Advanced Planning System (APS) Applied to the Inbound Logistics in a Fuel Distribution Company in Brazil: An Action Research

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ABSTRACT

This paper addresses the initiatives in the optimization of the inbound logistics in a fuel distribution company, in which the outbound logistics optimization is a well-known process for more than ten years. Meanwhile, the fuel distribution market in Brazil has grown, in contrast to the lack of government investments in infra-structure such as refineries, ports, railways and waterways, resulting in many logistics bottlenecks all over the country. This fact motivates the present action research: how to model the inbound logistics using an APS to deal with dozens of constraints in supply and transportation that came up, especially in the last decade. Thus, the main objective of this paper is to present how this model was created, how it helps to identify more economical network flows and what actions need to be taken in order to ensure that every month the inbound logistics can be easily optimized and its results evaluated.

KEYWORDS. Network Optimization, Logistics Bottlenecks, Supply Chain Management software.

Paper topics:

1- **Logística e Transportes (L&T)**
2- **PO na área de Petróleo e Gás (P&G)**
3- **PO na Indústria (IND)**

1. Introduction

The fuel distribution supply chain network in Brazil consists basically of five different types of players: 1-refineries, 2- biofuels plants, 3- distributors, 4- customers and 5- final consumers. Refineries produce petroleum derivatives such as gasoline and diesel. Biofuel plants produce biodiesel and ethanol. Legislation determines the percentage of 73% of ethanol mixed in gasoline and a 7% of biodiesel mixed in diesel.

In Brazil we have basically four distribution companies that hold almost 80% of the market, so it’s a very competitive market. In general, the main distributors in the country own primary and secondary storage terminals. They are called primary because these terminals receive gasoline and diesel straight from refineries by pipelines and ships. On the other hand, secondary terminals are located far away from refineries, usually in the interior of the country and are supplied by railways, waterways and roadways from primary terminals.

At the end of the supply chain we have customers such as service stations, wholesale consumers and retail sellers. According to ANP (Agência Nacional do Petróleo) in the case of service stations, we have more than 99,000 regulated entities spread all over the country that supplies the end consumers consisting of trucks and cars. From a fuel distribution company´s view, we call inbound logistics all product flows from refineries and biofuel plants to primary/secondary terminals and still all product flows from primary to secondary terminals. The outbound logistics consists of all product flows from primary and secondary terminals to customers as it can be seen in Figure 1.

Almost 100% of the customers are served by roadway. In fact, this is the most indicated modal for this type of delivery due to the short distances and especially because most of them are located in large urban centers with lots of restrictions about circulation. Although, even in long distance deliveries, roadways are still used very much since the logistics infra-structure in Brazil leaves much to be desired. Insufficient investment in railways, waterways and ports and the absence of an economy of scale provided by this type of transportation, prevent investments by distributors in the construction of secondary terminals. The consequence is the poorly assisted markets located in the interior of the country, forcing far roadway deliveries.

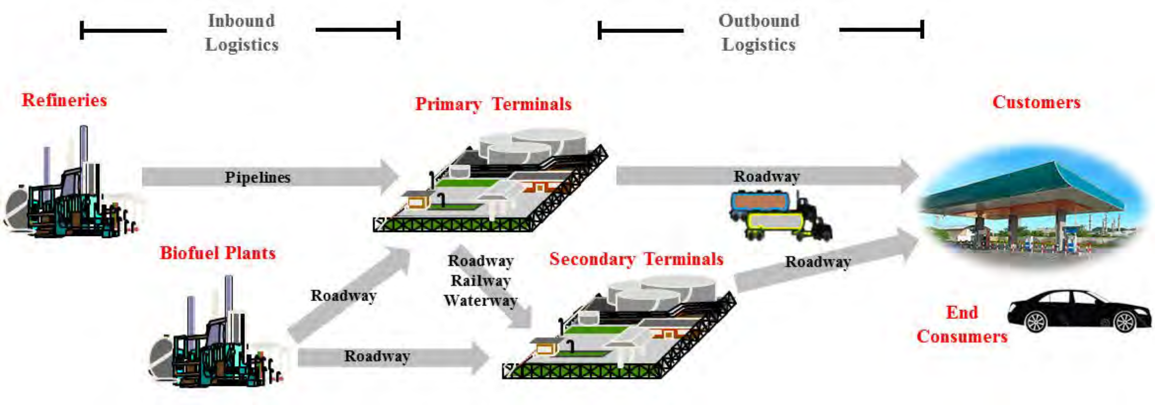

Figure 1 - Fuel Distribution Supply Chain Network

Another important point is the increase of the fuel consumption in Brazil, growing systematically since 2004 (4,87% CAGR – Compound Annual Growth Rate), reaching more than 800 million of PBE (Petroleum Barrels Equivalent) according to ANP. Therefore, some problems are expected in the fuel distribution industry with the emergence of many logistics bottlenecks. These bottlenecks are not only related to transportation, but to storage and production as well.

Three important factors about this model. First, we did not include biofuel plants because this part of the inbound logistic is already tackled in another model for more than five years.

Since ethanol and biodiesel are transferred by roadways in almost 100% of the cases, it is not the main goal of this *action research*, in which we are focusing on analyzing part of the supply chain that has never been optimized and includes different transportation modes and its trade-offs. So, biofuel prices and freights were aggregated in storage terminals by weighted averages. Second, stocks were not considered, because at this point the team involved were interested in evaluate the trade-offs between the different transportation modes and the refinery prices only with no influence of inventory costs. Third, this model was designed to run every month to predict the supply chain behavior of the next thirty days, so it is a single period model in which all prices and freights are known and updated. The refinery prices in the fuel distribution market in Brazil does not change very frequently, that is why the team felt comfortable to ignore all variability presented in this type of approach. On the other hand, biofuel prices are very volatile and need to be updated weekly. That is another reason for not including biofuel plants in this model and tackle it in another model which is updated once a week.

Here is the proposition we worked on: it is possible to attend the same actual demand with lower cost using a logistic model created in an APS. This proposition will be verified once we are able to prove that the same volume (measured in m³ - cubic meters) can be attended, respecting all constraints, but with a lower cost. Units to analyze potential savings were calculated in R$ (reais).

Action Research Cycle

After evaluating the results, we applied the opportunities identified in the optimization model. One important comment about this action research is that this entire process demanded an intensive interaction among different areas of the company involved in the inbound logistics. In many rounds the output of the model pointed to impossible solutions, since some constraints were missing and had to be included one by one, resulting in more than 1,000. After repeating the cycle for the third month, the process was already consolidated and the model represented reality. So, this kind of approach produced a ripening process, which would be very difficult to happen if the company decided to hire an external consulting firm. According to Coughlan et al (2002), *action research* and *consultancy* are different in some aspects. We list two of them: consultants work under tighter time and budget constraints; consultation process is frequently linear (engage, analyze, act and disengage). On other hand, *action research* is cyclical – gathering data, analyzing data, planning action, taking action and evaluating, leading to further data gathering and so on. Indeed, the company could perceive the advantage of acquiring and learning how to use the appropriate supply chain software, that allowed their own team to lead the present *action research* achieving good results.

2. Literature Review

Defining the most appropriate policy to serve the customer is a critical issue for a company's success. Basically, there are two options a company can choose. First, a fast response policy characterized by a stock centralization with intensive express transport and very low dependence on demand forecasting. Second, a demand anticipation policy with decentralized stock, located closer to the customers and the use of intensive consolidated shipments. The fuel distribution market is a good example of the second policy. The reason why is that all the products have low added value and low obsolescence risk. Furthermore, the demand profile is relatively stable even in a recessive economy. These elements combined minimize the risks associated with stock decentralization. This second policy has important implications like a strong dependence on demand forecasting in order to balance the stock level at each link in the supply chain. In this case, the main element that adds value to this strategy is the expectation that the additional cost related to stock maintenance and order processing are compensated by economies of scale in consolidated shipments (WANKE, 2000).

According to an extensive survey lead by CEL/Coppead (Centro de Estudos em Logística/Instituto de Pós-Graduação e Pesquisa em Administração) and IBP (Instituto Brasileiro do Petróleo), there are many logistics bottlenecks in Brazil related mainly to railways, one of the most indicated modals for products with low added value like biofuels and petroleum derivatives. These bottlenecks have a great impact on the fuel distribution market, increasing the systematic use of roadways, the less economic modal. In a country where the energy matrix is already very dependent on roadways, it puts more pressure on inflation, since these additional costs are transferred to domestic consumers. Calculating the impact of these additional costs, it reaches R$ 50 million a year. It represents 6% of the service station´s margins and 20% of the distributor´s margins. The cost to adequate the railways and solve this problem reaches R$ 700 million (FIGUEIREDO, 2006).

The roadways already represent 31% of the volume transferred from primary to secondary terminals and 100% of the volume delivered to customers. In fact, the most indicated modal of delivery is the roadway, since the demand is very widespread in the country and most of it is concentrated in large urban centers. But since the bottlenecks growth mentioned, customers located 1,000 km from the storage terminals (and even 2,000 km), are being served by roadways. Ballou (2006) mentioned an average distance of 460 km (286 miles) for full truck load (TL) deliveries. Despite these long distances, deliveries correspond to a percentage of 4% but represent 20% of the total transportation cost. If Brazil had a better logistic infra-structure, not only railways, but pipelines and waterways too, it would certainly enable the construction of many other secondary terminals closer to these poorly assisted markets, reducing the distances covered by roadways. The survey estimates an increase of 3,000 vehicles per year if no investment is made (FIGUEIREDO, 2006).

In the last decades, the high level of requirements set by environmental agencies and by ANP hindered a faster expansion of the storage capacity of the terminals. According to distributors, the approval to build new tanks, for example, takes more than a year (internal information). In a survey lead by the World Bank, Brazil figures in the 127th position among nations regarding the time to acquire construction licenses. On the production side, Brazil has 16 refineries spread in 9 different states and 8 of them are located in the southern region. These units operate close to their capacity limits, especially in São Paulo in which more than 90% of their capacity is already being used (WERNECK & RODRIGUES). Unfortunately, all the four new refineries that were projected will not be finished, or will operate in a level much below initially planned. In this case, we will probably see Brazil become more dependent on fuel imports in the next years.

Regarding new IT technologies, after the vertiginous growth of the Enterprise Resource Planning (ERP) systems, we began to see in the 90s a new wave of Supply Chain Management technologies (SCM). According to Mckinsey consulting, between 1999 and 2002, more than US$ 15 billion were sold in SCM licenses, not including expenses on implementation or maintenance (AROZO, 2003). However, acquiring licenses for these new technologies is not enough to guarantee the success of their use. Many companies have already given up their SCM solutions because some (or several) important issues were not taken into account. Some golden rules were defined to drive efforts in order to help in the correct usage of these powerful capabilities. Among them, we could list five that are key concepts for this present study: commitment of the senior management, project aligned with business goals, understand the software capabilities, a step by step approach for incremental value gains, being prepared to change business processes and measure success with Key Performance Indicators - KPIs (FAVILLA & FEARNE, 2005). Favilla and Fearne (2005) point to the fact that strong leadership as the most important factor for the success of a supply chain transformation. The top executives must be actively involved in the entire project. Without their commitment, the impetus for change can quickly fade out. Top executives still have to be able to recognize the skill gaps in their own organization and search for outside partners with new ideas and new software capabilities.

There is an emerging trend related to the acceptance of third party software and systems support for supply chain applications. Even companies with internal capabilities to develop their own solutions are recognizing the value of partnerships with software vendors and consultants. The reason for this is based on the emphasis that is being given to modularity and expandability that allows supply chain participants to add modules and programming interfaces as needs arise. Since most SCM software firms have formed partnerships with ERP companies, integration is no longer the problem it once was (GREEN, 2001).

According to Arozo (2003), his survey showed that companies are investing great efforts to build end-to-end solutions for SCM such as SAP, Manugistics (acquired by JDA in 2006), I2 (acquired by JDA in 2010), CAPS-BAAN e Synquest (acquired by Penske in 2002). If we take a look at the main criteria used by companies in the selection of their SCM solution provider, we can see that the top three are: trust in the solution provider, integration/ compatibility and adherence to their needs. On the other hand, evaluating solutions after implementation showed the three worst results: user friendly solution, implementation time and total investment (AROZO, 2003). Arozo also brings a nice contribution showing the main difference between ERP systems and SCM software (APS). ERP systems are focused on the operational level, not having many analytic capabilities to help in decision making processes. ERP systems can show, for example, the actual stock level in a certain site, but they are not ready to answer what should be the optimal stock level at this site. So, the second part of the problem can be answered by SCM software. Stadler (2005) also wrote about the importance of APS to fill a gap left by ERP systems, since its strength is not in the area of planning. On the other hand, APS do not replace ERP systems but complement it (Fleischmann & Meyr, 2003).

3. Methodology

This study is considered an *action research* because the following characteristics are present: research *in* action rather than research *about* action; participative; concurrent with action; a sequence of events and an approach to problem solving (COUGHLAN & COGHLAN, 2002). Summarizing, researchers involved in this study were immersed in the proposition previously set, becoming agents of change. Furthermore, these main *action research* steps were followed: data gathering, data analysis, action planning, implementation and evaluation (COUGHLAN & COGHLAN, 2002).

We discussed the importance of partnerships with SCM software firms. So, the tool used in the modeling process was Supply Chain Guru®, a software developed by LLamasoft, an American supply chain solutions provider. The company under this *action research* decided on LLamasoft's technologies because its solutions distinguish it from other traditional tools in important factors:

- Easy Learning solution: reduce implementation time and investments;
- User friendly: tables easy to populate, nice map interface with many filtering capabilities; integration with Tableau, a Business Intelligence (BI) solution for sophisticated output analysis;
- Modularity/Expandability: offers inventory optimization, simulation and transportation analysis to be used as the company gains know-how;
- Integration: Database module solution (Data Guru®) that allows data analysis in order to populate tables in a fast and easy way, with additional forecasting module.

The first two topics are exactly those ones mentioned by many companies as negative points of traditional tools, but it is not too difficult to do in Supply Chain Guru.

Optimization Model Structure

The following procedures were part of the approach in order to populate Supply Chain Guru tables:

- Listed all throughput capacity (refineries) – maximum capacities by product (Total constraints 61).
- Listed all constraints related to transportation – maximum capacities (bottlenecks); minimum volumes by contracts (Total constraints 209).
- Listed all constraints related to primary and secondary terminals – maximum loading and unloading capacities (Total constraints 781).
- Collected freights for each flow and for each transportation modal.
- Collected demand preview by terminal (primary and secondary).
- Taxes – depending on the destination of the product different taxes are charged by states in which the terminal is located.
- Freights – for each transportation modal, according to the distance to be covered.
- Storage Fees – third party terminals charge fees.

In the Figure 2 located in the Appendix we have the optimization model structure, where:

- $Products_i$ (i = 1, 2, …, I = 3) – Types: Gasoline, Diesel S500, Diesel S10.
- Hub_j (j = 1, 2, …, J = 34) – refineries/pipelines.
- Billing $terms_k$ (k = 1, 2, …, K = 5) – Types: LCT, ETM, EXA, LPA, LTM. Abbreviations related to the way products are delivered: in the tank, in the truck, in a maritime terminal and pipelines.
- Primary $terminals_m$ (m = 1, 2, …, M = 34)
- Secondary $terminals_w$ (w = 1, 2, …, W = 36)
- Transportation $modal_y$ (y = 1, 2, …, Y = 5) – Types: pipelines, ships, railway, waterway and roadway.
- Decision variable: Q – amount of product i flowing between nodes.
- Objective Function: Z = Min (PC + TA + TT + FA + FT + SA + ST); each component of the global cost (in R$).

Note: Supply Chain Guru’s mathematical solver based on linear programming and mixed integer programming.

4. Results and Discussions

To protect the confidentiality of the company all information about product prices, freights and terminal names were not mentioned, since the company under this *action research* has strategic reasons for not sharing this information.

Global Economy

The baseline scenario used in this comparison considers *structured flows*. We call structured flows all flows that are not emergency ones. In other words, flows used to compensate daily problems related to the operation were not considered. So, for more than 150 structured flows analyzed, 35 flows are new, since they showed to be more economical after optimization. Among these 35 flows, 20% of them concentrate 80% of the logistical gain. The top three will be detailed below to show important results. But first, notice the contribution of each cost to the global cost. The *Product Cost* represents 74% of the global cost, bringing the greatest impact on the supply chain. Second, *Taxes* represent 25%, followed by *Freights* with only 0.8% and *Storage Fees* with 0.2%.

In Table 1, we can see the top three biggest savings. All of these three opportunities are related to Diesel S500. For the city of Cascavel in the state of Paraná (PR), the trade-off price/freight shows an alternative supply of R$ 71 /m³ cheaper than the standard supply (-91 + 20 = -71) even covering twice the distance. In this case even if the roadway were used the economy would be R$ 37 /m³. For the city of Londrina, the saving for the alternative supply is R$ 26 /m³, covering a distance of 1.3 times the standard supply with a less economic transportation mode. For the city of Ourinhos in the state of São Paulo the saving is R$ 43 /m³, covering practically the same distance in a less economic transportation modal. (Note: All taxes were taken into account but it does not make a significant difference in these cases).

Supply	City 1 - Cascavel/PR				City 2 - Londrina/PR			
	Price	Freight	Distance	Modal	Price	Freight	Distance	Modal
Standard	P1	F1	D1	Rail	P2	F2	D2	Rail
Alternative	P1-91	F1+20	2,0xD1	Rail	P2-54	F2+28	1,3xD2	Road

Supply	City 3 - Ourinhos/SP			
	Price	Freight	Distance	Modal
Standard	P3	F3	D3	Rail
Alternative	P3-54	F3+11	1,0xD3	Road

Table 1 – Top Three Opportunities (Prices and Freights in R$/m³ - Distance in km)

Comparison Price Gaps and Freights

Table 2 shows a comparison between products price range (greatest gaps) and freights. For example, the most expensive price for Gasoline (refinery 1) is R$ 185 /m³ above the cheapest one (refinery 2). But a roadway transfer freight between these two refineries is R$ 169 /m³. In other words, we can have the same product in refinery 1 for R$ 16 /m³ cheaper, traveling 1,000 km in the less economic modal from refinery 2. A similar result is achieved for Diesel S500, since the difference is only R$ 6 /m³ and the distance to be covered in this case is more than 1,100 km.

Product	Range	Freight	Difference
Gasoline	185	169	-16
Diesel S500	156	162	6
Diesel S10	179	221	42

Table 2 – Comparison Range Prices EXA and Roadway Freights (R$/m³)

These numbers explain why if we take away constraints related to transportation the total transportation costs increases 34%, having a gain of 50% in roadway usage (not intuitive at first). This happens because, on the other hand, we have a 0.7% decrease in product cost, that means a global reduction in costs, since *Product Cost* represents the most part of the global cost.

Alternative Scenario Analysis

Since the gaps among prices showed to have great influence in the supply chain flows, we decided to simulate a hypothetical scenario in order to measure bottlenecks costs. To achieve this we set all prices to *medium values*, in order to keep all refineries at the same price level with no gaps at all and then optimized the model one last time to compare two scenarios: one with real constraints (the same scenario used before) and the other one without any constraints related to transportation. The main idea is to measure how much the volume in railways increase, since this transportation modal is cheaper than roadways. In fact, we observed a 12.6% increase in railway usage in contrast to a 12.4% decrease in roadway. Therefore, we could estimate how much the transportation bottlenecks are costing to the supply chain: R$ 1.6 million per month.

5. Conclusions

After analyzing several scenarios, one interesting conclusion is that transportation constraints are not the ones that bring the greatest impact on the supply chain's global cost, as supposed in the beginning. As we could see in the top three greatest opportunities listed, there are basically two factors to explain that. The first one is that products costs represent 74% of the global cost, while transportation costs represent around 1% only. The second one is that the price gaps between refineries are so big, that in many cases it compensates the usage of less economic transportation modal (roadway), even in larger distances flows. As we could see, these huge price gaps between refineries ends up putting even more pressure on the less economical transportation modal. So, investments in railways are important but will not necessarily bring much difference in fuel transportation in Brazil.

In this *action research* we did not consider inventory costs. According to Wanke (2000) as mentioned, the fuel distribution market profile requires a demand anticipation policy with decentralized stocks, resulting in a strong dependency on demand forecasting in order to balance stock levels. So, in a future approach, we could focus on the study of safety stocks for the fuel distribution market, since each storage terminal has to maintain a certain stock level in order to absorb lead time and demand uncertainties. By now, the company achieved good results with the present approach and in fact, the model is very adherent to reality. We observed that all suggestions pointed by the model are being implemented, except when unexpected situations related to external factors occurs and demand a different plan.

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Appendix

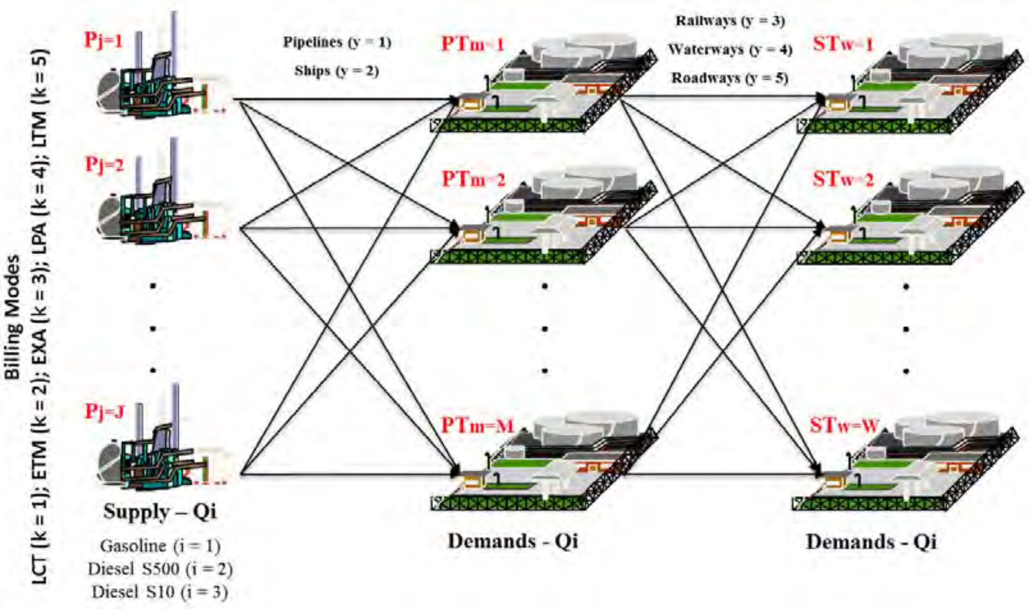

Figure 2 – Optimization Model Structure

$$TA = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{m=1}^{M} Qijm \times TAjm$$ TA - Taxes in Acquisiton Flows

$$TT = \sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{w=1}^{W} Qimw \times TTmw$$ TT - Taxes in Transfer Flows

$$FA = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{m=1}^{M}\sum_{y=1}^{Y} Qijmy \times FAjmy$$ FA - Freights in Acquisition Flows

$$FT = \sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{w=1}^{W}\sum_{y=1}^{Y} Qimwy \times FTmwy$$ FT - Freights in Transfer Flows

$$SA = \sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{m=1}^{M} Qijm \times SAjm$$ SA - Storage Fees Primary Terminals

$$ST = \sum_{i=1}^{I}\sum_{m=1}^{M}\sum_{w=1}^{W} Qimw \times STmw$$ ST - Storage Fees Secondary Terminals

Note 1: The decision variable Q (cubic meters – m³) once multiplied by all units costs (R$/m³) the final result is in R$ (reais).