Strategic and Tactical Planning of the Downstream Petroleum Supply Chain

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Abstract

This paper aims to develop a Mixed Integer Linear Programming (MILP) mathematical model that will support the definition of a distribution strategy for supplying markets with oil derivatives that may span over more than one country. The literature review revealed that the downstream segment of Petroleum Supply Chain (PSC) is an important field of study regarding operations research and that integrating more than one decision-planning level can bring better results. Therefore, the model addresses strategic and tactical decisions (such as determining optimal location and capacities for distribution centers, selection of transportation modes, determining flow allocation, etc.). A real case of Portuguese PSC and its operation in Iberia was used to show the applicability of the model. The results not only consider the current network and how it can be optimized in terms of resource usage, but also foresee which network adjustments would be more advantageous in the case study selected.

Keywords: downstream petroleum supply chain, optimization, mathematical programming, mixed integer linear programming, strategic and tactical planning

1. Introduction

Today the oil and gas industry supplies more than 50% of the whole world energy. Oil is also a source of raw material to petrochemical industry, which uses it to produce plastics, rubber, solvents, etc. (BP - British Petroleum, 2018). Therefore, there are many research opportunities for studies regarding the oil industry as a constant need of improvement exists.

One important field of study regarding the oil industry is the planning and management of its supply chain. Petroleum Supply Chain (PSC) is a complex and dynamic system, which involves high revenues and high costs. It is divided into three main sectors: upstream, which comprises oil exploration and production; midstream, responsible for refining operations; and downstream, considering oil products distribution (Lima, et al., 2018).

As the upstream sector has been well researched, there is a great opportunity to explore the downstream sector in research terms (Fernandes, et al., 2014). As this segment deals with several products' distribution it includes a set of diverse facilities such as storage depots, wholesale and retail market that area linked to two types of distribution: primary and secondary. The distribution includes several transportation modes, which may even be combinable with each other (Lima, et al., 2016). Therefore, the complexity of the downstream segment is huge since it deals with a multi-product distribution between several storages in wholesale and retail market that can be performed using several types of transportation modes including a combination of more than one mode.

The activities of such systems are costly and in order to seek for minimum costs or maximum profit, without compromising safety and quality of the operations there is a need of decision supporting tools to aid the decision-making process (Lima, et al., 2018). This paper explores this need and aims to develop a strategy for optimizing the distribution of oil derivatives in markets that may span over more than one country and to develop a Mixed Integer Linear Programming (MILP) mathematical model in order to do it.

The remainder of the paper is organized as follows. In section two, the literature review is presented. Section three defines the problem. Section four presents the model formulation and validation. In section five, the case study applied to the model in order to show its potential and the results obtained are presented. Section six concludes the paper and presents suggestions for further works.

2. Literature Review

A literature review was performed on downstream PSC optimization. A set of several keywords such as “downstream”, “oil and gas”, “petroleum supply chain”, “optimization” and “operations research” and their combination were used to search for papers in platforms as Google Scholar, Science Direct and Web of Knowledge. The search resulted in 39 papers but only the most relevant and recent ones were analysed. The discarded papers presented models in the upstream and midstream segments of the PSC and, therefore, they were not considered relevant as this work will focus on the downstream supply chain. It is true that some of the 24 selected papers are more focused in refining operations than in the downstream segment itself but these papers also consider the products distribution to the customers and so they were analysed. The majority of papers reviewed were published in the last 10 years, despite that the time frame of the collected papers covers the last 20 years. Still, the older papers are still relevant in the field. The papers selected were classified in five different categories based on their decision-planning level (or the integration of more than one level).

According to Lima et al. (2016), the decision process is classified into three planning levels: strategic, tactical or operational. Each of these levels diverge on the type of decisions and time planning horizon (Lima, et al., 2018). There is a hierarchy among these levels: the strategic imposes limit to the tactical and the tactical imposes limit to the operational (Lima, et al., 2016). Moreover, the decision planning can be vertically integrated, combining two planning levels of decision, for example, strategic-tactical, strategic-operational or tactical-operational (Misni & Lee, 2017), which is a strategy that may help to improve the outcomes (Lima, et al., 2016).

The strategic planning level deals with long-term decisions, in an annual scale (Lima, et al., 2018). The decisions within the strategic level are related to identify the facilities best locations to be structured, to determine their capacities and to select the technologies to be applied at each facility. Facility relocation problems, outsourcing and investment planning are also considered as strategic decisions (Sahebi, et al., 2014). The strategic level decisions are the most complex ones because as they comprise the definition of the structure of the supply chain, the set-up costs for implementation are high (Lima, et al., 2016).

The decisions in tactical planning have medium-term implications, in a monthly scale and they are restrained by the configurations established in the strategic planning. In this planning level, the decisions are related to the establishment of the best material flow across the chain (Lima, et al., 2016), and to the production planning and inventory management (Misni & Lee, 2017).

The operational planning level deals with short-term decisions, in a weekly scale. These decisions are restrained by the operating policies established in the tactical level (Lima, et al., 2018). The decisions in this level concern to vehicle routing and scheduling of products and activities (Misni & Lee, 2017).

From the performed analysis it was possible to conclude that there are some research gaps regarding the downstream segment of PSC that are still to be addressed. Analyzing the papers selected, 16 out of 24 presented models that integrated more than one decision-planning level. Furthermore, due to the high-cost environment that the PSC is inserted and the strategic planning level relation with high investments, it is important to look into the strategic and tactical planning, where the treatment of real cases should be explored, as this allows the validation of the developed models.

3. Problem Definition

In this paper, the problem can be defined as to develop a MILP mathematical model that supports the definition of a distribution strategy for supplying markets that may span over more than one country. This later feature is important since in different countries, different public policies may apply to the distribution operation and these must be accounted when managing the supply chain.

Knowing that strategic decisions comprise the determination of locations and capacities of storage, terminals and distribution bases and planning of transportation modes; and that tactical decisions look into aspects such as the planning of transportation modes, flows' allocation and evaluation of the need to import products or the opportunity to export them, the problem addressed can be generically described as follows:

Given a downstream PSC, in which one company fully manages a set of oil products from a set of refineries to supply a set of locations according to their demands through a set of depots using possible and available transportation modes.

Determine the design and planning of the supply chain, which consists on the installation and and/or closure of facilities while considering its required capacity and how these are going to be operated at a planning level – which transportation modes and routes to use, what are the material flows, refinery productions and import or export of materials.

Subject to customer demands, oil products yield, material balance and storage and transportation capacity constraints.

So as to minimize the costs regarding opening new distribution centers and distribution, which are mainly related to transportation, inventory, import and export.

4. Model Formulation and Validation

4.1. Model Formulation

After defining the problem, the following step was to formulate a mathematical model in order to solve it. The model was based on that developed by Kazemi & Szmerekovsky (2015), which addresses strategic and tactical decisions (such as determining optimal location and capacities for distribution centers, selection of transportation modes, determining flow allocation, etc.) considering multiple products while minimize the fixed and distributing costs.

In order to formulate the MILP mathematical model, we consider two countries A and B, that are commercial partners, and the model was developed under country A's perspective. This is, the objective of the problem is to design and plan the downstream petroleum supply chain minimizing country A's costs. It is also possible to consider more than two countries, this is a more generic model considering a country of origin A and a set B of countries, and all data regarding the other countries considered would replace country B's.

The notations used for the mathematical model were as follows:

<u>Sets</u>

$i \in I$: set of refineries, i = 1, 2, …, I

$j \in J$: set of depots, j = 1, 2, …, J

$p \in P$: set of products, p = 1, 2, …, P

$r \in R$: set of transportation modes, r = truck, barge, rail, pipeline

$u \in U$: set of customer demand nodes, u = 1, 2, …, U

<u>Subsets</u>

$a \in A \subseteq I$: set of refineries a in country A

$b \in B \subseteq I$: set of refineries b in country B

$n \in N \subseteq J$: set of possible new depots locations n in country A

$h \in H \subseteq J$: set of depots h in country A

$k \in K \subseteq U$: set of customer demand nodes k in country A

$w \in W \subseteq U$: set of customer demand nodes w in country B

<u>Parameters</u>

$C_{p,a,j,r}$: transportation cost per unit of product p from refinery a to depot j via transportation mode r

$D_{p,u}$: annual demand for product p at customer node u

f_n: fixed cost of opening the distribution center n

M: a large number (10^9) used as an upper limit for variable V_n

$PEXP_{p,a,b}$: price per unit of product p sold by refinery a to refinery b

$PIMP_{p,b,a,r}$: price per unit of product p sold by refinery b to refinery a transported by transportation mode r

$QDC_{j,k,r}$: annual maximum capacity of transportation from depot j to demand point k using transportation mode r

$QRD_{a,j,r}$: annual maximum capacity of transportation from refinery a to depot j using transportation mode r

$QRR_{b,a,r}$: annual maximum capacity of transportation from refinery b to refinery a using transportation mode r

S_i: capacity of refinery i (tons of products per year)

$T_{p,j,k,r}$: transportation cost per unit of product p from depot j to demand point k via transportation mode r

$TIMP_{p,b,a,r}$: transportation cost per unit of product p from refinery b to refinery a via transportation mode r

$\alpha_{b,p}$: refinery b capacity utilization per product p

β_n: cost per unit of capacity at distribution center n

$\Psi_{p,a}$: maximum fraction of product p that is reasonable to be produced by each refinery a

Binary variable

X_n: 1, if the depot n is opened; 0, otherwise

Continuous variables

z: objective variable: total costs

$\gamma_{a,p}$: refinery a capacity utilization per product p

V_n: capacity of distribution center n (tons per year)

$Y_{p,a,j,r}$: amount of product p shipped from refinery a to depot j with mode r

$Z_{p,j,k,r}$: amount of product p shipped from depot j to demand point k with mode r

$IMP_{p,b,a,r}$: amount of product p imported from refinery b to refinery a with mode r

$EXP_{p,a,b}$: amount of product p exported by refinery a to refinery b

Objective function

The objective function (1) minimizes the total cost for country A of opening distribution centers, shipping products from its refineries to the demand nodes, import and export products from/to country B.

$$\begin{aligned} z = \min \sum_{n \in N} f_n X_n + \sum_{n \in N} V_n \beta_n + \sum_{p \in P} \sum_{a \in A} \sum_{j \in J} \sum_{r \in R} C_{pajr} Y_{pajr} \\ + \sum_{p \in P} \sum_{j \in J} \sum_{k \in K} \sum_{r \in R} T_{pjkr} Z_{pjkr} \\ + \sum_{p \in P} \sum_{b \in B} \sum_{a \in A} \sum_{r \in R} TIMP_{pbar} IMP_{pbar} \\ + \sum_{p \in P} \sum_{b \in B} \sum_{a \in A} \sum_{r \in R} PIMP_{pbar} IMP_{pbar} \\ - \sum_{p \in P} \sum_{a \in A} \sum_{b \in B} PEXP_{pab} EXP_{pab} \end{aligned} \quad (1)$$

The first term represents the total fixed cost of opening distribution centers and the second term is the total variable cost of opening distribution centers, associated with its capacity. The third term indicates the cost of transporting products from refineries in country A to depots and the fourth represents the cost of transporting products from depots to customer nodes. The fifth term states the cost of transporting imported products from country B to country A. The sixth term comprises the price paid by country A to country B for the products imported and the seventh term consists on the price paid by country B to country A for the products exported by country A. As the seventh term represents a revenue of country A, it is negative.

Constraints

$$\sum_{j \in J} \sum_{r \in R} Z_{pjkr} = D_{pk} \quad \forall p \in P, \forall k \in K \quad (2)$$

$$V_n \leq M X_n \ \forall n \in N \quad (3)$$

$$\begin{aligned} \sum_{b \in B} S_b \alpha_{bp} + \sum_{a \in A} \sum_{b \in B} EXP_{pab} \\ - \sum_{b \in B} \sum_{a \in A} \sum_{r \in R} IMP_{pbar} \\ \geq \sum_{w \in W} D_{pw} \ \forall p \in P \end{aligned} \quad (4)$$

$$1.10 \sum_{p \in P} \sum_{k \in K} \sum_{r \in R} Z_{pnkr} \leq V_n \quad \forall n \in N \quad (5)$$

$$\sum_{a \in A} \sum_{r \in R} Y_{pajr} - \sum_{k \in K} \sum_{r \in R} Z_{pjkr} = 0 \ \forall j \in J, \forall p \in P \quad (6)$$

$$\begin{aligned} \sum_{j \in J} \sum_{r \in R} Y_{pajr} \\ \leq S_a \gamma_{ap} + \sum_{b \in B} \sum_{r \in R} IMP_{pbar} - \sum_{b \in B} EXP_{pab} \ \forall p \in P, \forall a \in A \end{aligned} \quad (7)$$

$$S_b \alpha_{bp} \geq \sum_{a \in A} \sum_{r \in R} IMP_{pbar} \ \forall p \in P, \forall b \in B \quad (8)$$

$$S_a \gamma_{ap} \geq \sum_{b \in B} EXP_{pab} \ \forall p \in P, \forall a \in A \quad (9)$$

$$\sum_{p \in P} \sum_{a \in A} \sum_{j \in J} Y_{pajr} \leq \sum_{a \in A} \sum_{j \in J} QRD_{ajr} \ \forall r \in R \quad (10)$$

$$\sum_{p\in P}\sum_{j\in J}\sum_{k\in K} Z_{pjkr} \leq \sum_{j\in J}\sum_{k\in K} QDC_{jkr}\ \forall r \in R \quad (11)$$

$$\sum_{p\in P}\sum_{b\in B}\sum_{a\in A} IMP_{pbar} \leq \sum_{b\in B}\sum_{a\in A} QRR_{bar}\ \forall r \in R \quad (12)$$

$$\sum_{p\in P} \gamma_{ap} \leq 1\ \forall a \in A \quad (13)$$

$$\gamma_{ap} \leq \psi_{pa}\ \forall a \in A, \forall p \in P \quad (14)$$

Constraint (2) guarantees that the demand for each product in each customer node in country A is satisfied by the amount of products that arrives to final customers in country A from the distribution centers.

Constraint (3) aims to limit the capacity of each distribution center that is opened and to ensure that no capacity is going to be assigned to a distribution center that will not be opened.

Constraint (4) states that the amount of each product produced by country B's refineries, plus the amount of each product that country B import from country A, minus the amount of each product that country B exports to country A, must satisfy (which means that it must be greater than) country B's demand for each product.

Constraint (5) ensures that the capacity of each new depot must be higher than the amount of products that flows through this depot. The factor 1.10 that multiplies the left side of the equation aims to guarantee that the depot can handle up to a 10% increase in the demand.

Constraint (6) is a mass balance constraint. It states that all of the amount that arrive in a depot from a refinery will be transported from this depot to each customer node.

Constraint (7) ensures that the amount of each product produced and imported by refineries in country A, minus the amount of each product exported by country A, must satisfy the amount that is transported to refineries to depots.

Constraint (8) indicates that the amount of each product that a refinery in country B can produce must be higher than the amount of the same product that it exports.

Constraint (9) indicates that the amount of each product that a refinery in country A can produce must be higher than the amount of the same product that it exports.

Constraint (10) ensures that the total amount of products transported by each mode from refinery a to depot j does not exceed the mode's maximum capacity.

Constraint (11) ensures that the total amount of products transported by each mode from depot j to customer node k does not exceed the mode's maximum capacity.

Constraint (12) ensures that the total amount of imported products transported by each mode from refinery b to refinery a does not exceed the mode's maximum capacity.

Constraint (13) states that in each refinery the sum of refinery capacity utilization per product must be equal or less than 1, as γa,p represents the percentage of total refinery capacity used to produce a product.

Constraint (14) states the maximum reasonable fraction of product p that should be produced by each refinery a.

4.2. Validation – Illustrative case study

In order to validate the model, an illustrative case study with no real data was implemented. Figure 1 presents the network considered, with the possible new depots to be opened or not (in yellow) and the pipelines in red to be installed or not.

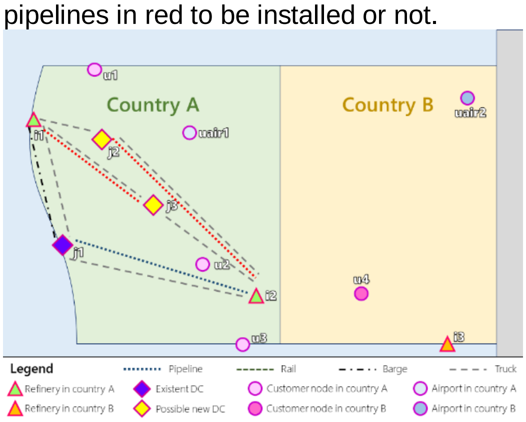

Figure 1. Illustrative case study

The model considering the illustrative case study (Illustrative Model 1) was implemented in GAMS programming language and solved using the solver CPLEX in a personal computer Intel® Core i3-4030U with 1.90GHz and 4 GB RAM memory. The model has 64 equations and 257 single variables, of which 2 are discrete. The execution time was 0.031 CPU seconds.

In order to obtain the minimum cost, the strategic decisions made by the model was that Country A should open only the distribution center j3 and build the pipeline between the refinery i1 and the DC j3.

In order to attest the efficiency of the model, the illustrative case was tested without considering the possibility of opening DCs j2 and j3 and building the pipelines

(Illustrative Model 2). Furthermore, both models were implemented considering a long-term planning horizon of 5 and 10 years, in order to obtain more expressive results. Table 1 presents the results obtained.

Table 1. Analysis in a long-term planning horizon

Long-term planning horizon analysis			
	Planning Horizon		
	1 year	5 years	10 years
	z (US$)	*z (US$)*	*z (US$)*
Illustrative Model 1	4.077×10^{9}	2.036×10^{10}	4.072×10^{10}
Illustrative Model 2	4.123×10^{9}	2.062×10^{10}	4.123×10^{10}
Percentage increase	1.11%	1.24%	1.26%
Absolute increase	45 million	253 million	513 million

The values in Table 1 helps to express the importance of strategic planning. Without investing in opening depot j3 and building the pipeline between refinery i1 and depot j3, it would cost 45 million extra to Country A in a year, 253 million in 5 years and 513 million in 10 years.

5. Case-study

In order to show the model applicability, this is now applied to a real case that aims to develop a distribution strategy for supplying Iberia with oil products produced by a single company in Portugal while minimizing the costs for Portugal. The oil products to be considered are gasoline 95, gasoline 98, gas oil (diesel) and jet fuel.

In Portugal, there are two refineries, Sines and Matosinhos and both of them are managed by the same company. Thus, Portuguese distribution centers that are considered are Leixões, Boa Nova, Aveiras de Cima (CLC), Tanquisado, Sines (maritime terminal) and Sines storage. (Autoridade da Concorrência, 2018). The primary distribution is considered from both refineries to the depots and the secondary distribution from the depots to the capital city of each Portuguese district. In order to consider import and export from/to Spain, eight Spanish refineries were considered.

After acquiring the data regarding the Portuguese PSC and the Iberian market, the location for a possible new depot and two possible new pipelines were decided (see Figure 2). The location of the possible new depot was chosen at Portalegre district because the capital city (Portalegre) is almost equally distant of both refineries and it is located in the middle of the country, that can lead to a better distribution in this area.

The first pipeline was chosen to connect Lisbon and Aveiras de Cima (CLC) depot mainly because the largest airport in Portugal is located in Lisbon and it is supplied only through trucks. The problems of supplying only through trucks the country's largest airport includes jet fuel contamination and vulnerability for unforseeable events such as strikes. The second pipeline was chosen to connect the storage in Sines refinery to Faro, where is located another airport. Faro airport is supplied through train wagons from Sines refinery and through trucks from refinery La Rabida in Spain.

Figure 2. Location of possible new distribution center and pipelines

The real case was analyzed considering a one-year planning horizon and in a long-term planning horizon (5, 7 and 10 years).

The model considering the real case study was implemented in GAMS programming language and was solved using the solver CPLEX in a computer Intel® Xeon® CPU X5680 @ 3.33GHz 3.33GHz (2 processors) and 24 GB RAM memory. The model has 194 equations and 3,359 single variables, of which 3 are discrete. The execution time was 0.047 CPU seconds.

The solution obtained by the model considering the real case (variable *z*) was -4.4828×10^{9}. At first the value obtained seems weird as the objective function is the total cost but analysing the objective function, it is possible to see that there is a negative term, which is the total amount earned by exporting products. Therefore, if the amount exported is high, this term in the objective function equation can overlap the other terms. Analysing the results obtained and considering that both Portuguese refineries are operating in maximum capacity, that is exactly what happened.

As Portugal has an annual refining capacity installed of approximately 19.2 million m^3 (of which almost 14.8 million m^3 are used to produce gasoline 95, gasoline 98, jet fuel and diesel, if the refineries are operating at maximum capacity) and the total demand for gasoline 95, gasoline 98, jet fuel and diesel is approximately 7.5 million tonnes, which is less than half of the total refining capacity, Portugal can export around 7 million tonnes of these fuels annualy. The results show that exporting this extra production, the amount earned counterbalances all the transportation costs and still remains a revenue of EUR $4.4828{\times}10^9$. However, it is important to remember that the refineries in Portugal are not operating currently at maximum capacity (according to Galp's website, 100 MMboe are refined annualy in Portugal, what corresponds to approximately 82% of the maximum refining capacity installed) and the costs of refining and importing crude oil are not considered in this model. Therefore, the decision of operating in maximum capacity may not be the wisest from an economic point of view, although the model shows an enoumous revenue as result.

Another result proposed by the model is that there is no need for Portugal to import oil derivatives. However, in order to be self sufficient in terms of oil derivatives, crude oil must be imported and there are also refining costs, which were not considered in this model. Therefore, a suggestion for further works is to incorporate these costs in order to better analyse this decision.

Regarding the material flow, two important observations must be made about the results obtained. The first is that the model did not consider the transportation through rail from Sines storage to Faro. The reason that it happened is that the model chose the maritime route through Tanquisado depot, as maritime transportation is cheaper than via rail. However, as jet fuel can be easily contaminated and Faro demands jet, at least jet fuel should be transported via rail.

The second observation is that the supply in Lisbon is occurring only through the depot of Tanquisado using maritime transportation. However, the problem is that Lisbon airport demands a high amount of jet fuel and, as jet fuel can be easily contaminated, it would be better to transport the jet from Sines refinery to Aveiras de Cima depot through pipelines and after that through trucks to Lisbon airport, which is the route used today.

Therefore, it is important to consider in further works that jet fuel should be transported through pipeline and rail preferably and the shorter distance as possible through barge and trucks.

Considering a one-year planning horizon, the model suggested that the possible new depot in Portalegre should not be opened and both pipelines should not be built. However, as the investment is high, it is important to analyse these decisions in a long-term planning horizon.

In order to do this analysis, the annual demands and the maximum capacity of each transportation mode were multiplied by the horizon and these values were replaced in the original model. The refining capacity of Portuguese refineries was considered as 82% of the maximum capacity in order to better fit the reality. After running these models in GAMS, the strategic decisions suggested by each of them are available at Table 2.

Table 2. Strategic decisions in long-term analysis

	Strategic decisions		
Planning Horizon	Installing pipeline between Aveiras de Cima and Lisbon	Installing pipeline between Sines storage and Faro	Opening a depot at Portalegre
1 year	-	-	-
5 years	-	-	-
7 years	-	Yes	-
10 years	Yes	Yes	-

Analysing the results of the models considering different planning horizons, it is possible to see that even though installing a pipeline between Sines storage and Faro would require a higher investment than the pipeline between Aveiras de Cima and Lisbon, it would be recommended to so if a 7-year planning horizon analysis is performed. However, if a 10-year planning horizon analysis is performed, the model recommends to invest in both pipelines. Figure 3 illustrates the decisions over the time horizons analysed.

The decision of not opening the depot at Portalegre can be understood because this new depot would require a high investment and it would be accessible only through trucks, which is the most expensive transportation mode. Another reason is that Portugal is a small country and its depots are already strategically located.

Again, it is important to emphasize that the model made the decisions under an economic point of view. Considering a 7-

year planning horizon, the model decided to install a pipeline between Sines storage and Faro and not to install a pipeline between Aveiras de Cima and Lisbon. However, other non-economic factors should be analyzed in order to make this decision, such as jet fuel contamination. For example, Lisbon airport, which is the one that most demands jet fuel in Portugal, is only supplied through trucks and supplying only through trucks is subject to unforeseeable conditions such as delays in the deliver and strikes. Moreover, Sines storage and Faro are already connected through rail and although transportation is more expensive than through pipelines, the issue about jet fuel possible contamination is solved. Therefore, the decision of installing a pipeline between Aveiras de Cima and Lisbon is more crucial and urgent than installing a pipeline between Sines storage and Faro, as it seemed in the model results.

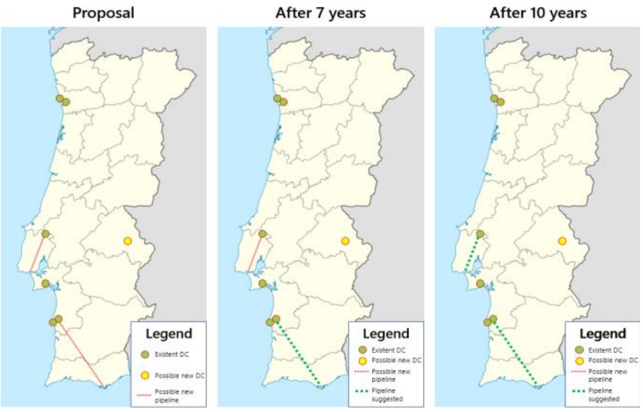

Figure 3. Strategic decisions in long-term

6. Conclusions

This paper aimed at developing a mathematical model to define a strategy for supplying markets with oil derivatives that may span over more than one country considering strategic and tactical planning. It achieved the goals proposed and it is able to make strategic and tactical decisions. The strategic decisions comprise:

- Opening or not a new distribution center and determining its capacity;
- Installing or not a new pipeline between two nodes.

On the other hand, the tactical decisions consisted in:

- Choosing the best material flow in each route between two nodes via each transportation mode;
- Choosing the amount that should be imported and exported.

The model developed was based on Kazemi & Szmerekovsky (2015) and the main contributions of the model developed when compared with the base one were:

- More than one country is considered and, therefore, costs related to import and export were incorporated;
- The model limits the capacity of a transportation mode and it does not establish flow in an unfeasible route;
- The model decides the fraction of total refinery capacity should be used to produce each product considered;
- Already existent distribution centers are considered along with the decision of opening or not a new distribution center;
- The model is versatile and it can determine if a distribution center should be opened or not, if a pipeline should be built or not or both features together.

After formulating the model, it was validated using an illustrative case study. The analysis performed regarding the illustrative case study verified that the results were better when strategic and tactical planning were integrated, what was stated in literature (Lima, et al., 2016).

Then, a real case of Portuguese PSC and its operation in Iberia was used to show the applicability of the model. It is worth noting that the model made important strategic decisions regarding the real case study. The model decided when analyzing in the long-term that a pipeline between Sines storage and Faro and a pipeline between Aveiras de Cima and Lisbon should be installed. These decisions are very important, mainly regarding the second pipeline because Lisbon airport is the largest airport in Portugal and it is supplied only through trucks. Supplying the largest airport only through trucks involves risks such as jet fuel contamination and lack of supply due to strikes.

Furthermore, the model made the tactical decision that, before installing these pipelines, Faro and Lisbon airports should be supplied through barge. However, Faro airport is supplied through rail from Sines storage and through trucks from refinery La Rabida in Spain due to the ease of jet fuel contamination and Lisbon airport is supplied through the routes Sines refinery to Aveiras de Cima via pipeline and from Aveiras de Cima to the airport via trucks due to the same reason. Therefore, it is important to incorporate features in the model that would prioritize jet fuel transportation through pipelines and rail.

Thus, after analyzing the results proposed by the model, some suggestions for further works were addressed:

- Limit the transportation by trucks to distances lower than 250 km in order to fit best the reality in Portugal;
- Prioritize jet fuel transportation through pipeline and rail rather than through barge and trucks due to the fact that jet fuel can be easily contaminated;
- Integrate the model with features of upstream and midstream segments such as cost of importing and transporting crude oil and refining cost;
- Consider also biofuels because Spain and Portugal have different agreements regarding the amount of biofuels that they should incorporate;
- Integrate the whole distribution in Iberia, minimizing the cost for all companies that operate in Iberia in a cooperative manner.

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