DESIGN NETWORK MODEL WITH LOCATION TO THE SOYBEAN CHAIN IN BRAZIL

Ana Paula Milanez
Faculty of Electrical and Computing Engineering
University of Campinas
Av. Albert Einstein, 400, CEP 13083-852, Campinas-SP-Brazil
ana.milanez@cose.fee.unicamp.br

Anibal Tavares de Azevedo
Faculty of Applied Sciences
University of Campinas
R. Pedro Zaccaria, 1300, 13484-350, Limeira-SP-Brazil
anibal.azevedo@fca.unicamp.br

Andréa Leda de Oliveira Ramos
Faculty of Applied Sciences
University of Campinas
R. Pedro Zaccaria, 1300, 13484-350, Limeira-SP-Brazil
andrea.oliveira@fca.unicamp.br

Takaaki Ohishi
Faculty of Electrical and Computing Engineering
University of Campinas
Av. Albert Einstein, 400, CEP 13083-852, Campinas-SP-Brazil
taka@densis.fee.unicamp.br

ABSTRACT

The soybean exporter chain has high participation in the Brazil economic performance. However, the main producing areas are far from seaports and exposed to several logistical problems arising from the lack of planning and investment in infrastructure. As a result, producers are burdened by the costs and have the available capital decreased to future investments. Faced with this reality, this paper proposes to develop a mathematical model that describes the soybean exportation chain in order to create an analysis tool to define the hubs location and routes to optimize this chain. In special, it is considered that hubs can storage, switching, and consolidated flow.

Keywords: Hub location, Logistic, Brazilian soybean exporter chain

L&T - Logística e Transportes, AG&MA - PO na Agricultura e Meio Ambiente

1. Introduction

According to United State Department of Agriculture (2013), Brazil became the largest grain's producer and exporter in the world in 2012/2013 harvest, the agribusiness accounts for almost half of total Brazilian exports, and the soybean is one the most important exportation product. The soybean is produced at Midwest Brazilian region, very far from the seaports, and dependent of transportation system.

Transportation planning has shown its potential as a competition strategy for many economic sectors. Nevertheless, transportation logistics is currently a challenge to the development of Brazilian economy. Such challenges – represented by the precarious conditions of highways, by low efficiency and the lack of railways capacity and by the disorganization and excessive bureaucracy of seaports – resulted in an increase in truck traffic in the main export seaports, long waiting period for ships to dock and the non-fulfillment of the delivery deadlines in the international market. Altogether, that resulted in an increase in the costs and in a reduced competitiveness with regard to Brazilian products abroad (OLIVEIRA e SILVEIRA, 2013).

The peak of Brazilian soybean exports usually occur in April and in the end of June, during which almost two-thirds of the year's soybeans are exported (USDA, 2013). In this period, the lack of capacity to storage soybeans in producing areas force the producers sell the crop in advance. Consequently, there are higher demands for trucks, to transport the soybeans from producing areas to seaports, increase in transportation costs, and congestions in seaports, which do not have enough capacity to handle the largest amount of the grains. These problems are maximized by record grain harvests in Brazil.

Deficient transportation systems affect all economy, and in recent years have been more investments on infrastructure, public and private. For these reasons, it has been increasing the interest on developing models to support decisions that improve this chain. Thus, this paper proposes a network design mathematical model that localizes hubs and warehouses on the present Brazilian soybean exportation system.

Some studies have been developed to treat this problem. Specific researches dedicate to Brazilian soybeans are: Ferrari (2006) that proposes a location model to locate warehouses, determine the size of them and consider the model dynamic to represent the changes in costs and demand throughout time; Dubke and Pizzolato (2011) develop a location model to locate specialized terminals to transform soybean grains in oil and meal, these terminals are used as transshipment points in soybeans chain; Amaral *et al.*, (2012) propose a location model of p-median location for intermodal terminals using the main routes used for export of soybeans.

The current literature is concerned just in locate facilities as warehouses, transshipment points, and specialized terminals or in minimize transportation costs in a network. Most of them don't suppose the necessity of modeling of simultaneous mode the facilities location problems and network design problems (CONTRERAS AND FERNÁNDEZ, 2012), as it occurs in the hub network design problem.

Hub network design is utilized in large-scale transportation because they can reduce transportations costs, to take advantage of the economies of scale, increase service frequencies and reduce the uncertainty in demand (LIUM *et al.*, 2009).

In the hub problems the goal depends on the locations of hubs facilities and the routing flows (CAMPBELL AND O'KELLY, 2012). Moreover, additional constrains may be involved: the allocation of non-hubs nodes may be a single allocation or multiple allocation, different types of capacity restrictions on hubs or arcs may be assumed, etc. Several hub location problem models have been considered in literature. A detailed review of hub location problem can be found in Alumur and Kara (2008), Campbell and O'Kelly (2012), and Farahani *et al.* (2013).

Among the studies developed Ebery *et al.*, (2000) propose a model for capacitated with multiple allocation (CMAHLP). The authors introduce the capacity restrictions on hubs nodes to limit the volume to be handled; also the number of establishment hubs is derived by mathematical model. Boland *et al.*, (2004) study uncapacitated and capacitated multiple allocation hub location problems and develop preprocessors procedures and tightening constrains to already existents formulations.

Some studies also consider the possibility of the size of the hub be a part decision making process to single or multiple allocation hub location problem. In this cases, for each potential hub node it was assumed that a set of different capacitates are available to be chosen (CONTRERAS *et al.*, 2012; CORREIA *et al.*, 2010).

Contreras *et al.*, (2011) introduce the dynamic uncapacitated hub location problem. In dynamic hub problems is allowed to open and close hubs according the necessity of period. Correia *et al.*, (2012) propose a multi-period hub location problem where the changes in the network structure can occur in the hubs and in the hubs edges.

In order to propose an analysis tool that encompass all single characteristics of Brazilian's soybeans exporter chain - seasonal crop, support the exportation across the year, demand and costs variations - and its logistics problems - and limited capacity in producing areas, transshipment points, and seaports - this paper proposes a new model using hub network design with special features that enable some hubs to storage flow throughout time, defines the operational size to each hub, and locates hubs in a dynamic network.

2. Problem description

Brazilian efficiency in some agricultural sectors is widely acknowledged, especially regarding the following products: soy and derivatives, sugar and alcohol, orange juice, coffee and meat. Part of this efficiency is due to the countless transformations that have occurred in the Brazilian farming industry, from the focus shift in public policies to the access to rural credit and to agriculture support programs. In Brazil, facts such as technological changes and research investments are noteworthy, and they have led to high productivity gains (OLIVEIRA e SILVEIRA, 2013).

However, these competitiveness gains have occurred in the first phases of the productive process, while some deficiencies still exist in the remaining phases, especially those deficiencies connected to transportation and storage infrastructure.

In the case of Brazil, it is also worth noting that logistical costs are an important component of the end prices of products, because of the spatial scattering of the production, the domestic market distribution and the long distances pertaining to intra- and inter-regional trade.

This point applies to agricultural products, given their spatial configuration and the scattering of the consumer markets. Hence, transportation logistics is one of the segments that interferes the most in the efficiency and in the competitiveness gains. Usually, the predominance of road transportation in the Brazilian transportation matrix has been indicated as the main source of inefficiency and reduced profitability of agricultural producers (OLIVEIRA e SILVEIRA, 2013).

In recent years, Brazil reached a top position among major world soybean's producers and exporters. Inside the country, the largest producing and exporting state is Mato Grosso (MT) located in Midwest area of Brazil, which one has exported 33 percent of total Brazil's exportation in 2012. The major MT soybeans export market are China, Spain, Netherlands, Thailand, etc. (MDIC, 2013).

Due to large China's demand, 70% of all Brazilian soybeans exported, the majority of soybeans are sent by south and southeast seaports. In especial, Santos Port and Paranaguá Port, because their ocean freight rates for shipping soybeans are cheaper than ports of the north and the northeast (USDA, 2012).

Therefore, the higher distances from MT to seaports, the Brazil's deficient transportation system, and lack of infrastructure, decreases Brazilian's soybean competitiveness. Despite the existence of access to seaports by intermodal transport, their low capacity to receive and send the commodity, the higher costs, and lack of storage facilities into the state force soybeans to be sent to seaports by trucks.

According to IMEA (Mato Grosso Institute …, 2013) the state of MT needs increase the storage capacity in 20 million tones to be able to storage their crop. Furthermore, Brazil higher freight rates are result from extensive use of road transport. The country has a large territorial extension and most part of his production is transported by road, the most expensive and inefficient modal of transport to this kind of commodity.

Figure 1 shows the map of Brazil, where the State of MT is colored area. It's represented, in red, green, and blue lines, the main routes utilized to transport the soybean from the State to seaport, the intermodal terminals available and seaports utilized.

The transshipment points utilized are (1) Porto Nacional located in state of Tocantis (TO); (2) Araguari located in state of Minas Gerais (MG); (3) Maringá located in state of Paraná (PR); in these transshipment points the soybeans arrive by truck and go to seaport by rail; (4)

Porto Velho (RO) located in state of Rondônia (RO), where soybeans arrive by truck and go to seaport by river; and (5) São Simão (GO)/Anhembi (SP) are two points in same path the first one is located in state of Goiás (GO), where soybeans arrive by truck and go to Anhembi by river. Anhembi is located in state of São Paulo (SP) and after arrive in this point soybeans go to seaport by truck. Inside the state of Mato Grosso also there is a transshipment point called Alto Araguaia where soybeans go to seaport by rail, it is located in southeast of the State.

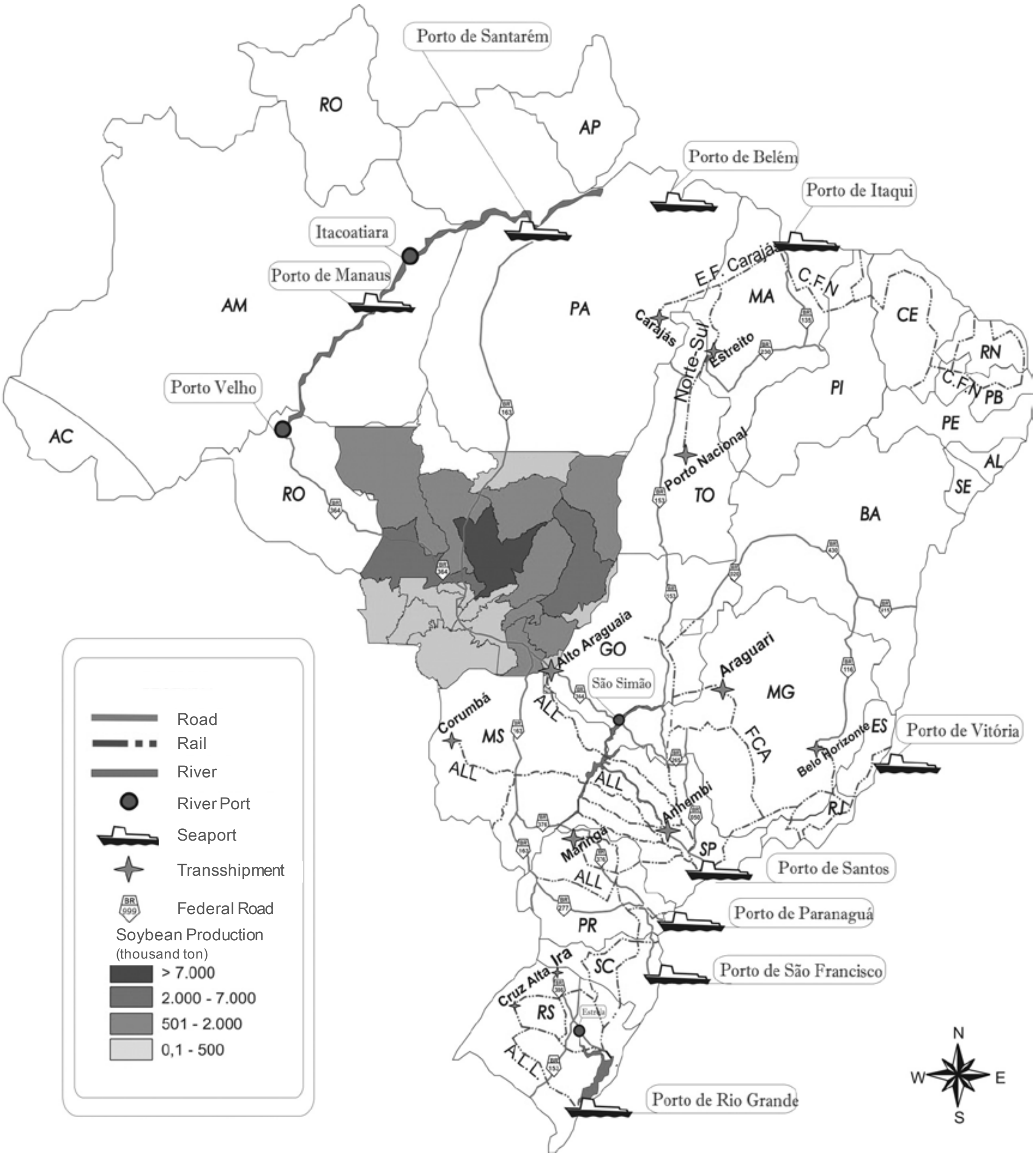

Figure 1. The main routes from State of Mato Grosso to seaports

The seaports considered are Brazil's main exporter ports: Manaus Port, Santarém Port, Itaqui Port, Vitória Port, Santos Port, Paranaguá Port, and São Francisco do Sul Port located in state of Amazonas (AM), Pará (PA), Espirtito Santo (ES), São Paulo (SP), Santa Catarina (SC), and Rio Grande do Sul (RS), respectively.

The routes to arrive to Manaus Port and Santarém Port and Itaqui Port have to use the Porto Velho (RO), river port, and Porto Nacional (TO), rail port. But to arrive to south and southeast ports, Vitória Port, Santos Port, Paranaguá Port, and São Francisco do Sul Port, there are more the one route option. Some routes are just for roads or are a composition of road, river, and rail. For example, from Alto Araguaia (MT) to Santos Port, it's possible transport the soybeans direct by road, direct by rail, or by road until São Simão (GO), where soybeans are transported by river until Anhembi (SP), and consequently, by road until the final destination. Between the routes considered, the route utilized to connect the state of MT to Itaqui Port (MA) that use Porto Nacional (TO) transshipment point is a future route that has been implemented by federal government to improve the Brazil's logistics.

To better treat the soybean production, the State of MT that is divided in 22 producer's areas (AR 01 …, and AR 22) according to IBGE (Brazilian Institute…, 2013). The different colors determine the amount of soybeans produced in which area. The red lines represent federal roads that cross the State and connect him to transshipment points, river ports, and seaports, Figure 2.

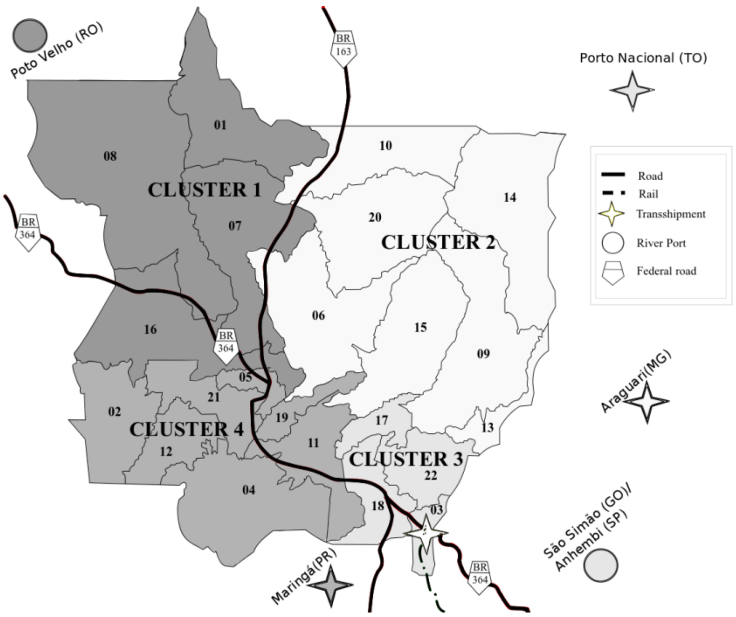

Figure 2. The State of Mato Grosso and the 22 producer's areas

3. Formal definition and formulation of the problem

In this research the network is represented by a complete graph G = (N, A) with node set N = {1, …, n}, where nodes correspond to origins, destinations, and potentials hub locations, A = N x N is the set of arcs, T = {1, …, t} set of time periods in the considered time horizon, S = {1, …, s} the set of capacity to each node N. Let c_{ij}^{p} be the transportation cost of a unit of flow between *i* and *j* in period *p*, F_{kv} be the fixed cost of establishment a hub at node *k* with capacity *s*, and γ_k^p be the storage cost of a unit of flow at node k in period *p*. To each node P_i^p is the total amount of flow available at node *i* in period *p*, D_j^p is the amount of flow demanded by node *j* in period *p*, and Γ_{kv} the size of a hub at node *k* with capacity level *v*. Consider M a big number and α the factor of discount for transport flow between hubs, due to the inter-hub transfer efficiencies.

In this formulation, the following decision variables are considered: X_{ik}^{p} amount of collection flow from node *i* to hub *k* in period *p*; Y_{kl}^{pm} amount of flow traversing arcs hub (*m*, *k*) and (*k*, *l*) in period *p*; Z_{lj}^{p} amount of distribution flow from hub *l* to node *j* in period *p*; ε_k^p amount of flow storage at hub k in period p; H_{ks} equal 1 if a hub of size v is opening at node k and 0 otherwise.

The model consists in determining the location and size of a set of hubs, and a feasible routing of commodity flows through at hub nodes. It is allowed an origin/destination node be attended for one or more hub, the flow be routed through one or more hubs, and the capacity of a hub is an upper bound on its incoming flow.

Note that the classical assumption of hub location literature that defines the amount of flow between an origin-destination pair was relaxed and the distance between nodes i and j does not necessarily satisfy the triangle inequality.

Formulation:

$$\min \sum_{p\in T}[\sum_{i\in N}\sum_{k\in N} c_{ik}^{p} X_{ik}^{p} + \alpha \sum_{k\in N}\sum_{l\in N}\sum_{m\in N}(c_{mk}^{p} + c_{kl}^{p}) Y_{kl}^{pm} + \sum_{l\in N}\sum_{j\in N} c_{lj}^{p} Z_{lj}^{p}] + \sum_{k\in N}\sum_{v\in S} F_{kv} H_{kv} + \sum_{p\in T}\sum_{k\in N} \varepsilon_k^p \gamma_k^p \quad (1)$$

Subject to:

$$\sum_{k\in N} X_{ik}^{p} = P_i^p \qquad \forall\, i\in N, p\in T \qquad (2)$$

$$\sum_{l\in N} Z_{lj}^{p} = D_j^p \qquad \forall\, j\in N, p\in T \qquad (3)$$

$$\varepsilon_k^{p-1} + \sum_{i\in N} X_{ik}^{p} + \sum_{l\in N}\sum_{m\in N} Y_{lk}^{pm} = \varepsilon_k^p + \sum_{m\in N}\sum_{l\in N} Y_{ml}^{pk} + \sum_{j\in N} Z_{kj}^{p} \qquad \forall\, k\in N, p\in T$$

$$(4)\ \varepsilon_k^{p-1} + \sum_{i\in N} X_{ik}^{p} + \sum_{m\in N}\sum_{l\in N} Y_{lk}^{pm} + \sum_{m\in N}\sum_{l\in N} Y_{kl}^{pm} \le \sum_{v\in S} \Gamma_{kv} H_{kv} \qquad \forall\, k\in N, p\in T$$

$$(5)\ X_{ik}^{p} \le P_i^p \sum_{v\in S} H_{kv} \qquad \forall\, i,k\in N, p\in T$$

$$(6)\ Z_{lj}^{p} \le D_j^p \sum_{v\in S} H_{lv} \qquad \forall\, j,l\in N, p\in T$$

$$(7)\ Y_{lk}^{pm} \le M \sum_{v\in S} H_{mv} \qquad \forall\, m,k,l\in N, p\in T$$

$$(8)\ Y_{lk}^{pm} \le M \sum_{v\in S} H_{lv} \qquad \forall\, k,m,l\in N, p\in T$$

$$(9)\ Y_{lk}^{pm} \le M \sum_{v\in S} H_{kv} \qquad \forall\, k,m,l\in N, p\in T$$

$$(10)\ Z_{lj}^{p}, Y_{kl}^{pm}, X_{ik}^{p}, \varepsilon_k^p \ge 0 \qquad \forall\, k,l,i,j\in N, p\in T$$

$$(11)\ H_{kv} \in \{0,1\} \qquad \forall\, k\in N\ e\ v\in S$$

(12)

The objective function (1) evaluates the overall cost which is divided into the cost of collection, transfer, distribution, the cost for installing the hubs, and cost for storage the flows. Constrains (2) ensures that all available flow is collected by hubs in each period t, and (3) guarantee that all demand in period t is attended by a hub. Constrain (4) guarantee the balance of flow at a hub, when the flow storage in a previous period plus all incoming flow have to be equal all flow that keeps at hub plus flow that leaves the hub. Constrain (5) ensures that the previous flow at hub plus all incoming flow have to be smaller or equal than the size of hub. Constrains (6)-(10) guarantees that all flow is transported via hubs, and (11)-(12) define the continuous and binary decisions variables, respectively.

Constraint given by Eq. (4) connects hub allocations and flows through time in order to represent the storage of product. This is a feature that plays a key role in Brazilian soybean supply chain decisions as will be shown in computational experiments.

Note that the model is a mixed integer problem composed by $4n^3t+4n^2t+5nt+ns$ constrains and $n^3t+2n^2t+nt+ns$ variables, where ns are binary variables and n^3t+2n^2t+nt are continuous variables.

4. Computational experiments

A computational study has been carried out in order to evaluate the performance of the formulation on the soybean's data and illustrate the potential of analysis of the model. The soybean's data which we have been using are actual data.

To create the instances evaluated it was considered the State of Mato Grosso and the points that compose the main exportation routes as transshipment points, seaports, and main countries MT's soybean buyers. So, this network include 39 nodes which are: 22 producer's areas (AR) located inside the State, 5 transshipment points located in different States that represent intermodal transportation points, 7 majors seaports responsible to ship the soybean until the demands markets, and the 5 largest exporter's countries from MT's soybeans. The period considered was the year of 2012, this way, 12 months.

The costs were based in the transportation costs, tariffs of seaport and transshipment points practiced in the operations in 2012. To MT's areas the capacity available to be opened is the real capacities (CONAB, 2013). To seaports it was considered 33% of the current grains capacity (ANTAQ, 2012), based in the fact that Mato Grosso exports 33% of Brazilian's soybeans (MDIC, 2013). The establishment costs are 45 dollars by ton opened (FERRARI, 2006). So, the set of storage capacity is composed by three levels in which the first level corresponds to the capacity available defined previous. The second and third levels represent possible storage capacity expansion to double and triple of the first level amount, respectively.

A sensitivity analyses was carried out in order to measure the influence advantages in consolidated flow by exploiting economies of scale.

To exploiting economy of scale was considered the current transportation costs (MC – Market Costs with $\alpha=1$), and was supposed a higher efficiency in the inter-hubs transfer (MCDF - Market Cost with Discount Factor with $\alpha=0.8$).

The solver used in the study was Cplex 12.4 run under Linux and processor was an Intel(R) Xeon(R) with 2,83GHz and 8GB of RAM memory.

Table 1 shows the results from mathematical model. The different economy of scale are explored, MC and MCDF, as shown in the first column. The next column is the number of hubs opened (H). The next six columns show the total cost (TC), collection cost (CC), distribution cost (DC), transfer cost (TRC), establishment cost (EC), and storage cost (SC). The next is the time or CPU time, in seconds, required to obtain the solutions in each scenario, and the last one is the GAP.

Table 1. General results

	H	TC (million US$)	CC (million US$)	DC (million US$)	TRC (million US$)	EC (million US$)	SC (million US$)	CPU (s)	GAP (%)
MC	27	3,349.18	601.07	498.09	626.04	916.50	707.47	5,991.83	0.02
MCDF	27	3,215.55	520.04	497.91	573.74	916.37	707.47	7,579.31	0.03

Nowadays, Santos Port operates with storage capacity severely constrained compared with the amount of flow that the seaport have to handle. The preference to shipping the flow through the Santos Port, it is because the seaport is the cheapest maritime cost from Brazilian seaports to China, the major Brazilian soybeans buyer.

Influenced by transportation costs, ocean freight rates, and capacity available, the seaports chosen to operate are: Santos Port, Paranaguá Port and São Francisco do Sul Port. To be able to shipping all soybeans exporter, it is opened in the Santos and the Paranaguá Ports all the three levels of capacity and in São Francisco do Sul Port the third level.

It should be noted that, the first level is 33% of the current seaports grain capacity and the second and third are 66% and 99%, respectively. Thus, when all three levels of capacity are opened, it means that almost the double the current seaport grains capacity has been used to shipping soybeans from Mato Grosso.

As previously mentioned, to access the South and Southeast seaports there are more than one route. The available routes include the transshipment points that are opened as hubs to access Santos Port as São Simão (GO)/Anhembi (SP) transshipment point and AR 03 – Alto Araguaia, and to access the Paranaguá Port and the São Francisco do Sul Port as Maringá (PR) transshipment point.

4.1.1. MC scenario

In MC scenario are established 27 hubs where 18 of them are located inside of the State with different levels, as shown in Figure 3.

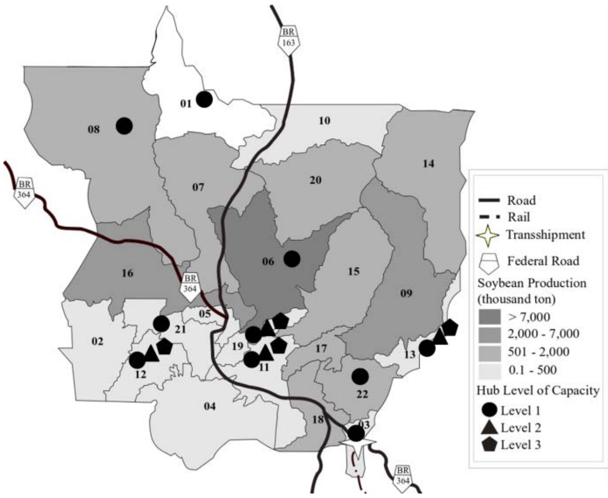

Figure 3. Hubs established to MC scenario.

The hub location is influenced by producing areas, the seaport's choice. The major producer's areas are AR 06, AR 09, and AR 16. So, these areas and the areas around, that are located next to main routes to South, and Southeast seaports are areas to hub establishment.

Figure 4 shows the stocks of the hubs opened and the stock behavior across the year. To better visualizing, it was considered the four clusters formed by the areas in State of Mato Grosso, as showed in Figure 2.

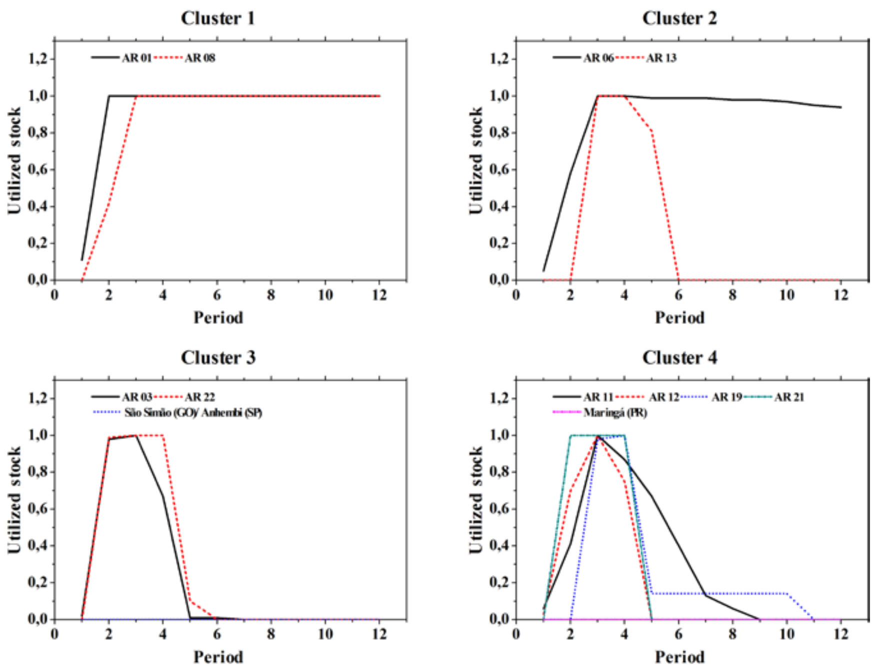

Figure 4. Stock's behavior to MC scenario.

For example, Cluster 1 represents the Mato Grosso's Northwest, where is opened hub in the AR 01, and AR 8. Being an area located far from seaports, these hubs act just as storage hub. Although, the hubs located in the Clusters 02, 03, and 04 act as storage, switching, consolidation hubs, except São Simão (GO)/ Anhembi (SP), and Maringá (PR) transshipment points, which cannot act as storage points.

In MC scenario, Santos Port exports soybeans in the first six periods, while the Paranaguá Port exports at all periods evaluated. In the fifth period, the São Francisco do Sul Port is utilized to ensure that all demand will be met. Figure 5 illustrates the shipping of each seaport.

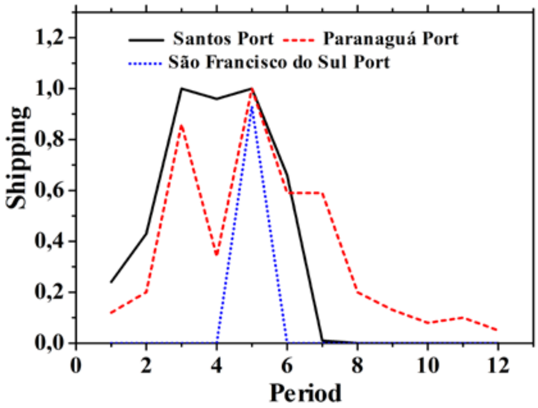

Figure 5. Shipping in each seaport to MC scenario.

The shipping behavior in seaports is justified by stock behavior responsible for supply Santos Port, and Paranaguá Port. For example, Santos Port is supplied by AR 13 in Cluster 02, and for all hubs in Cluster 03, in which ones the stocks end in the sixth period. Being the cost to transport the flow from the Cluster 4 to Santos Port so expensive, the seaport ends its shipping of flow, and the demand is met just for Paranaguá Port that is supplied by Cluster 4. Another important fact is that the most part of hubs are located in MT's Central region. The hubs location encourages the transport flows to the Port of Paranaguá, once the routes that go to Paranaguá Port are cheaper than the routes that go to Santos Port. Meanwhile, just the hubs located in MT's Southeast send their flows to Santos Port.

The percentage of flow, of all soybeans exporter from MT, shipping for each seaport throughout time is shown in Table 2.

Table 2. Percentage of flow exports by each seaport to MC scenario.

Seaports	MC
Santos (SP)	31.60%
Paranaguá (PR)	67.41%
São Francisco do Sul (SC)	0.99%

Given the fact that there are more than one route to reach Santos Port, and Paranaguá Port, it is important analyze the routes used to transport flow, and evaluated the amount of flow which use the intermodal routes. This analysis allows us to evaluate routes where is possible make improvements.

In MC scenario, the major part of flow that go to Santos Port is transported directly, while the major part of flow to Paranaguá Port is transported through hubs, as shown in Table 3.

So, the results show us that intermodal routes connecting producer's areas and Santos Port can be more explored through greater financial incentive to cargo consolidation.

Table 3. Transport mode to MC scenario.

Seaports	Transport Mode	MC
Santos (SP)	Direct	16.15%
	Through hubs	15.45%
Paranaguá (PR)	Direct	8.97%
	Through hubs	58.44%
São Francisco do Sul (SC)	Direct	0.00%
	Through hubs	0.99%
	Total flow transported through hubs	**74.88%**
	Total flow transported direct	**25.12%**

4.1.2. MCDF scenario

MCDF scenario also established 27 hubs with 18 located inside the State. Therefore, the hubs locations are spread inside the State, as shown in Figure 6.

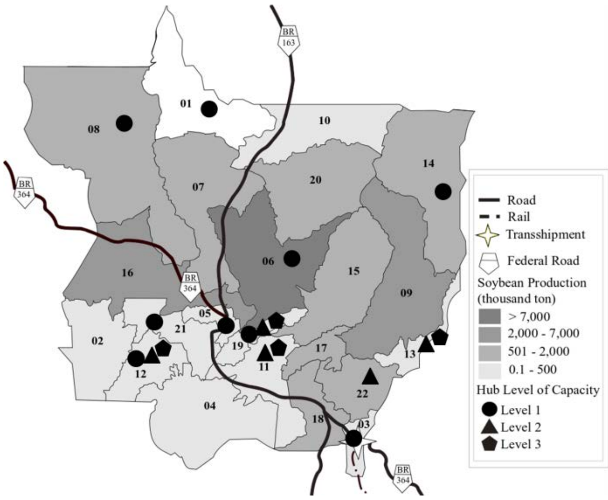

Figure 6. Hubs establishment to MCDF scenario.

The new hub configuration decrease the distance between producer's areas and collection hubs diversifying the switching points.

Despite of the changes in configuration, when compared with the configuration of MC scenario, there are few variations in the shipping behavior in Santos Port and the Paranaguá Port, mainly at the peak of the Brazilian soybean exportation, as shown in Figure 7.

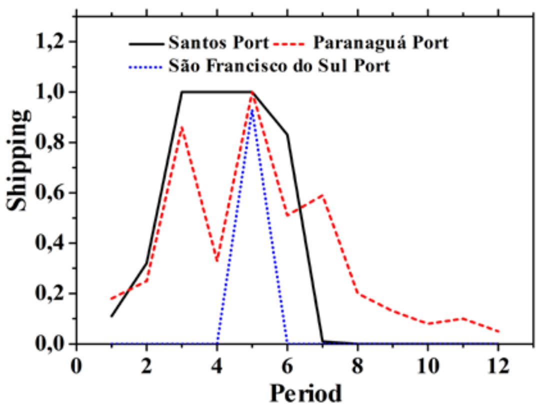

Figure 7. Shipping in each seaport to MCDF scenario.

Wherefore, the percentage of flow shipping for each seaport throughout time also presents few variations, as shown in Table 4.

Table 4. Percentage of flow exports by each seaport to MCDF scenario.

Seaports	MCDF
Santos (SP)	31.39%
Paranaguá (PR)	67.63%
São Francisco do Sul (SC)	0.99%

Inside the State, the most of hubs have their stocks finalized in the 6th period, and after this the seaports are supplied by AR 06, while the other hubs act as switching points, as shown in Figure 8.

The most important change observed in MCDF scenario, it is the use of the routes. When the discount factor is considered the transport through hubs, or intermodal routes, to reach Santos Port is prioritized, while the transport to Paranaguá Port isn't modified, as shown in Table 5.

Table 5. Transport mode to MCDF in expandable case.

Seaports	Transport Mode	MCDF
Santos (SP)	Direct	3.48%
	Through hubs	27.90%
Paranaguá (PR)	Direct	8.98%
	Through hubs	58.65%
São Francisco do Sul (SC)	Direct	0.00%
	Through hubs	0.99%
Total flow transported through hubs		**87.54%**
Total flow transported direct		**12.46%**

This way, it is possible to say that the costs practiced in MC scenario do not encourage transport the flow to Santos Port through intermodal routes.

Comparing the routes utilized in MC and MCDF scenario, also it is possible to say that MCDF do not create additional consolidation route even with economy of scale.

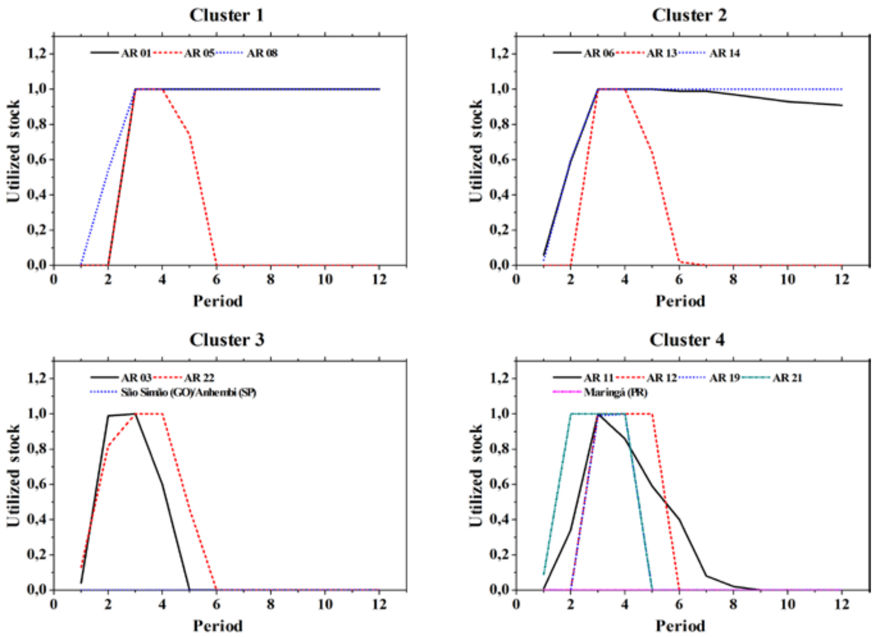

Figure 8. Stock's behavior to MCDF scenario.

5. Conclusion

Brazilian soybean exporter chain has higher participation in economic performance of Brazil, and has shown steady growth in recent years. Therefore, the lack of infrastructure - storage facility, intermodal transportation, and reduced capacity of ports - is directly reflected in the competitiveness of Brazilian soybean.

In this paper, motivated by a real world application of Brazilian soybean exporter chain, we proposed a hub network design model that encompasses the needs of this chain. The model includes soybean chain requirements as: dynamic modeling, establishment of hubs able to storage, switching, and consolidate flow; permit the size of the hubs to be part of the decision making process; and allows flow be routed through one or more hubs. The main contribution of this work comes from the need of Brazilian soybean chain, where the hubs also act as storage facilities.

The results obtained present the hubs act as storage points, the hubs act as switching and consolidation points, and the hubs act as storage/ switching /consolidation points; the better routes to be utilized, and the impact of consolidation in the viability of routes; the seaports utilized, and the amount of flow shipped for each seaport, according their capacity.

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