Network Design Model for Fuel Retail

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Advisor:

Summary: Fuel retailing is a very competitive market, with low margins and price-sensitive customers. In Brazil, where ethanol is competitive against gasoline and produced in locations different from those that produce petroleum fuels, it is possible to optimize the distribution network in order to increase transportation fleet utilization and thus decrease distribution costs and increase profitability. This work adopts Mixed Integer Linear Programming (MILP) modeling in order to recommend a multi-commodity fuel distribution network design throughout the Brazilian Center-South. The resultant prescriptions were subjected to Monte-Carlo simulation to establish their robustness under different business scenarios.

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Key insights:

1. Considering the entire transportation network when locating new retail stations led to 20% higher fleet utilization and 5% higher profit in the model;

2. Considering the route topography when calculating route costs led to a network design with 2% higher profit when compared with not considering topography;

3. The model used average data for 33 cities in Brazil. Factors beyond the scope of this project (such as exact address of the station) affect the station fixed costs and sales volume and account for most of the variability in station profits.

Introduction

Fuel retail is a highly competitive sector, with average margins around 3%, and price-sensitive customers, with data from our research showing that a 1% reduction in retail prices leads to a 5% to 10% increase in retail sales volume. The secondary distribution transportation cost is significant thus a proper supply chain management is fundamental in order to guarantee profitability.

This project evaluated how the sponsor company may use the supply chain configuration in order to

increase its profitability. Our hypothesis was that proper placement of the stations throughout the Brazilian Center-South could increase the transport fleet utilization and thus decrease costs and increase profit substantially. Such increase in utilization is possible because the different fuels provided in Brazil (petroleum-based fuels and ethanol) are produced in different regions of the country. Figure 1 shows the relationship between prices and fuel consumption for 600 cities in Brazil, where a correlation between these two factors can be observed.
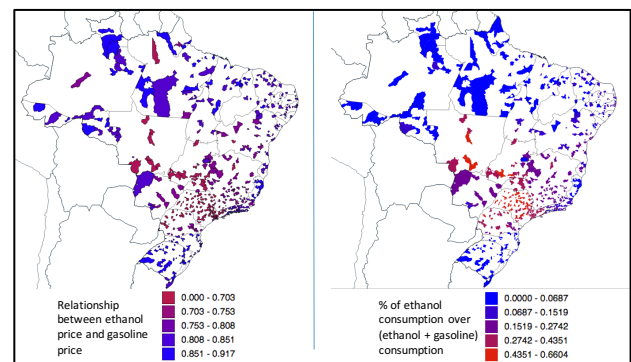

Figure 1: Relationship between ethanol and gasoline prices, and % of ethanol consumption in the fuel matrix (ANP, 2017a)

This study identified the factors that impact costs and revenue, the potential transportation routes, the historical retail and wholesale prices in multiple cities, and modeled the system in order to identify the combination of retail locations that could return the highest profit.

Methodology

The following data were provided by the sponsoring company:

- Retail price of all fuels, day-by-day since 2013;
- Wholesale cost of fuel purchased from distributors since 2013;
- Sales volume of each fuel at each day since 2013;
- Financial data and expenses;
- Fuel consumption of the distribution fleet.

Additionally, the following data were obtained from public sources:

- Monthly average fuel retail and wholesale prices in 600 cities since 2013 obtained from the Brazilian Petroleum Agency;
- Monthly fuel consumption, population and GDP per city for all cities in the country obtained from the Brazilian Institute of Statistics;
- Topographic data for all the 528 routes, with up to 1000 elevations per route, using Google Maps Direction API and the Google Maps Elevation Application Programming Interface.

The topography of the routes and the company trucks' specification allowed to obtain fuel consumption and transit time for each route, using existing fuel consumption models. Together with the company's financial data, it was possible to calculate the route cost for empty and loaded trucks.

The project developed a MILP model with the goal of optimizing profit by placing 10 stations distributed among 33 selected cities. The decision variables were the number of stations in each city and the tanker truck routes between the cities. The constraints required the routes to attend all the station demand, the number of trucks into a node to equal the number of trucks out (conservation of trucks) and the stations to comply with a set maximum number per city.

Results

The model outputs the recommended number of stations in each city, number of trips carrying petroleum liquids (gasoline and diesel) between the nodes, number of trips carrying petroleum ethanol between the nodes and number of empty back haul trips. Also the uncertainties in price and cost of fuel were considered by carrying out Monte Carlo simulations.

The model application for a complete regular case indicates that, with the premises adopted, robust indications for placement of stations in 4 different cities, with supply of ethanol from Goiás region and supply of petroleum-based fuels from São Paulo region, as per Figure 2. The truck utilization in this case is 60%, above the maximum of 50% obtainable when the network is not considered.
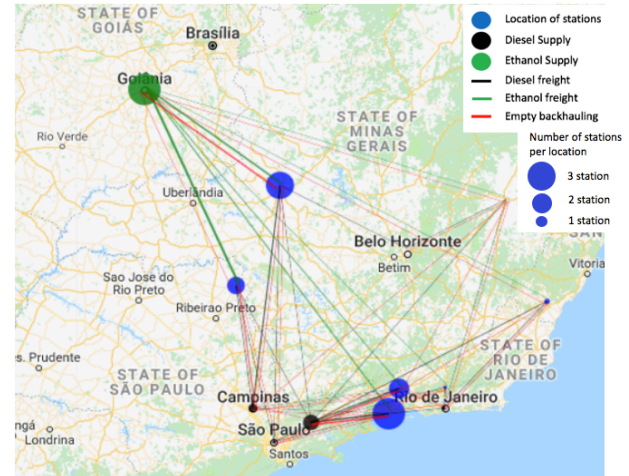

Figure 2: Map of station locations, supply locations and freight routes for the full regular case – probabilistic average result of 500 simulations

Conclusions

The results, Table 1, show that designing the location of the new retail facilities with consideration of the logistics network, including the planning of backhauling in order to increase truck utilization, can increase the expected profit by 5%. Additionally, considering the route topography instead of only the route distances led to additional 2% profit increase, leading to a design 7% more profitable than the base case.

Table 1: Operating Income (EBITDA) (in 1,000` US$) as function of sales volume, calculated with the parameters of the Complete model, for each models

Operating Income as function of sales volume	Model result – Regular case	Model result – Non-topography case		Model result – non-backhauling case	
Sales volume (liters per month)	EBITDA - in 1,000` US$	EBITDA - in 1,000` US$	Difference to Regular case	EBITDA - in 1,000` US$	Difference to Regular case
120,000	12.9	12.8	-1%	12.5	-3%
100,000	9.3	9.2	-1%	9.0	-3%
80,000	5.8	5.7	-2%	5.5	-5%
60,000	2.3	2.3	0%	2.3	0%
40,000	0.0	0.0	0%	0.0	0%

The practical applications of these results, however, are sensitive to actual sales price and volume and station fixed costs. These depend on market potential of the exact street-number level location of the station and may be more relevant to the profitability than the topography and network considerations of the model. In practice, the application of the model thus requires more detailed market evaluation on the potential exact locations.