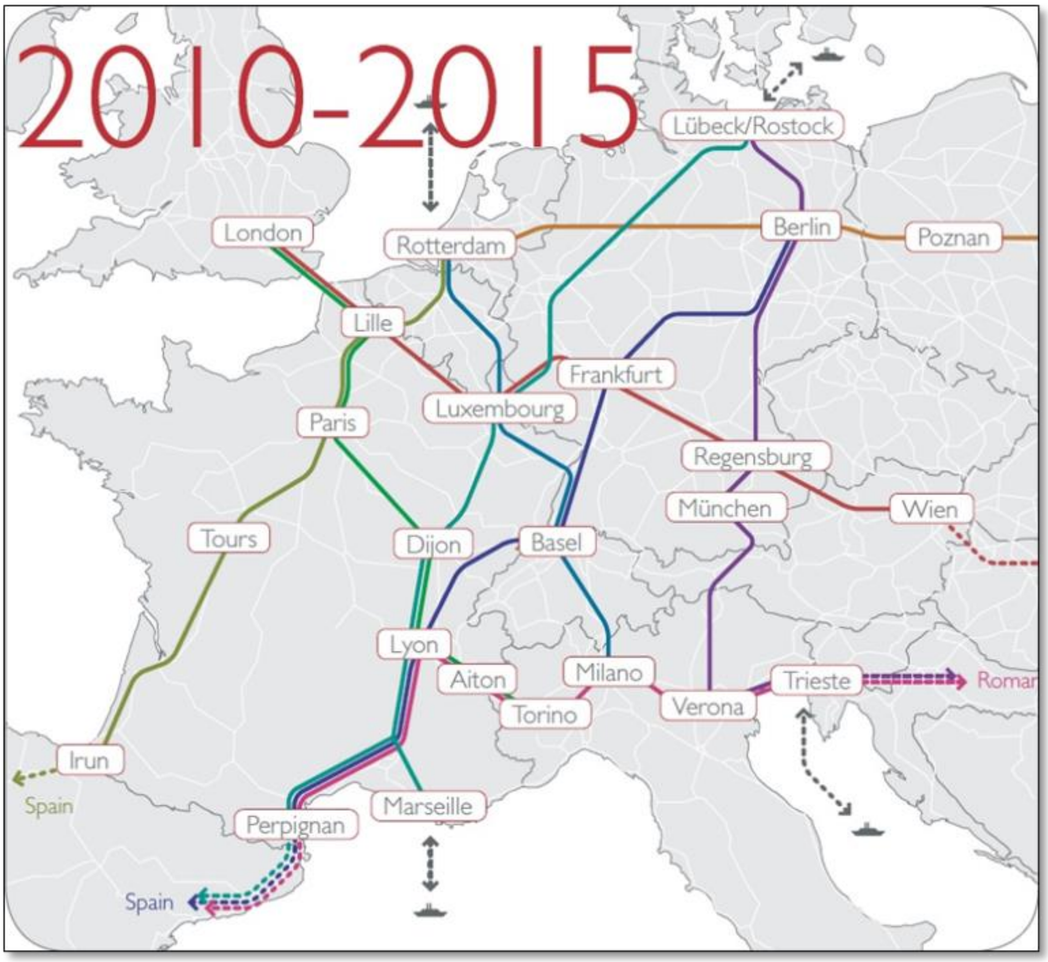


Figure 12. Modalohr system routes (existing and under project) in Europe
Source: Lohr Industries (2015)

The transshipment mode using the Modalohr technology does not require the use of dumpers or cranes, used in traditional methods. The loading and unloading operation is made by the truck driver, making it faster and more efficient.

The technology is a low-frame articulated railway wagon, specially designed for carrying standard cargo, including:

- A very low loading platform enabling 4 meters high trucks to be loaded within the limits of existing railway gauges (Figure 13);

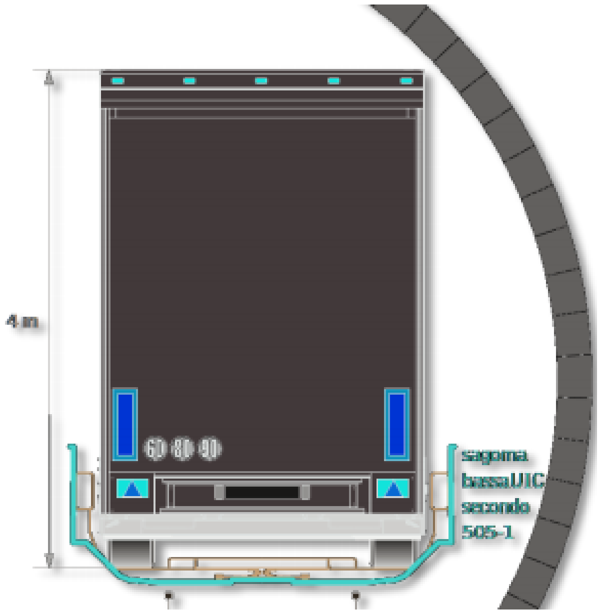


Figure 13. Truck engagement inside the Modalohr wagon

Source: Lohr Industries (2015)

- Standard bogies and wheels to keep servicing costs within the range of those of a conventional railway car;
- Trucks can be loaded horizontally and directly using the road tractor with no handling equipment (Figure 14);

Figure 14. Modalohr loading system

Source: Lohr Industries (2015)

- Lateral herring-bone loading of trucks for simultaneous, rapid transshipment (Figure 15);

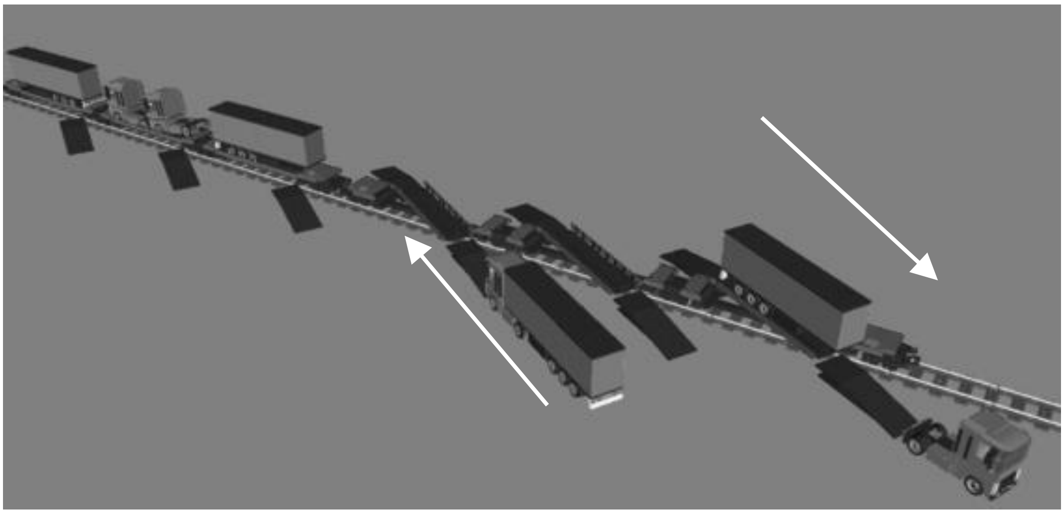


Figure 15. Simultaneous loading
Source: Lohr Industries (2015)

- A mechanical system for articulation and "opening" the wagons;
- A simple, low-cost transshipment terminal, consisting of asphalted areas on either side of the railway line (no platforms) and wagon opening systems fixed on the railway.

To guarantee reliability and lower rolling stock purchase and maintenance costs, there is no power actuator on the wagons. They are just simple mechanical units.

The wagon opening systems are part of the fixed equipment at the terminals. This is in line with economic logic because there are many more wagons than terminals. It is also much easier to maintain equipment fixed in one place than systems fitted to wagons. They are controlled from ground level by operating personnel who monitor the truck transshipment operations.

Each wagon is fitted with a secured lock which guarantees that it stays closed while moving along the tracks and, as soon as the train stops, the wagons are recentered on the position with respect to the opening systems.

Once unlocked by the platform personnel, the wagon's vertical load is taken over by the ground based equipment which then pivots the low-frame platforms. The trucks can then be unloaded and loaded. To close the wagons, the operation is repeated in reverse order.

Regarding the infrastructure, loading and unloading trucks on Modalohr rail cars needs a special transshipment terminal to be constructed. In view of the quantity of truck traffic using these terminals, it is preferable to build new installations outside urban areas, close to motorway interchanges. In this scenario, the region in Rondonópolis is suitable for a construction of such magnitude, connecting the soybean production areas through roads such as BR-163 and BR-364 to the ALL railway system.

A Modalohr terminal consists of a railway line with an asphalted surface on either side, at almost the same level as the rails. There is no need for gantries or handling equipment to be installed. The loading floor of the cars is low and by using lateral loading in herring-bone mode, trucks can be transshipped independently of the other trucks.

All the trucks can be loaded or unloaded at the same time so that 30 trucks can be loaded as quickly as one. The maneuvers that the driver has to accomplish (in a straight line) are also easy and fast.

After passing the entrance to the terminal, where it has been identified and inspected, the truck goes to the position bearing the number indicated, and waits for the train to arrive. Once the train has stopped, the truck to be loaded waits until the other truck, already on the wagon, has been unloaded, before driving on board (Figure 16 and Figure 17). The procedure of loading can be explained on the following steps:

- Wagon stopped with respect to the ground system, then the low-frame platform is unlocked;
- The low-frame platform is rotated by the ground opening system;
- The truck is loaded onto the wagon by driving in a straight line;
- The truck crosses the platform until the tractor reaches the other side;

- After uncoupling, the tractor is loaded onto the adjacent platform if the whole rig is travelling on the train, or leaves the terminal if the semi-trailer is travelling alone;
- The wagon is closed using the ground system, then locked and the wagon is ready to leave.

Figure 16. Loading and unloading system
Source: Lohr Industries (2015)

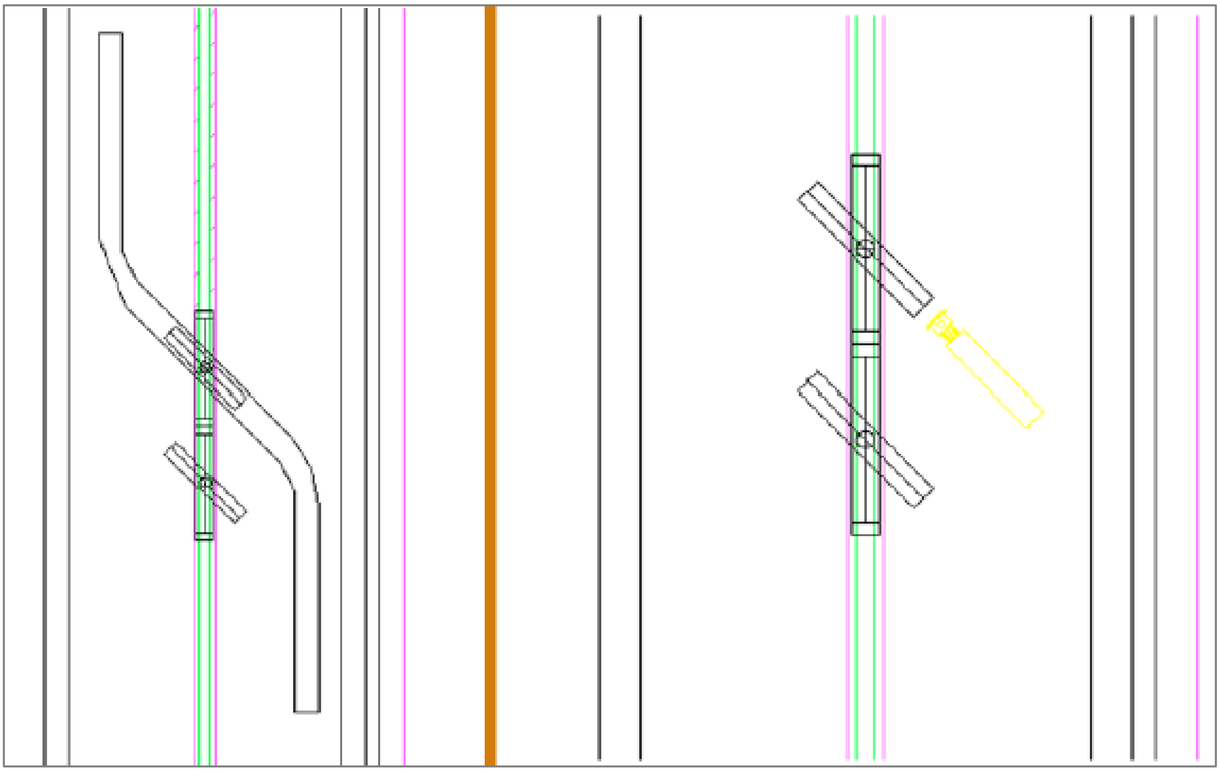


Figure 17. Schematic loading and unloading system
Source: Elaborated by the author

This technology has the further advantage of being able to unload or reload one or more trucks in the middle of the train without having to move the others. Intermediate stops can thus be planned giving drivers greater flexibility and optimizing train filling. Connections can even be envisaged between Modalohr trains, exchanging trucks.

Furthermore, this loading method manages to reduce the rail operator's running costs, once the time for which trains are stopped in terminals can be very short, and the rate of efficiency is high because they are moving approximately for 80% of the time they are in service. Since transshipment is horizontal, it can take place on a line using catenaries and trains can reach the terminal using normal electric locomotive, without having to detach it. Moreover, few personnel are required in the terminals, since the trucks are loaded directly by their drivers.

Besides that, the implementation of such technology relies on special wagons which need to be considered in the construction of such terminal. As it has been said, the Modalohr system was created to be suitable to the existing infrastructure and there is no need of changes in truck sizes or railway dimensions. On the other hand, special wagons are compulsory once they allow such technology to be applied (Figure 18 and Figure 19).

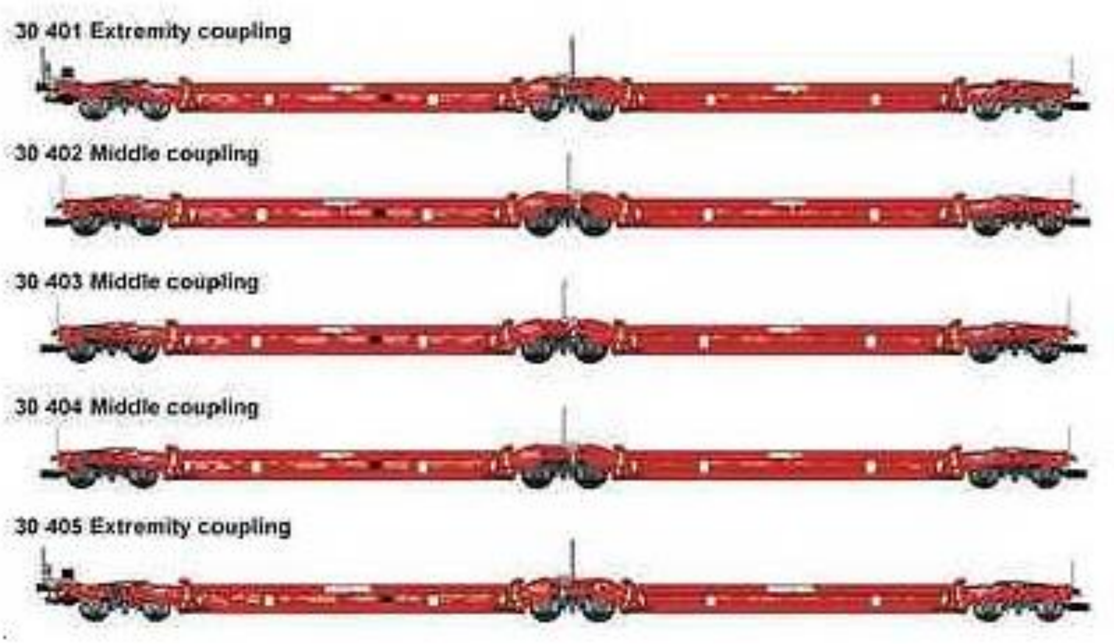
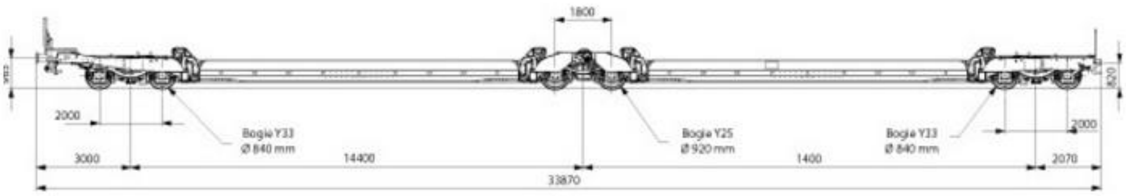
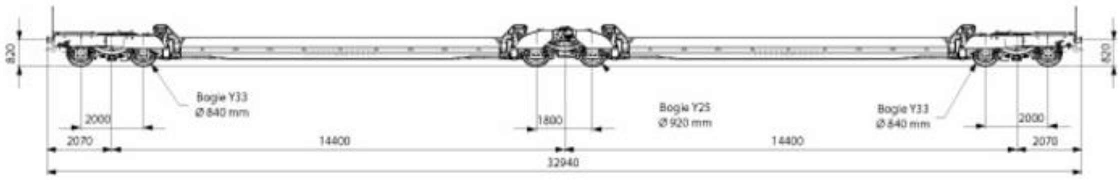


Figure 18. Special Modalohr wagons
Source: Lohr Industries (2015)

- LOHR UIC 1 end wagon



- LOHR UIC 2 intermediate wagon



- LOHR UIC 3 individual wagon

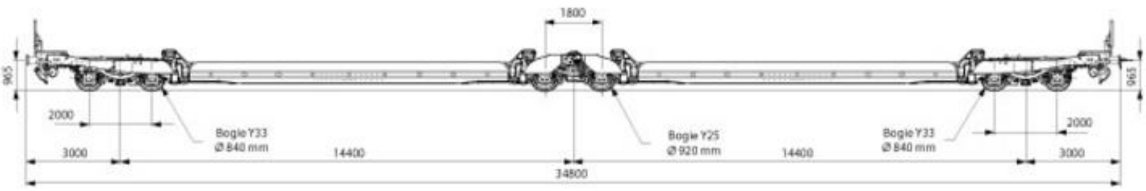


Figure 19. Types of Modalohr wagons – characteristics
Source: Lohr Industries (2015)

Additionally, it is important to emphasize that there are two current options available from the Lohr industries. The first option, usually adopted in Europe, the whole truck composition (including the tractor part) goes along with the train. In this option, also called accompanied trip, a wagon for dormitories is needed in order to accommodate the drivers which will continue the trip after the rail section.

The other option, or unaccompanied trip, the tractor part of the truck is uncoupled from the container and the train carries just the cargo without the driver. This method would be more appropriate to be used in the terminal proposed in Brazil once it can also unburden the high amount of trucks that arrive in the port of Santos. The main reasoning not to travel with the driver and the traction part of the train is due to the high dimensions of Brazil and the need of traveling great distances. Therefore, once just the containers arrive in the port of Santos, the logistisct to be adopted at the port would be easier than having to manage several arrivals of trucks. This scenario is opposite to what happens in Europe, where the need of capillarity and, therefore, trucks to be available either in the start as in the end of the rail section, the accompanied trip is better accepted.

Moreover, it will be presented the 5 current operating terminals in Europe with the Modalohr technology:

4.2.1. Aiton terminal (Chambéry, France)

The Aiton terminal was inaugurated in 2003 and is currently owned and operated by Autoroute Ferroviaire Alpine. It is equipped with the Modalohr system through one track with 500 meters of extension and a total surface of 20,000 sqm (Figure 20).

Figure 20. Aiton terminal
Source: Lohr Industries (2015)

4.2.2. Orbassano terminal (Turin, Italy)

The Orbassano terminal was also inaugurated in 2003, owned by RFI and operated by Terminali Italia SRL. Equipped with the Modalohr system, operates with an area of 50,000 sqm (Figure 21).

Figure 21. Orbassano terminal
Source: Lohr Industries (2015)

4.2.3. Le Boulou terminal (Perpignan, France)

Le Boulou terminal is in service since 2007 and is currently operated by Amborgio. It is a multimodal terminal equipped with the Modalohr system with an operating area of 90,000 sqm (Figure 22).

Figure 22. Le Boulou terminal
Source: Lohr Industries (2015)

4.2.4. Bettembourg terminal (Luxembourg)

The Bettembourg terminal was also inaugurated in 2007. Its Modalohr system has a total capacity of handling 45,000 semitrailers / year. The rail connection is composed of Antwerp, Lubeck, Helsingborg, Le Boulou, Milan and Trieste. It is currently managed by CFL multimodal (Figure 23).

Figure 23. Bettembourg terminal
Source: Lohr Industries (2015)

4.2.5. Port of Calais terminal (Calais, France)

This terminal, built-in by the Port of Calais and designed for unaccompanied semi-trailer traffic connecting the ferries going to and from England was recently inaugurated on October 23rd, 2015. The total cost of the construction was approximately EUR7.0 million. The new terminal is due to become the Northern railhead of a service to Le Boulou near the Spanish boarder, operated by SNCF subsidiary VIIA. The forecasted capacity is around 40,000 semi-trailers a year (Figure 24).

Figure 24. Port of Calais terminal
Source: Lohr Industries (2015)

Furthermore, several other terminals in Europe are under construction or in project willing to incorporate the Modalohr technology (Figure 25).

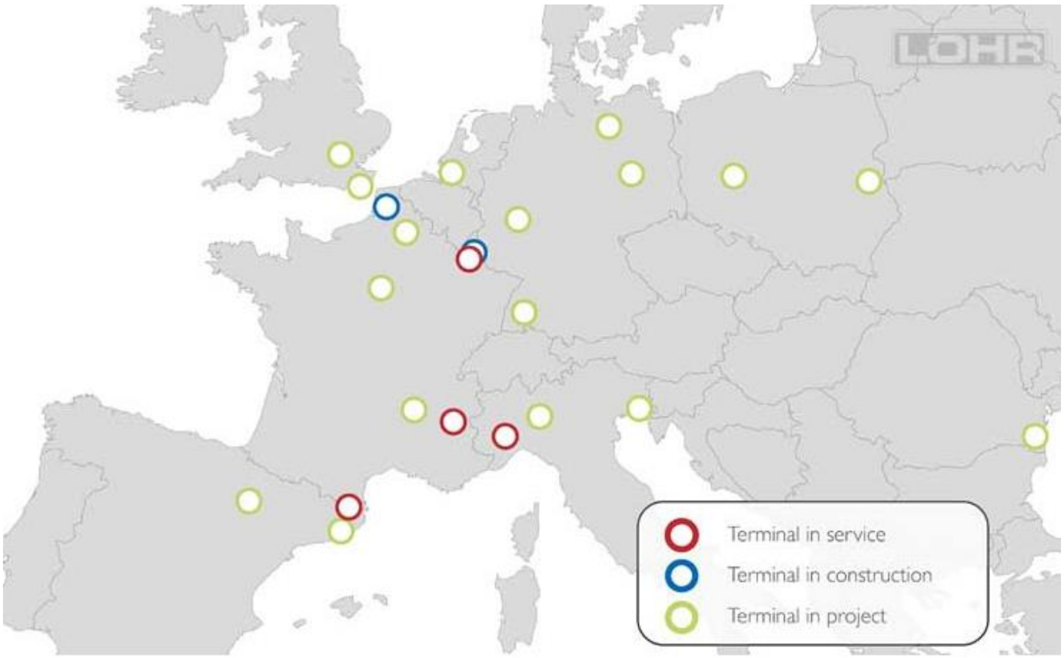


Figure 25. Current situation of Modalohr terminals (except for the Port of Calais terminal)
Source: Lohr Industries (2015)

4.3. Final considerations

The combined transport can be seen as a possibility of increasing the efficiency for the soybean transport between Sorriso and the port of Santos. More specifically, regarding the rail-road multimodal system, it is possible to profit from the capillarity of the roads and the faster journey promoted by railways. In this scenario, the large distances in Brazil make this choice much more attractive for the outflow of soybean. Thus it is proposed the Modalohr system, a technology currently available only in Europe and consists in a low-frame articulated railway wagon, specially designed for carrying standard cargo. The transshipment mode using the Modalohr technology does not require the use of dumpers or cranes, used in traditional methods. The loading and unloading operation is made by the truck driver, making it considerably faster. Additionally, that are currently 5 operational terminals in Europe and several other projects under development due to the high efficiency of this technology. Thus, further in this study, it will be shown the increase on efficiency that such terminal could bring in a proposed terminal in Brazil.

5. Methodological review

In this section, it will be presented a theoretical model for pricing the freights charged for the cargo handling to the port. In this context and aiming to maximize the efficiency of the proposed terminal, it will be showed how the ITS technologies could improve the multimodal complex performance.

Further ahead, it will be presented the methodology applied to calculate the potential environmental benefit that a new road-rail terminal would bring by reducing CO^2 emissions releases in the atmosphere.

5.1. Freight to the port

The price formation of the freight is very complex and also incorporates local and circumstantial factors, besides activity costs, which may be influenced by direct and indirect factors (CYPRIANO, 2005).

<u>Direct factors</u>: influenced by events that make the demand vary due to the service:

- Economy performance;
- Corporate strategies, such as location, production management, storage policy and warehouse centralization;
- International commercial agreements, such as Mercosur;
- Packaging materials;
- Reverse flows (e.g.: for recycling purposes);
- Market structure of the transported product supply and demand.

Indirect factors: factors that affect the cost of service providing (CYPRIANO, 2005):

- Regulation / deregulation;
- Fuel price variation;
- Vehicles and cargo compartments innovation;
- Traffic jams;
- Weigh limits for circulation.

In addition, there is seasonality in the freight value, which becomes higher during the soybean crop. In the producing regions of Mato Grosso, there is a deficit in storage, so there is the need for fast flow of the production to the export ports and for crushing industries. This flow increases the demand for transport and generates an increase in prices for these services. Moreover, the need for trucks is higher, due to the freight from the farm to the warehouses.

Thus, the soybean price calculation is held in the negotiation act with the seller, according to the Chicago prices and exchange rate of that moment, but not necessarily at the delivery time, and by other factors, such as internal demand for crushing.

The soybean price to be paid to the producer involves the following variables:

- Soybean price in the CBOT[*], expiring on the day of trading, quoted in cents of dollars per bushel;

[*] Chicago Board of Trade

- Premium performed in the port on the day of trading**;
- Port costs;
- Freight costs.

From this, the soybean price to be paid to the producers, for the product originated in Mato Grosso, can be calculated by the Equation 1:

$$Price_{soybean} = [(CBOT - PC_{Santos}) * FX_{commercial\ dolar})] - Freight_{Mato\ Grosso-Santos}$$

Equation 1. Soybean price paid for the producer
Source: CYPRIANO (2005)

With:

- CBOT: soybean price on the Chicago Board of Trade, summed with an additional port premium
- PC: port costs in Santos
- FX: Exchange rate for the commercial dollar
- Freight: price charged for the soybean handling from Mato Grosso to the port of Santos

It is noteworthy that the above formula provides an overview of the rationale for composing the soybean prices paid to producers and how the relevant variables are related to each other, and it may vary from case to case.

Thus, when analyzing the current situation, the high FX in 2015, coupled with the expectation of cheaper roadway freights due to the new road-rail terminal proposed, imply an increase of the soybean export parity price, based on the Mato Grosso state and the port of Santos (São Paulo). Therefore, higher prices positively impact the producer's earnings.

Moreover, in order to proceed with the scope of the ongoing research, it is interesting to discuss more specifically about the relation between the soybean price and the freight costs.

** Figure influenced by: force of the internal market supply and demand; maritime freight; and port differential

Thereby, a very important Figure analyzed by the producers from Mato Grosso is the ratio freight / soybean, which shows how much the freight prices of soybean participates in the value to be paid for the producer’s bushel.

In this scenario, if the grain freight rises in higher proportions than the soybean price, the percentage share of the freight on the soybean price will increase, causing a decrease on the producer’s margins.

Similarly, if the grain freight is reduced in higher proportions than the soybean price, the percentage share of the freight on the soybean price will decrease, and the producer’s margins, therefore, will be less impacted.

It can be noticed, as seen in Figure 26 that since 2014, the ratio freight / soybean in Sorriso is between 25% and 30%. Therefore, about one fourth of the soybean price is spent by the producer, in Sorriso, with handling the product.

As for the crop season, it can be seen that from January, the ratio starts to increase, mainly due to the more expensive freight prices. Although, in 2015, the month with the highest ratio, March, with 29%, still remained below from what was seen in 2014, which showed an average ratio freight / soybean of 34% in this period. This occurred by the combination of two factors. The first is the freight price, which performed slightly below that Figures recorded in 2014. In March, 2015, the average freight from Sorriso to the port of Santos was R$290.00 per ton, compared to R$300.00 per ton in 2014. The other factor is the soybean price, which in March, 2015, registered an average of R$58.95 / bag against R$53.42 / bag as for March, 2014. This difference of R$5.53 / bag mitigates the handling costs for the producers.

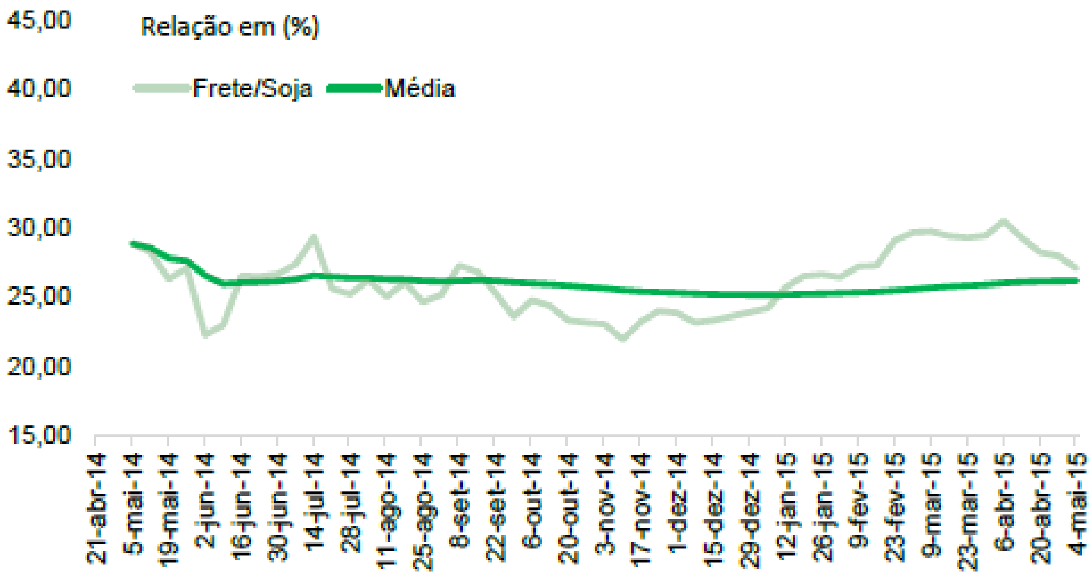


Figure 26. Freight ratio (Sorriso to Santos) and soybean price in Sorriso
Source: Aprosoja (2015)

5.2. Simulation of truck's logistics

Queuing theory is the study of waiting lines. It is one of the oldest and most widely used quantitative analysis techniques. Waiting lines are an everyday occurrence for most people. Queues form in business process as well. The three basic components of a queuing process are arrivals, service facilities, and the actual waiting line. Analytical models of waiting lines can help managers evaluate the cost and effectiveness of service systems.

Most waiting line problems are focused on finding the ideal level of service a firm should provide. In most cases, this service level is something management can control. When an organization does have control, they often try to find the balance between two extremes. A large staff and many service facilities generally results in high levels of service but have high costs.

Therefore, a deeper analysis through the possibilitiy of line formation is extremely important to better manage the Modalohr terminal. For the aforementioned analysis, a Poisson distribution was chosen to better simulate the truck's arrivals.

The most common case of queuing problems involves the single-channel, or single-server, waiting line. In this situation, arrivals form a single line to be serviced by a single station (railway system). Assuming that the following conditions exist in this type of system:

- Arrivals are served on a first-in, first-out (FIFO) basis, and every arrival waits to be served, regardless of the length of the line or queue.
- Arrivals are independent of preceding arrivals.
- Service times vary from one customer to the next and are independent of one another, but their average rate is known by inputing several scenarios.
- Service times occur according to the negative exponential probability distribution.

Furthermore, the Poisson distribution is shown with the following formula:

$$P(x) = \frac{e^{-\lambda}\,\lambda^{x}}{x!}$$

With:

- P (x): probability of x arrivals
- x: number of arrivals per unit of time
- λ: average arrival rate
- e: Euler number (2.7183)

5.3. Intelligent transport systems

The Intelligent transport systems consists on the application of applying a set of technologies to common issues in transportation, such as the lack of information and planning, traffic jams contingencies, among others. The international experience demonstrated that implementing ITS is a strategy to optimize investments and, adequate planning with an engineering approach are fundamental elements for a profitable and sustainable execution. Therefore, the proposed study can help to increase the return on investments, by reducing operational costs, enhance the functionality and the performance of the cargo management systems, and also mitigate the environmental impact of the sector in terms of emissions or fuel consumption.

ITS comprise multimodal control centers, monitoring systems, remote surveillance (cameras, sensors, probes and software), parking management, incident management, emergency response, electronic payment, dynamic pricing and user information in real time.

With this, in order to fit, in the best way possible, the technologies facilities to the studied multimodal terminal, it may be used as a maturity assessment technique the Intelligent Transport Maturity Model matrix, developed by IBM in the U.S.A., in which for each category, a level is assigned depending on the maturity stage (on a scale from 1 to 5): governance, transport network optimization and integrated transport services (Table 2).

Table 2. Intelligent Transport Maturity Model matrix

		Level 1: Single mode	Level 2: Coordinated modes	Level 3: Partially integrated	Level 4: Multimodal integration	Level 5: Multimodal optimized
Governance	**Strategic planning**	Functional area planning (single mode)	Project – based planning (single mode)	Integrated agency – wide planning (single mode)	Integrated corridor – based multimodal planning	Integrated regional multimodal planning
	Performance measurement	Minimal	Defined metrics by mode	Limited integration across organizational silos	Shared multimodal system – wide metrics	Continuous system – wide performance measurements
	Demand management	Individual static measure	Individual measures, with long-term variability	Coordinated measures, with short-term variability	Dynamic pricing	Multimodal dynamic pricing
Transport network system	**Data collection**	Limited or manual input	Near real-time for major routes	Real-time for major routes using multiple inputs	Real-time coverage for major corridors, all significant modes	System – wide real-time data collection across all modes
	Data integration and analytics	Limited with ad hoc analysis	Networked but periodic analysis	Common user interface with high-level analysis	Two-way system integration and analysis in real-time	Extended integration with multimodal analysis in real-time
	Network operations response	Ad hoc, single mode	Centralized single mode	Automated, single mode	Automated, multimodal	Multimodal real-time optimized
	Incident management	Manual detection, response and recovery	Manual detection, coordinated response, manual recover	Automated detection, coordinated response, manual recover	Automated pre-planned multimodal recovery plans	Dynamic multimodal recovery plans based on real-time data
Integrated transport services	**Customer relationships**	Minimal capability, no customer accounts	Customer accounts managed separately for each system / mode	Multichannel account interaction by mode	Unified customer account across multiple modes	Integrated multimodal incentives to optimize multimodal use
	Payment systems	Manual cash collection	Automatic cash machines	Electronic payments	Multimodal integrated fare card	Multimodal multichannel (fare cards, cell phones, etc.)
	Traveler information	Static information	Static trip planning with limited real-time alerts	Multichannel trip planning and account-based alert subscription	Location-based, on-journey multimodal	Location-based, multimodal proactive rerouting

Source: ANTP (2012)

5.4. Analysis on CO2 emissions

Considering the main transport options to export the soybean from Mato Grosso by the port of Santos, there were selected two options to calculate the emissions of greenhouse gases. The first corresponds to the handling made entirely by roads, since Sorriso (Mato Grosso), until the port of Santos. The second refers to the use of railway between the Modalohr multimodal terminal and the port of Santos, after the section from Sorriso to the terminal, made by trucks. It is important to explain that the municipality of Sorriso was selected as representative of the producing region of Mato Grosso by its outstanding position in the commodity culture.

The greenhouse gases emissions related to the soybean export made by roadways were calculated according to the rationale of national guidelines for greenhouse gases inventories from the IPCC[*] (Wakdron et. al., 2006). The rationale has an easy application, once it uses only the fuel consumption and the emission factor for the type of fuel used, as shown in the Equation 2.

$$E_r = F_j * EF_j$$

Equation 2. CO² annual emission by roadways
Source: DA CUNHA; CLAUDIO BARBIERI (2014)

With:

- $\mathrm{E_r}$ = Annual emission by the soybean corridor [kilograms of CO² / year];
- $\mathrm{F_j}$ = Total fuel consumption [TJ];
- $\mathrm{EF_j}$ =Emission factor for the fuel type j [Kg / TJ];
- j = Fuel type (e.g.: diesel, natural gas, gas).

According to the research made by Anpet “Potential reduction on emission of greenhouse gases through multimodal systems in the soybean handling”, it was not possible to obtain primary data of the total roadway consumption for the export corridor of the commodity, resulting on the use of the Equation 3 to estimate the total fuel consumed.

[*] Intergovernmental Panel on Climate Change

$$C_j = D * H * T$$

Equation 3. Total fuel consumption
Source: DA CUNHA; CLAUDIO BARBIERI (2014)

With:

- D = Roadway distance from Sorriso to the port of Santos [kilometers];
- H = Annually handled cargo from Sorriso to the porto Santos [tons];
- T = Consumption factors of fuel by ton-kilometer [liters / ton*kilometers].

The emission factor for diesel trucks, which enables to convert fuel into carbon dioxide (CO^2) was extracted from the First National Inventory of Air Emissions by Road Motor Vehicles prepared by the Environmental Ministry (2011), as shown in Table 3.

Table 3. CO^2 emission factors for trucks

Gasoline (kg/l)	Anhydrous ethanol (kg/l)	Hydrous ethanol (kg/l)	Diesel (kg/l)	NGV (kg/m³)
2.269	1.233	1.178	2.671	1.999

Source: DA CUNHA; CLAUDIO BARBIERI (2014)

For the multimodal alternative, on the other hand, calculation was carried out in two steps. First, it was analyzed the road connecting Sorriso to the multimodal integration terminal in Rondonópolis. Then the rail route was added to the section.

The emissions in both sections are summed, in order to estimate the total emission for the multimodal alternative (Equation 4).

$$E_i = D_r * V * T_r * EF_r + D_f * V * T_f * EF_f$$

Equation 4. CO^2 annual emission by road-rail systems
Source: DA CUNHA; CLAUDIO BARBIERI (2014)

With:

- D_r = Distance for the roadway section [kilometers];
- H = Annually handled cargo from Sorriso to the port of Santos [tons];
- T_r = Consumption factor of fuel by ton-kilometer of soybean handled by roadway [liters / ton*kilometers];
- EF_r =Emission factor by liter of diesel consumed by the roadway system, [kilograms of CO² / liter];
- D_f = Distance for the railway section [kilometers];
- T_f = Consumption factor by NTK* of soybean handled by railway [liters / NTK];
- EF_r =Emission factor by liter of diesel comsumed by the railway system [kilograms of CO² / liter].

The monthly fuel consumption in each section of the rail route and its cargo handling in GTK**, were provided by the railway concessionaire responsible for operating the studied corridor, from October 2012 to September 2013 (Table 4). From these data, it was considered the median between the calculated energy efficiency. It should be noted that there is a substantial variation in this parameter for the analyzed sections, due to variations in the track gradient, type of locomotive, the cargo handled or the loading method. This variety was the reason to use the median instead of the average, in this case, in order to result on a figure closer to reality.

As fuel consumption data were not provided in liter / NTK, the relationship between the movement in net ton kilometer and gross ton kilometer was estimated at 0.73. This estimate was based on information provided by the concessionaire for the most recurring locomotive models in the soybean transport on this route, the size of the compositions, the tare weight of the wagons, as well as the net cargo usually transported by a wagon. Furthermore, it is interesting to state that in the Araraquara stop, a locomotive is added to the composition, ensuring greater driving force for the second part of the trip.

* Net Ton Kilometer

** Gross Ton Kilometer

Table 4. Monthly consumption of fuel and cargo handling

Section	Distance [km]	Annual consumption [liter of diesel]	Annual handling [GTK]
Alto Araguaia - Olacyr Morais	98	4,552,770	1,343,338,268
Olacyr Morais - Chapadão do Sul	111	511,411	260,238,402
Chapadão do Sul - Santa Fé do Sul	308	2,755,618	1,423,603,184
Santa Fé do Sul - Rio Preto Paulista	218	10,388,509	3,549,461,519
Rio Preto Paulista - Santa Adélia	89	3,064,704	835,151,861
Santa Adélia – Araraquara	114	4,061,579	1,102,022,040
Araraquara – Rio Claro Novo	123	13,483,445	2,507,750,847
Rio Claro Novo – Itú	135	9,482,507	2,614,311,321
Itú – Embúguaçú	69	13,733,230	2,206,554,024
Embúguaçú – Paratinga	27	3,853,028	1,484,850,802
Paratinga – Conceiçãozinha	44	1,120,939	426,335,777

Source: DA CUNHA; CLAUDIO BARBIERI (2014)

The emission factor for railways was obtained from the national guidelines for inventories of greenhouse gas emissions produced by the IPCC in 2006 (Table 5), since there is no specific regulation for railway emissions in Brazil and therefore, still not disclosed the average factors for locomotive models in operation in the country (ANTP, 2012). For conversions to joule liter of fuel consumed it was adopted the ratio of 8,160 kcal / liter as the calorific value of diesel power.

Table 5. Emission factor for railways

Emission factor [kilogram of CO^2 / TJ]	
Default	74,100

Source: DA CUNHA; CLAUDIO BARBIERI (2014)

6. Case study

In this section, it will be presented analysis and results of the soybean flow produced in Mato Grosso to the port of Santos by installing a multimodal terminal with the Modalohr technology in Rondonópolis. For this study, it was made a comparison with an existing terminal in the region that uses the tipping and storage method to handle the commodity. It is noteworthy that the proposed idea is complementary to that terminal and aims to add capacity to the system, besides enhancing the use of the multimodal option for primary products in Brazil.

Firstly, there were considered some input data that was provided by ALL (America Latina Logistica), the operator of the existing terminal in Rondonópolis:

- Standard truck: average transport capacity of 45 tons;
- Standard railway train: average of 120 wagons per train;
- Standard wagon: average transport capacity of 110 tons.

6.1. Capacity analysis on the existing terminal in Rondonópolis

After consulting the Company, ALL provided the following operational data of the terminal:

- Loading capacity: 3.5 hours per train
- Terminal operations: 24 hours per day, 362 days per year (3 days per year are intended for maintenance)

Thus, the terminal's capacity was estimated, as shown in the Table 6:

Table 6. Total capacity of the existing Rondonópolis terminal

Annual capacity for handling general cargo	32.8 million of tons / year
Maximum attendance	2,011 trucks / day

Source: Elaborated by the author

From the data published by ALL, 2015, eight months after opening the terminal, 6.5 million tons of general cargo were handled. Of these, 3.5 million were due to the soybean. Thus, one can estimate that approximately 54% of the terminal operations are intended for the oil seed. Moreover, the company reported that the average number of service is 1,200 trucks / day, representing a usage approximately 60% of the total available capacity. Table 7 shows the capacity and annual average transportation soybean transshipped in Rondonópolis:

Table 7. Soybean handling of the existing Rondonópolis terminal (estimates)

Annual capacity for soybean handling	17.6 million tons / year
Effective annual soybean handling	10.5 million tons / year

Source: Elaborated by the author

6.2. Capacity analysis on the proposed terminal with the Modalohr technology

Assuming a same size terminal such as the existing Rondonópolis one, above analyzed, in order to evaluate the increase in efficiency that the Modalohr technology can provide, this section will present the capacity analysis of a new terminal with such technology.

The French company Lohr, asserts that a train can be loaded within 2 hours, 75% faster than the ALL operating terminal. Therefore, the characteristics of the implementation of such terminal can be seen in the Table 8.

Table 8. Operational data of a terminal in Rondonópolis with the Modalohr technology

Annual capacity for handling general cargo	57.3 million of tons / year
Maximum attendance	3,520 trucks / day
Projected attendance	2,100 trucks / day
Annual capacity for soybean handling	30.9 million tons / year
Effective annual soybean handling	18.4 million tons / year

Source: Elaborated by the author

6.3. Analysis on freight rates in the soybean flow

In order to better understand the current soybean logistics, it was developed an analysis of freight rates in the commodity flow to the port of Santos. It was used, as reference, the producing municipality of Sorriso as representative of the Mato Grosso region.

First it was analyzed the prices charged by major logistics companies, for handling the soybean from Sorriso to the port of Santos entirely by road transport (Table 9).

Table 9. Road freight between Sorriso - port of Santos

Company	**Price (R$/ton)**
Transvidal	275.00
Diamante transportes	290.00
Sandra ca1rgas	275.00
MN + logistics	295.00
Fribon transportes	285.00
Median	**285.00**

Source: www.fretebras.com.br (2016)

Table 10. Road freight between Sorriso - Rondonópolis

Company	Price (R$/ton)
Rodolider transportes	99.00
Belluno	98.00
Transvidal	97.50
Diamante transportes	103.00
Fribon transportes	92.00
Median	**98.00**

Source: www.fretebras.com.br (2016)

Table 11. Historical railway freight between Rondonópolis - port of Santos

Month	Freight
Jan-13	165.00
Feb-13	175.00
Mar-13	228.00
Apr-13	194.00
May-13	165.00
Jun-13	179.00
Jul-13	191.00
Aug-13	206.00
Sep-13	204.00
Oct-13	190.00
Nov-13	170.00
Dec-13	178.00
Jan-14	167.00
Feb-14	230.00
Mar-14	219.00
Apr-14	183.00
May-14	180.00
Jun-14	185.00
Jul-14	178.00
Aug-14	181.00
Sep-14	161.00
Oct-14	139.00
Nov-14	139.00
Dec-14	142.00
Jan-15	143.00
Feb-15	160.00
Mar-15	214.00
Apr-15	205.00
May-15	190.00
Jun-15	190.00
Jul-15	193.00
Aug-15	202.00
Sep-15	213.00
Oct-15	213.00
Median	**184.00**

Source: ALL (2015)

Then, through the median of the prices charged for road transport between Sorriso and Rondonópolis (Table 10) and the historical series of Jan-13 to Oct-15 of rail freight between Rondonópolis and the port of Santos (Table 11), it was obtained an average value of R $ 282.00 for the soybean current multimodal transport.

With the analysis made, it was found that the logistics cost for the producer when choosing from road or multimodal options does not have a significant difference. As previously mentioned and easily verified by the Table 11 presented, the freight price charged for the railway section is very volatile and only in some periods of the year, road-rail transport becomes interesting.

Thus, it is relevant to discuss in detail the analysis of a potential reduction in the current rail freight with the installation of new Modalohr terminal in the region.

First, one must consider that today there is no multimodal competition in the region, allowing greater fluctuations in prices according to the demand for the soybean flow. The introduction of a new terminal would add a competitive framework in Rondonópolis, possibly with a significant impact on the transport prices charged for the rail use today. Therefore, through the soybean pricing formula already presented in the methodological review section, it can be said that a possible reduction in the rail freight, and consequent reduction in the price for soybean handling, between major producers in Mato Grosso and the port of Santos, would most likely increase the profitability of producers as a whole.

6.4. Simulation of truck’s logistics

An efficient logistic of the truck’s arrivals is extremely important to provide a better flow to the whole system in the terminal. Therefore, it will be presented the result of several service levels by showing the line formation for different average of attendance.

The intention of this study is to understand the line formation that could be observed in the proposed terminal which will directly impact the terminal efficiency and, in case of higher chances of queuing, actions should be made, such as the application of a more integrated system thorugh the ITS tools available.

The following graphs show the Poisson distribution for different average of truck's arrivals. It was also shown the results for the scenario where the terminal operates with an average arrival equal to the terminal's capacity (2.44 trucks / minute).

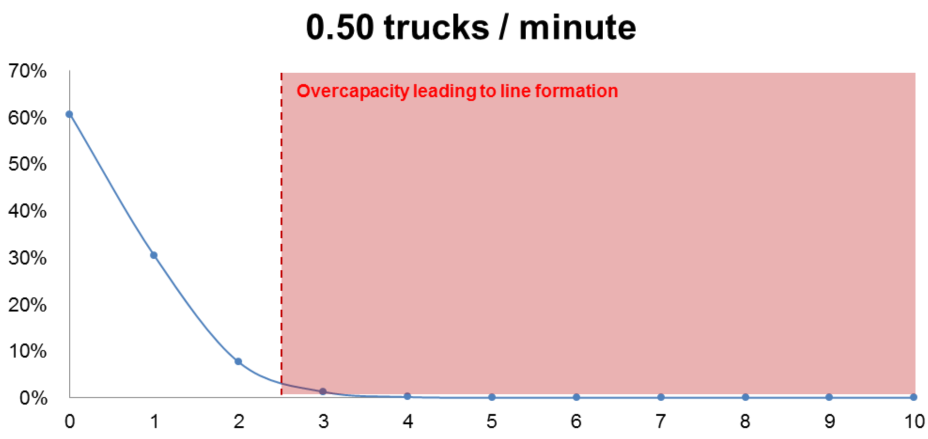


Figure 27. Poisson distribution consideraing an average arrival of 0.50 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation is extremaly low, with approximately 1% chance of line formation.

The following graph shows the accumulated result:

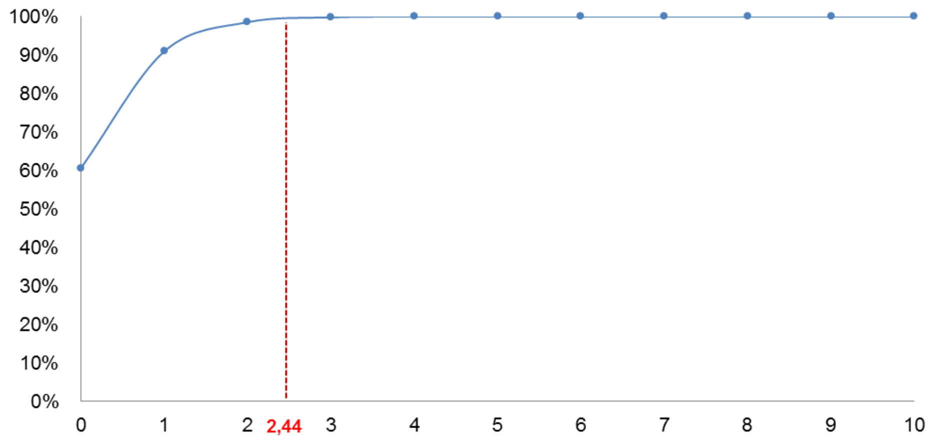


Figure 28. Accumulated Poisson distribution consideraing an average arrival of 0.50 trucks / minute
Source: Elaborated by the author

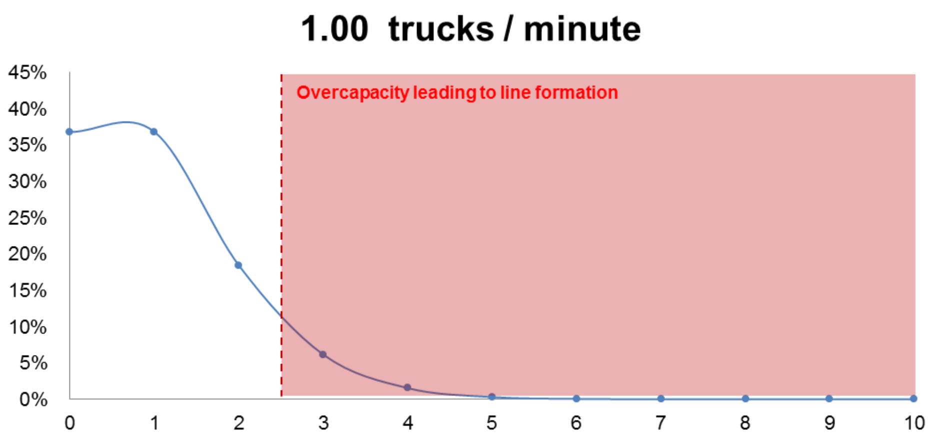


Figure 29. Poisson distribution consideraing an average arrival of 1.00 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation remains low, with approximately 8% chance of line formation.

The following graph shows the accumulated result:

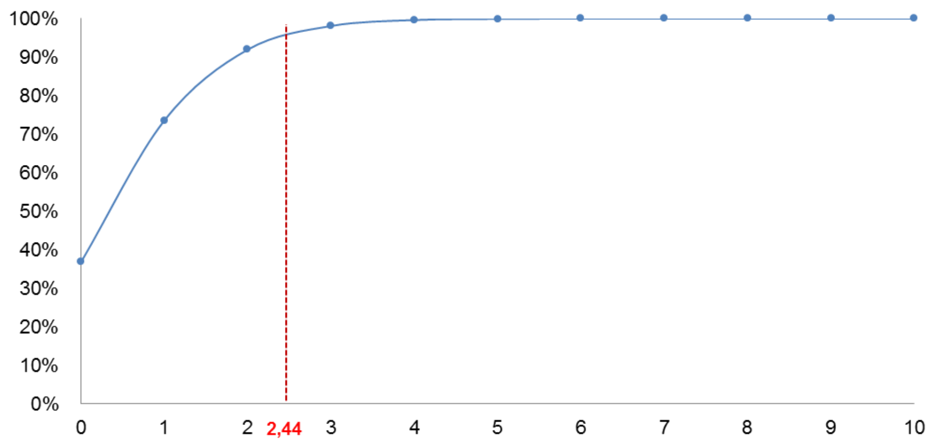


Figure 30. Accumulated Poisson distribution consideraing an average arrival of 1.00 trucks / minute
Source: Elaborated by the author

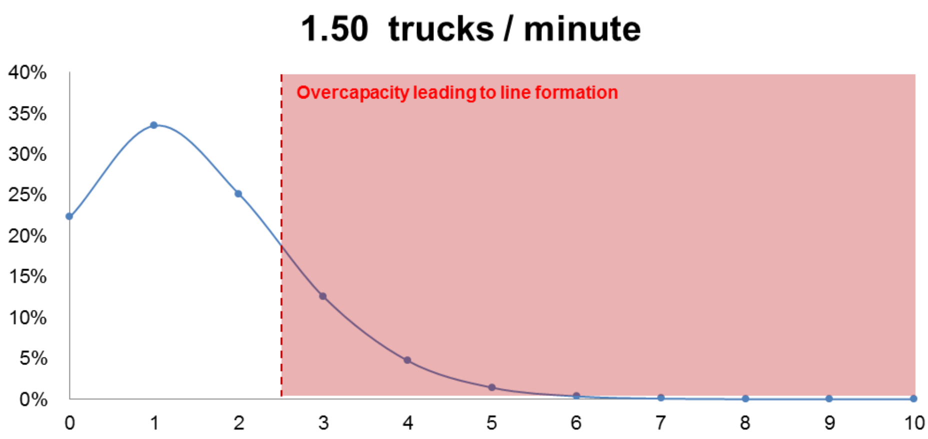


Figure 31. Poisson distribution consideraing an average arrival of 1.50 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation increases, with approximately 19% chance of line formation.

The following graph shows the accumulated result:

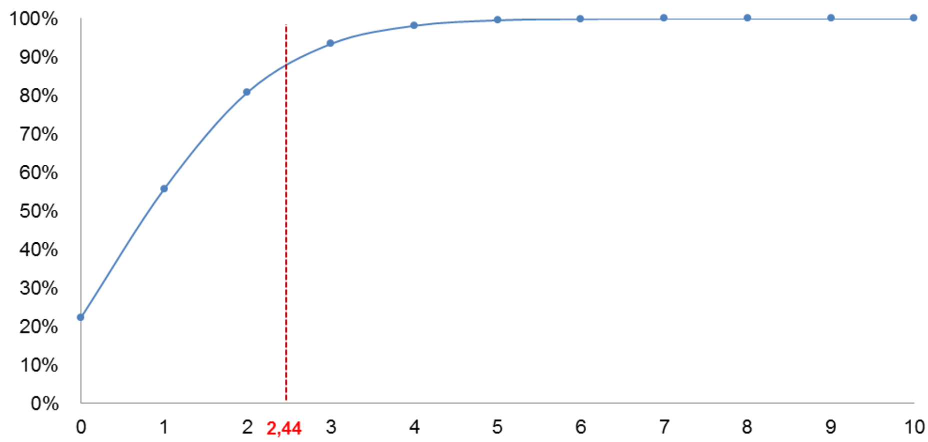


Figure 32. Accumulated Poisson distribution consideraing an average arrival of 1.50 trucks / minute
Source: Elaborated by the author

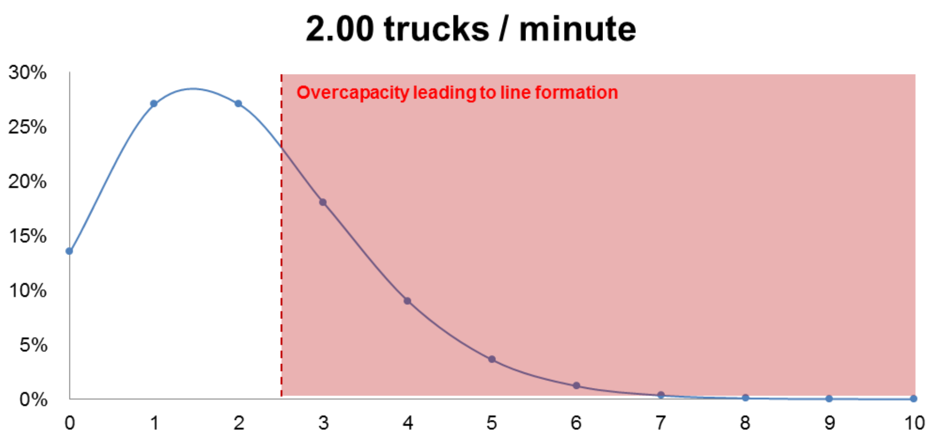


Figure 33. Poisson distribution consideraing an average arrival of 2.00 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation starts to be considerable, with approximately 32% chance of line formation.

The following graph shows the accumulated result:

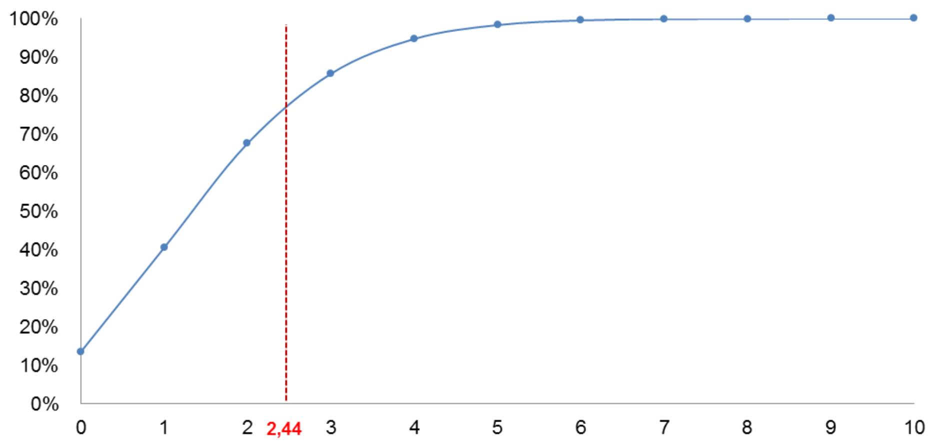


Figure 34. Accumulated Poisson distribution consideraing an average arrival of 2.00 trucks / minute
Source: Elaborated by the author

The following scenario represents an average arrival equal to the terminal`s capacity of 2.44 trucks / minute:

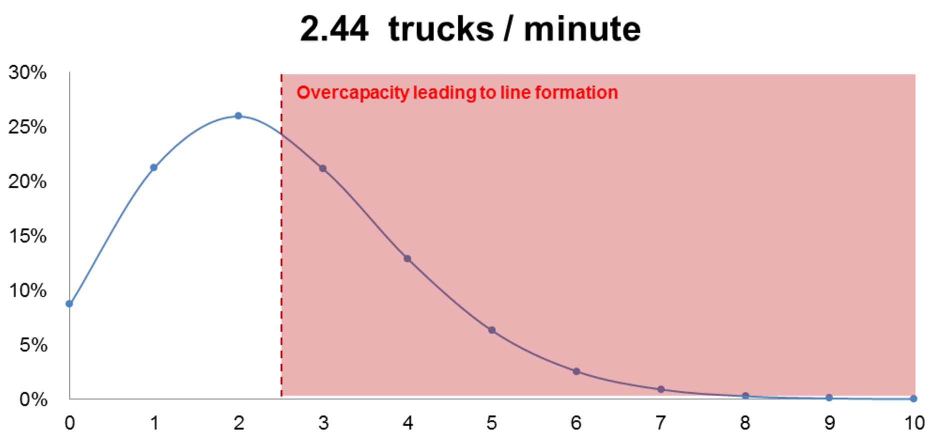


Figure 35. Poisson distribution consideraing an average arrival of 2.44 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation is considerably relevant, with approximately 44% chance of line formation.

The following graph shows the accumulated result:

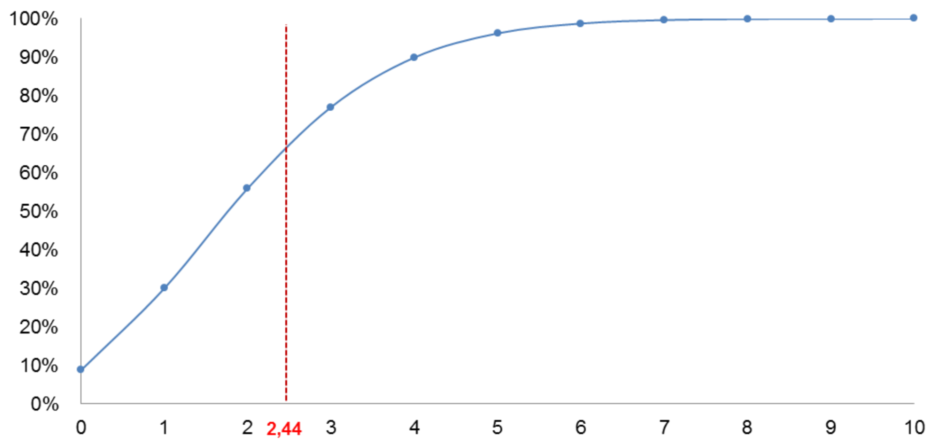


Figure 36. Accumulated Poisson distribution consideraing an average arrival of 2.44 trucks / minute
Source: Elaborated by the author

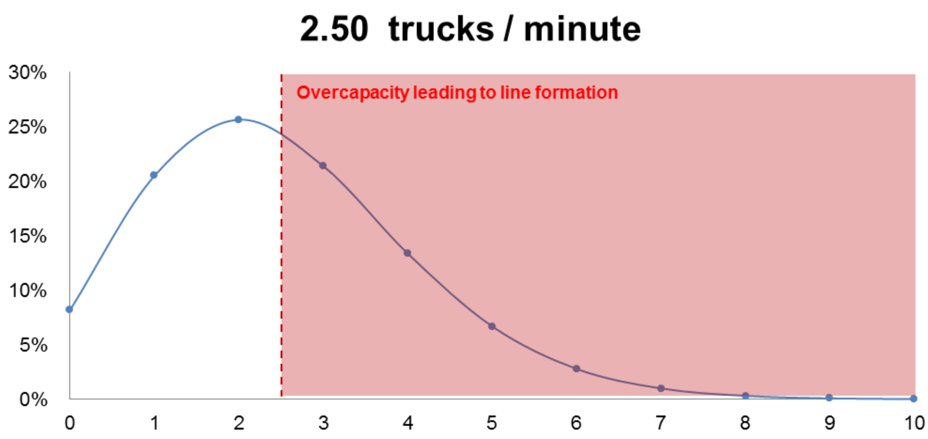


Figure 37. Poisson distribution consideraing an average arrival of 2.50 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation is considerably relevant, with approximately 46% chance of line formation.

The following graph shows the accumulated result:

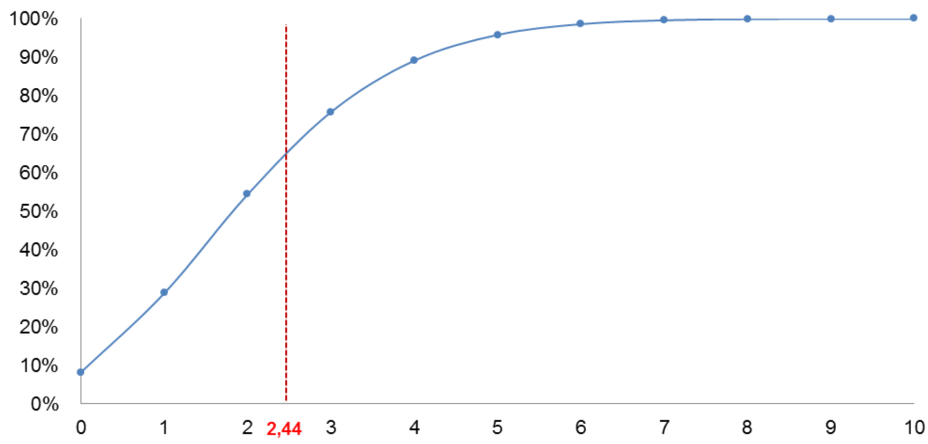


Figure 38. Accumulated Poisson distribution consideraing an average arrival of 2.50 trucks / minute
Source: Elaborated by the author

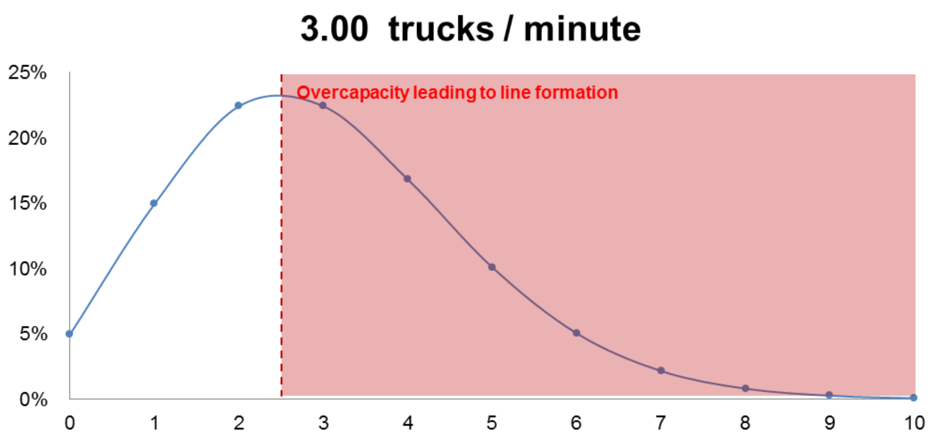


Figure 39. Poisson distribution consideraing an average arrival of 3.00 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation is considerably high, with 58% chance of line formation.

The following graph shows the accumulated result:

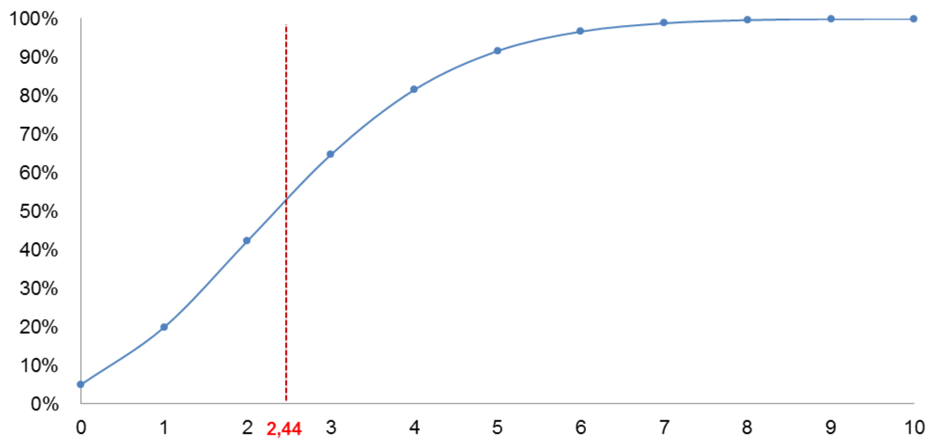


Figure 40. Accumulated Poisson distribution consideraing an average arrival of 3.00 trucks / minute
Source: Elaborated by the author

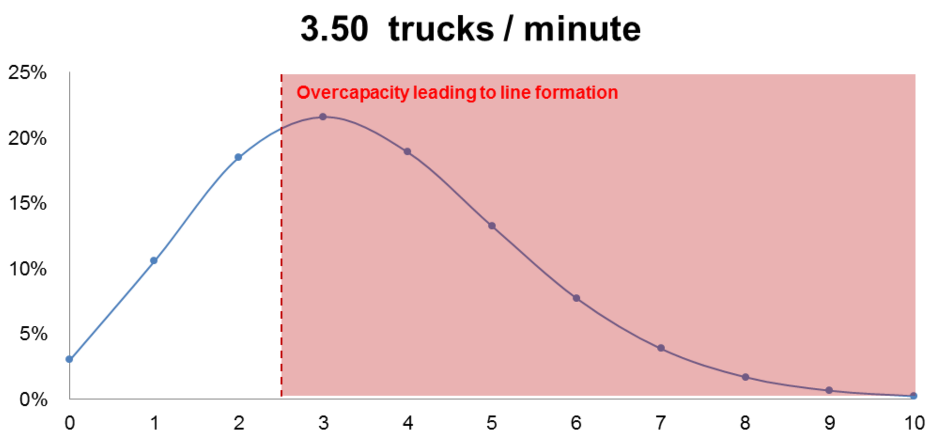


Figure 41. Poisson distribution consideraing an average arrival of 3.50 trucks / minute
Source: Elaborated by the author

Considering the above scenario of operation, the probability of line formation is considerably high, with 68% chance of line formation.

The following graph shows the accumulated result:

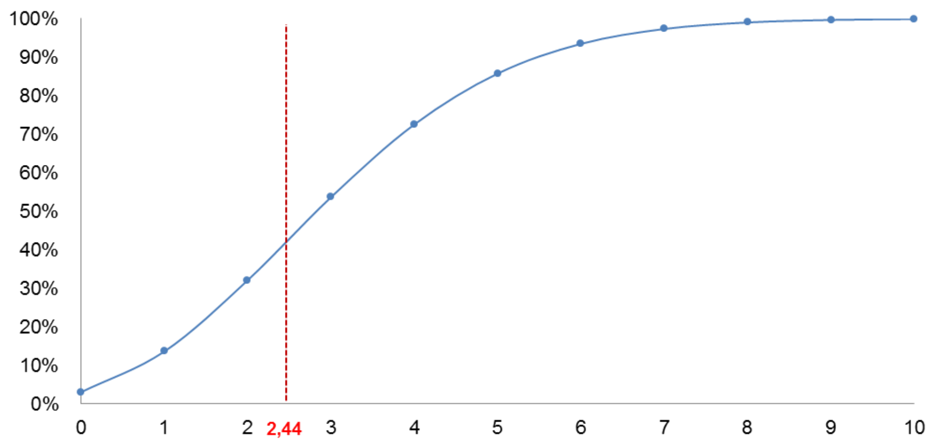


Figure 42. Accumulated Poisson distribution consideraing an average arrival of 3.50 trucks / minute
Source: Elaborated by the author

6.5. Analysis on the application of ITS tools in the Modalohr terminal

With the reasoning of technology applied to the Modalohr system, it improvements can be applied relating with automation, telecommunication and operational control. This study aims to optimize the multimodal system in order to speed the transshipment and, consequently, reduce the aggregated cost of the soybean commodity.

Regarding the automation, it is extremely important that the arrival and departure of the semi-trailers are synchronized so as not to cause unnecessary delays. The operation occurs with a 30º rotation of the wagon's axis with the loading made as a "herring bone", of all trucks at the same time, as can be seen in Figure 43.

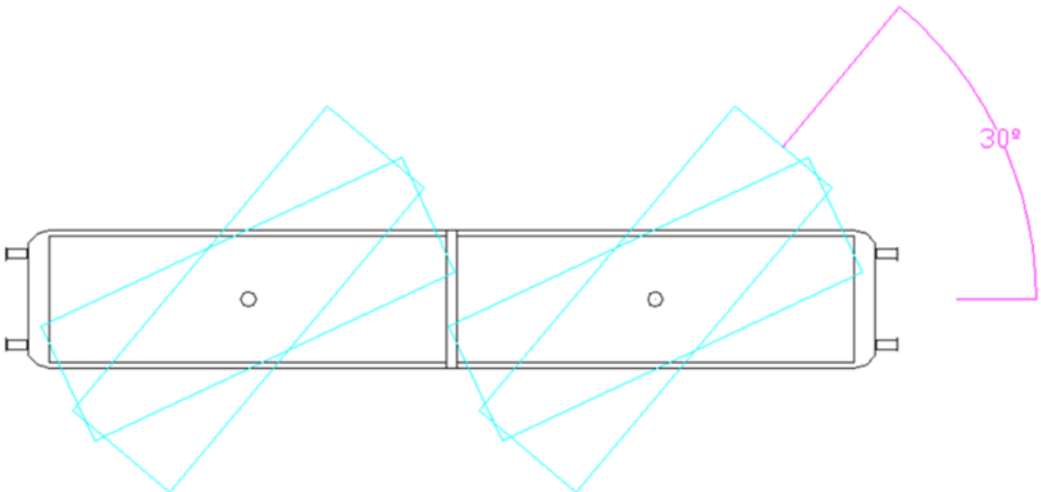


Figure 43. Rotation scheme of a standard Modalohr wagon
Source: Elaborated by the author

As for telecommunications, it can be installed wireless systems and the Radio Frequency Identification (RFID) in the terminal as a solution to integrate and better manage the arrival and departure of the trucks and the trains. The proper logistic management of the trucks has a substantial effect on the system efficiency and should be properly detailed in this study.

Therefore, an interesting system to be implemented is the use of electronic tags on trucks, which consists of the installation of an electronic device on the windshield in order to identify the vehicle and optimize its logistics, as well as significantly reduce the time spent on customs. Another interesting technology to be introduced is the automatic weighing, also aiming to reduce the time spent in the terminal. As for the weighting, in the entrance it is recommended to be installed a less precise scale called weighting motion and an additional, more précised scale, inside the terminal in order to decrease the time spent at the weighting operation.

The operational control system integrates various aspects such as operational monitoring, operational management, operational safety, signaling suitability, support to equipment maintenance, electrical control system, among others.

It is worth emphasizing that a combination of the aforementioned items is essential in order to take advantage of the best possible from the technologies already on the market and benefit of potential synergies from the interaction of the installed devices.

Another aspect to be considered is the maturity evaluation of the project, as can be seen in the IBM matrix resubmitted in this section with such analysis (Table 12), in which is represented the approximate level of the proposed terminal with the installation of the technologies described above. Thus, it is clear that it is a highly technological system with high level of efficiency, requiring integration and constant monitoring of all operative activities. Among them, proper execution of the logistics on arrival and departure of trucks is crucial so as to be compatible with the frequency of trains on the terminal.

Moreover, another ITS system that is mandatory in a project of such type is the surveillance equipment to be installed in the terminal. It is very important to understand that such terminal needs protection and a strict custom service, once it relies mainly on the handling of export cargo.

Table 12. Intelligent Transport Maturity Model matrix analysis

		Level 1: Single mode	Level 2: Coordinated modes	Level 3: Partially integrated	Level 4: Multimodal integration	Level 5: Multimodal optimized
Governance	Strategic planning	Functional area planning (single mode)	Project – based planning (single mode)	Integrated agency – wide planning (single mode)	Integrated corridor – based multimodal planning	Integrated regional multimodal planning
	Performance measurement	Minimal	Defined metrics by mode	Limited integration across organizational silos	Shared multimodal system – wide metrics	Continuous system – wide performance measurements
	Demand management	Individual static measure	Individual measures, with long-term variability	Coordinated measures, with short-term variability	Dynamic pricing	Multimodal dynamic pricing
Transport network system	Data collection	Limited or manual input	Near real-time for major routes	Real-time for major routes using multiple inputs	Real-time coverage for major corridors, all significant modes	System – wide real-time data collection across all modes
	Data integration and analytics	Limited with ad hoc analysis	Networked but periodic analysis	Common user interface with high-level analysis	Two-way system integration and analysis in real-time	Extended integration with multimodal analysis in real-time
	Network operations response	Ad hoc, single mode	Centralized single mode	Automated, single mode	Automated, multimodal	Multimodal real-time optimized
	Incident management	Manual detection, response and recovery	Manual detection, coordinated response, manual recover	Automated detection, coordinated response, manual recover	Automated pre-planned multimodal recovery plans	Dynamic multimodal recovery plans based on real-time data
Integrated transport services	Customer relationships	Minimal capability, no customer accounts	Customer accounts managed separately for each system / mode	Multichannel account interaction by mode	Unified customer account across multiple modes	Integrated multimodal incentives to optimize multimodal use
	Payment systems	Manual cash collection	Automatic cash machines	Electronic payments	Multimodal integrated fare card	Multimodal multichannel (fare cards, cell phones, etc.)
	Traveler information	Static information	Static trip planning with limited real-time alerts	Multichannel trip planning and account-based alert subscription	Location-based, on-journey multimodal	Location-based, multimodal proactive rerouting

Source: ANTP (2012)

The three main strategies where performance levels are evaluated are governance, transport network optimization and integrated transport services. The model is a macro level multimodal analysis. Like most maturity models, an organization's current and best practice levels can be mapped and gaps identified. Leading practice is considered to be shifting to the right over time (level 5: multimodal optimized).

6.5.1. Strategic planning

The Modalhor system consists on integrating the transport of soybean originated in the fields from Moto Grosso until the port of Santos. Due to that reason, it connects several regions but limited to the municipality of Rondonópolis. Therefore it can be classified as level 4 in the strategic planning criteria from the IBM matrix.

6.5.2. Performance measurement

For the system proposed, the criteria regarding the performance measurement should be considered as level 5 in the IBM matrix presented above. Taking into consideration that the technology proposed is considerably new worldwide and has never been implemented in Brazil before, it is extremely important to install high-tech systems that could measure the performance of the new terminal in several levels, such as the frequency of arrivals and departures, either of trucks and trains, for instance. It is also relevant to propose not only operational measurements, but also a financial analysis of the return rate that the new terminal would be able to bring in the long term.

6.5.3. Demand management

In order for the system to be competitive among the order soybean transport options available, the pricing model to be adopted should be integrated between the logistic companies that operate the trucks and ALL, which operates the railway system. Being established and incorporated with a pre-defined single fare, the demand of the new terminal would be settled and therefore, the criteria regarding the demand management can also be considered as level 5 in the IBM matrix.

6.5.4. Data collection

In Brazil, real-time update of transport utilities is not yet developed and is a very important topic that should be discussed in future studies. Due to the lack of information in this field, data collection can be considered as being level 4 in the IBM matrix and can be collected, mainly in the railway section. The road section between the producing fields in Mato Grosso to the Rondonópolis terminal will be extremely hard to be analyzed in real time. In order to be as accurate as possible, electronic tags can be installed in the trucks in accordance with the operator companies. With such technology, the arrival of trucks in the terminal can be better managed, increasing the overall efficiency.

6.5.5. Data integration and analytics

The Modalhor terminal consists in a system with two different types of modal: rail and roadway. Therefore, the data integration and analytics can be considered as level 4 in the IBM matrix. This criteria is correlated to the data collection and the same electronic tags aforementioned should be used in order to guarantee better performance in the proposed terminal.

6.5.6. Network operations response

In the network operations response criteria, the same reasoning presented for data collection regarding the lack of development in real-time update for transport utilities would make it to better suit the level 4 in the IBM matrix. It is important to emphasize that further studies should be promoted in this field in Brazil in order to guarantee the competitiveness of the country worldwide.

6.5.7. Incident management

Once more, the incident management criteria faces the same problem that data collection and network operations response and is also coupled with a very limited technology developed in Brazil. Therefore, it can be considered as level 3 in the IBM matrix.

6.5.8. Customer relationship

In the proposed multimodal system, it is very important to create and organize a unified customer account to ease either the clients choice as for the operator of the terminal. An integrated system can face difficulties to be installed at a first instance but should also be improved. Therefore, the customer relationship criteria can be considered also as level 4 in the IBM matrix. In order to promote the integration, currently available options that could be used would be the SAP, TOTVS and Oracle systems.

6.5.9. Payment systems

Regarding the payment systems, it is very important to ease the client`s payment method in order to make the terminal more competitive regarding the other modal options. Therefore, an integrated fare should be implemented and always seeking for improvement. This criteria was considered level 4 because Brazil is still developing new payment methods and at a first instance it would be hardly possible to have state-of-the-art technologies regarding such criteria.

6.5.10. Traveler information

The traveler information criteria was considered as level 4 in the IBM matrix because of the importance of such data either for the client as for the terminal operator. The reasoning for this consideration is mainly due to the need of providing information to the client about the merchandise arrival to the port of Santos. It still faces update problems due to lack of technology in the country and it still cannot ve considered as level 5.

6.6. Evaluation on environmental impact caused by implementing the Modalohr terminal

Brazil currently has a transport infrastructure that does not operate efficiently between modes, causing a serious imbalance in the transport framework. Logistics costs in Brazil reached an amount equivalent to 11.6% of GDP in 2008, equivalent to R$349 billion. Therefore, with the inefficiency of the system, it is observed that for the environment, these costs can result in high greenhouse gases emission levels (VALENTE, 2008).

The transport sector has been the leading consumer of oil in Brazil for a long time, through the extensive use of cars powered with gasoline and diesel, fossil fuels most used in the industry. In 2009, the sector alone was responsible for the consumption of 51.2% of the total oil products consumed in the country (EPE, 2010).

Within such a high consumption of petroleum products, the transportation sector was responsible for the intake of 35.8 million cubic meters of diesel, with 97% of this consumption only in the road sector, which corresponds to 34.6 million cubic meter (EPE, 2010). This consumption of diesel by road was equivalent to 78% of diesel consumption in Brazil in 2009 (EPE, 2010). Gasoline is a fossil fuel that is used only by the transport sector, and is the second most used fuel in the country. Figure 44 illustrates the fact that the energy consumption and CO^2 emissions per amount of cargo (grams of CO^2 per net ton-kilometer) are higher for road transport, followed by rail and waterway transport.

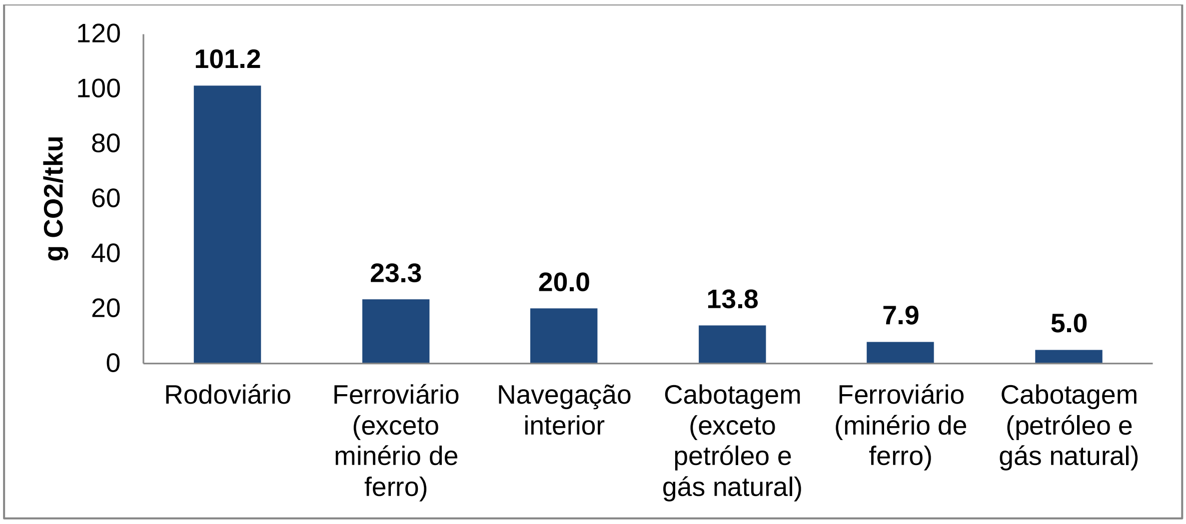


Figure 44. CO^2 emissions by transport mode in Brazil
Source: EPE (2010)

It is noted, therefore, that changing the modal in a regional transport of cargo from road to less intensive energy modes, can have a potentially important role in greenhouse gases mitigation. The sector plan for transport and urban mobility for the mitigation and adaptation to climate change*, on the cargo transport, prepared by the transport ministry, explores this role, estimating the potential impact of the implementation of projects from the national plan for logistics and transport** (IEMA, 2015).

* "PSTM – Plano Setorial de Transporte e da Mobilidade Urbana para Mitigação e Adaptação à Mudança do Clima"

** "PNLT – Plano Nacional de Logística e Transportes"

In this way, it was preceded with the analysis of the potential CO² reduction emitted into the atmosphere through the installation of Modalohr terminal. The conducted study aimed to quantify the maximum reduction that the installation of the proposed technology would bring to the environment by reducing the number of outstanding trucks on the highways from Mato Grosso to the port of Santos. For this, the following distances from Figure 45 were considered as evaluation assumptions:

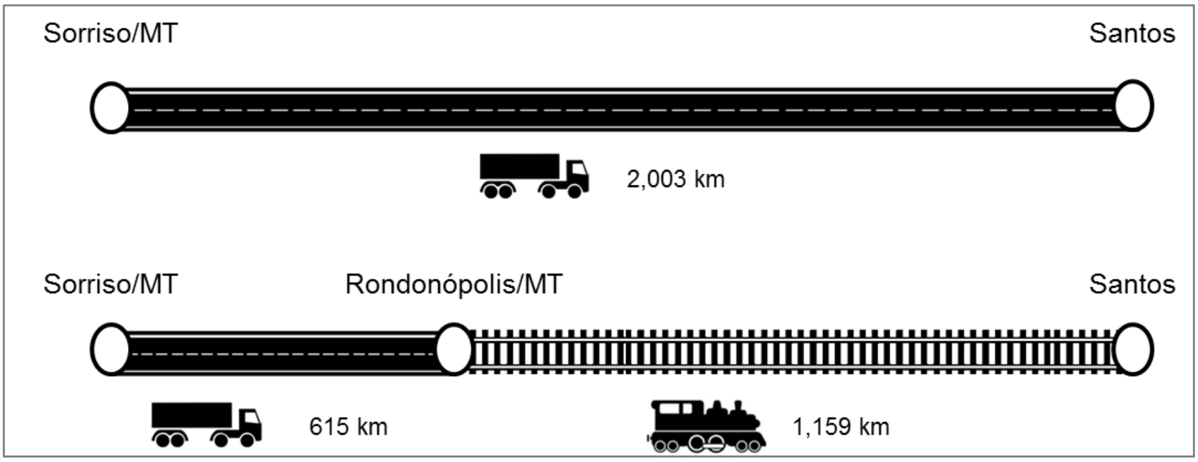


Figure 45. Distances between Sorriso (Mato Grosso) and the port of Santos - road and road-rail options
Source: Elaborated by the author

In order to encourage the rail modal efficiency for the selected section, it was taken the data provided by the railway concessionaire ALL for this analysis. The value used in the calculations was the median between the selected sub-sections resulting on an efficiency of 4.64 * 10^{-3} litros/NTK (Table 13).

Table 13. Railway energetic efficiency

Section	Annual comsumption [liters of diesel]	Annual handling [NTK]	Efficiency [lliters / 10^3*NTK]
Alto Araguaia - Olacyr Morais	4,552,770	980,636,936	4.64
Olacyr Morais - Chapadão do Sul	511,411	189,974,033	2.69
Chapadão do Sul - Santa Fé do Sul	2,755,618	1,039,230,324	2.65
Santa Fé do Sul - Rio Preto Paulista	10,388,509	2,591,106,909	4.01
Rio Preto Paulista - Santa Adélia	3,064,704	609,660,859	5.03
Santa Adélia – Araraquara	4,061,579	804,476,089	5.05
Araraquara – Rio Claro Novo	13,483,445	1,830,658,118	7.37
Rio Claro Novo – Itú	9,482,507	1,908,447,264	4.97
Itú – Embúguaçú	13,733,230	1,610,784,438	8.53
Embúguaçú – Paratinga	3,853,028	1,083,941,085	3.55
Paratinga – Conceiçãozinha	1,120,939	311,225,117	3.60

Source: DA CUNHA; CLAUDIO BARBIERI (2014)

From this and making the use of rationale presented in the theoretical background section, the following CO^2 emission results were obtained (Figure 46):

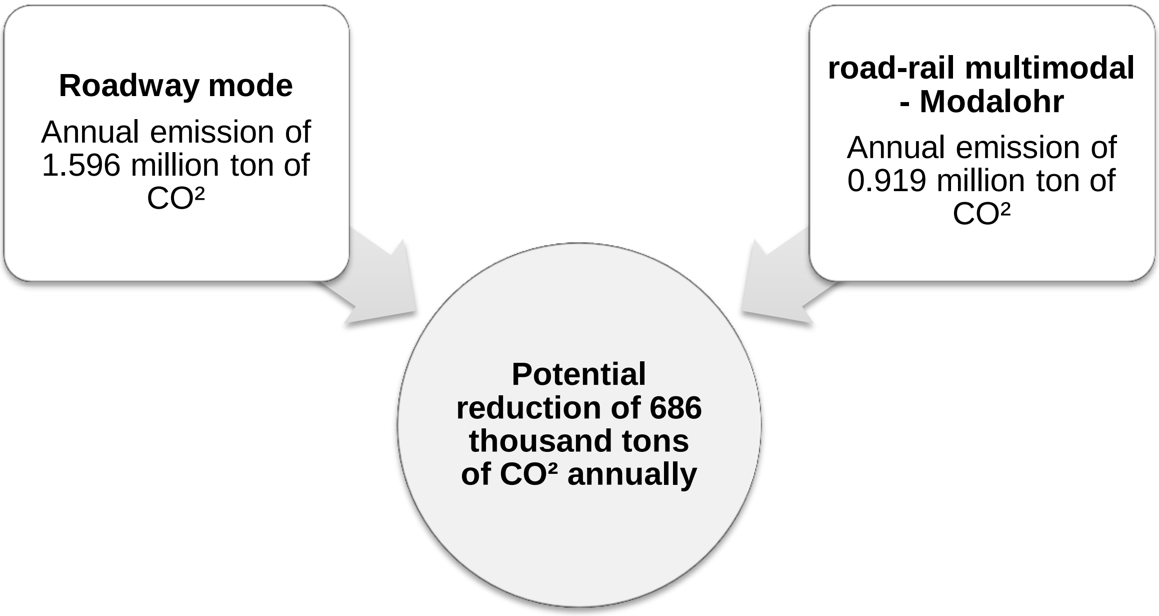


Figure 46. Maximum CO^2 emissions

Source: Elaborated by the author

With the result it is possible to see that the installation of the proposed terminal would have a significant impact on decreasing the CO^2 emissions per year. It is worth emphasizing that the study considers the maximum potential on CO^2 reduction only regarding the soybean transport. In the scenario that it is considered the soybean handling for the early years of operations for the terminal, the approximate gain in reducing CO^2 emissions would be projected as being 409,000 tons per year. This value shows that even if not operating at its full capacity, this multimodal system is already able to promote a relevant impact on the environment.

7. Conclusions

This study was intended to analyze the flow of the Brazilian soybean from the main producing farms from the state of Mato Grosso to the port of Santos. Such assay is fundamental for the country's economy and for maintained its important position among the main global players.

Therefore, in order to improve the current system, it was proposed a new technology, currently only available in Europe, to be installed in the tropical country. The referred proposal was the Modalohr system. The idea was the implementation of a transshipment terminal in the municipality of Rondonópolis (Mato Grosso) to add capacity of the already existing terminal that uses the tipping technique.

Thereby, after detail analysis made possible due to the data provided by the company that operates the existing terminal (ALL), it was possible to verify that new technologies are critical for the Brazilian competitiveness worldwide. Another very important aspect to mention is the lack of infrastructure projects that the country currently faces and its negative effect in the soybean market.

After the study, it was also possible to understand that the soybean producers are the most affected by high freight prices, once the final price charged by then is directly influenced by the handling cost. In this context, the results obtained revealed very considerable increase in efficiency compared to one of the best multimodal terminals in Brazil. With the Modalohr technology, the time for loading a train compared to the existing terminal in Rondonópolis would drop from 3.5 hours / train to 2.0 hours / train, which leads to a 75% increase in the efficiency, with a capacity leveraging from 1.4 to 2.4 trucks / minute. This new capacity represents a total transport of soybean of 30.9 million tons / year instead of the current 17.6 million / year.

Additionaly, it is important to emphasize that it was not possible to gather a detailed data from the current operational terminal in order to simulate the arrival of the trucks in the terminal. Therefore, it was conducted a simulation of several possible scenarios that the new terminal could operate to understand and to forecast the best performance as possible. In order to do so, it was used the Poisson distribution for the arrivals and an interesting operating scenario would be with an average attendance of 2.0 trucks / minute, which implicates in a 32% chance of line formation. Higher averages would probably cause delays that could impact the aforementioned results.

Moreover, another analyzed feature was the need of ITS technologies in the new terminal in order to promote all the benefits discussed in the material. Thus, with the correct installing of such items, the proposed terminal can provide a more efficient system.

Furthermore, a very important analysis was made regarding CO^2 emissions. The result showed the possibility to reduce up to almost 700 thousand tons of CO^2 / year. Therefore, it is fundamental to invest in cleaner transport methods, mainly the ones with such a substantial impact due to the high volume of cargo handled.

In short, this material was able to show the aforementioned intention of proving that the Modalohr technology would cause a positive impact in the Brazilian infrastructure regarding the soybean market. Therefore, it is very important to mention that further studies toward the infrastructure as whole are sorely recommended in order to promote development and integrate the vast territory in Brazil.

Thereby, regarding future studies, after explaining the aforementioned results, it is interesting to understand that such technology proposed is most likely to be accepted by the private sector in Brazil. Therefore, this study was intended and aimed to the producer`s point of view. As for a future concessionary to operate the terminal, further studies are highly recommended to be produced in order to guarantee maximum return on invested capital. Another important aspect to be further discussed would be the operation of the terminal during low seasons, or in other words, between the crops. During this period, the amount of transported soybean is considerably lower and other types of products to be transported should be studied in order to provide minimum conditions of operation in the terminal and make the project more attractive to investors. Thus, as it relies on a very new technology yet gaining space in Europe, it is very important to mention that this study was intended to bring new ideas to Brazil and further studies to improve and get more specific about such technology is recommended to be produced in the future.

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