Extended Abstract to obtain the Master of Science Degree in
Industrial Engineering and Management

Jet Fuel Distribution System: Lisbon Airport Case Study

Guilherme Barreiros Pereira

Department of Engineering and Management, Instituto Superior Técnico, Universidade de Lisboa

guilherme.barreiros.pereira@tecnico.ulisboa.pt

Abstract: Crude oil and its products are present in the supply chain of most goods and services and are a key resource in many industries. The transportation sector is a major example of this. Before the pandemic state, crude oil products accounted for 94% of the sector total energy demand. The aviation sector is no exception, as it depends directly on jet fuel to refuel the aircrafts in order to keep flights running as well as the remaining airport operations. This dissertation will focus on the supply of jet A-1 to Lisbon airport, which was one of the economic activities most affected by the recent hazardous material drivers' strikes. The aim is to study the replacement of the current distribution system with a new pipeline system. Therefore we are faced with a decision-making problem where the final goal is to provide the necessary data and information to the decision makers in order to promote an informed decision of introducing a new pipeline system to replace the current distribution system of jet A-1 via road tankers. To tackle this problem it is developed a methodology which combines an investment analysis, where two decisive parameters of the problem arise, profitability and transport fee. With a Multicriteria Decision Analysis where multiple criteria are considered, including subjective ones. Considering all the results obtained from the methodology developed, they thoroughly support the replacement of the current system and the investment in a new pipeline system to transport the jet A-1 from CLC to Lisbon airport.

Keywords: Jet Fuel; Oil Pipeline; Investment Analysis; Multicriteria Decision Analysis; MACBETH.

1. Introduction

Just before the pandemic, crude oil products accounted for 94 percent of total transportation energy demand. The main products being gasoline, diesel and jet fuel (EIA, 2019). This dependency shows how important it is to guarantee their supply to end consumers, since they do not have direct alternatives. The focus of this dissertation will be on the supply of jet fuel to its final destination – i.e. the secondary distribution within the oil supply chain. Jet fuel is the main fuel used in aviation, but it can also be used in other jet turbine applications (Chevron, 2007; McKinsey, n.d.). Therefore, if there is lack of supply, economies will suffer since air transport supports both economic growth and prosperity trough tourism and trade (IATA, 2019a). Both tourism and trade will be negatively impacted due to flight cancelation and the impossibility of transport goods by air, respectively.

The event of an airport running out of fuel is unusual. However, in recent years Portugal has been dealing with socio-political problems which have affected the distribution of oil refined products via road tankers. In 2019, two strikes of hazardous goods truck drivers took place as a form of protest about their contractual conditions. This led to a full stop in the distribution of oil refined products to points of sale. In the most recent one, minimum services were not fulfilled, consequently airports and emergency gas stations were not supplied as they should have been.

Lisbon airport was one of the affected, with only one canceled flight and six delayed. However, these events showed how fragile the current system can be if there are no drivers available. Consequently, the Portuguese government felt the need to study alternatives to the current distribution system. There are five main modes of transporting oil refined products: road, pipeline, rail, barge (river) and ship (sea). The development of a new pipeline system to supply jet A-1, that will connect CLC directly to Lisbon airport, is projected by the Portuguese government, as the best fitted alternative to mitigate some of the risks of the current distribution system. This dissertation arises from the need to study this new pipeline system as an alternative to the current distribution system. So we are faced with a decision-making problem, where the final goal is to provide the necessary data and information to the decision-makers in order to promote an informed decision on whether to replace the current distribution system or not. However, this is a complex problem because it is at the same time a capital budgeting decision, for the company which will be investing in this new system, and a social interest project because it can have great impact to society in a social and environmental dimension. Our goal is not to focus on one of these dimensions but rather on all the three so the information gathered to support the decision making will comprise economic, environmental and social factors.

Thus the dissertation's methodology is different from the existing techniques, as it will combine a decision making analysis and an investment analysis, and generally just one of this methods is used. There are several methods applied to decision making problems where the methodologies based on economic principles are highlighted. These include two main approaches cost-benefit analysis (CBA) and cost effectiveness analysis (CEA) (EIB, 2013; Spackman et al., 2000). Despite being used worldwide there are some cases when the outputs of a project are difficult to measure monetarily where CBA and CEA are not the best fitted methodology to be applied (EIB, 2013). Multicriteria decision analysis (MCDA) is a decision making analysis technique which appears as an alternative to CBA and CEA (EIB, 2013; Tudela et al., 2006). Despite also being based on economic principles, the main difference between MCDA and the other methods is that it considers both quantitative and qualitative criteria whereas the other methods only consider quantitative criteria (Tudela et al., 2006; Yedla & Shrestha, 2003). MCDA is a technique where there are several criteria under consideration, which sometimes are contradictory to each other and have different importance (Baltussen & Niessen, 2006; Beria et al., 2012; Tudela et al., 2006). Therefore, MCDA goal is to guide the decision maker in the process of judging the multiple criteria and evaluating the alternatives, in order to promote informed decisions (Belton & Stewart, 2002). There are various techniques for developing a MCDA: Multi attribute utility theory, REGIME, ADAM type, Electre and Promethee outranking procedures, goal programming, Analytic Network Process (ANP), Analytic hierarchy process (AHP) and MACBETH (Spackman et al., 2000; Tudela et al., 2006). Although the AHP method has been widely applied by several authors for different purposes in the petroleum pipeline industry, there are other authors which point out some inconsistencies related with its methodology. Belton and Gear tackle the ambiguity inherent to what the decision maker recognizes as weight. Concluding that the root of inconsistency in Saaty's method is the normalization factor (Belton & Gear, 1983). Bana e Costa and Vansnick address a problem concerning the meaning of the priority vector derived from the principal eigenvalue method used in AHP. They concluded that the principal eigenvalue method (EM) used in AHP has a serious fundamental weakness which leads to inconsistencies in the model (C. A. Bana e Costa & Vansnick, 2008). In response to the lack of consistency in the AHP method, two new methodologies derived by it were proposed the Modified AHP (MAHP) method (Donegan et al., 1992) and the Dynamic AHP (DAHP) method (González-Prida et al., 2012). Moreover, MACBETH, the Measuring Attractiveness by Categorical Based Evaluation Technique, emerges as an alternative to AHP (Spackman et al., 2000). MACBETH is an interactive multi-criteria decision support approach. However, contrary to numeric methods, where the decision maker have to express quantitative judgments to construct value functions, the MACBETH approach uses qualitative judgments of differences in attractiveness in order to generate value functions (C. Bana e Costa et al., 2011). Since giving quantitative judgements can be a difficult task for the decision maker due to not being intuitive to express preferences with numbers (C. Bana e Costa et al., 2008; von Winterfeldt & Edwards, 1996), MACBETH'S approach solves this problem. That is one of the main reasons alongside the inconsistencies found by some authors for choosing MACBETH instead of AHP.

Regarding investment analysis, in corporate finance there are several techniques used to analyze potential investments in order to support capital budgeting decisions, these include: Net present value (NPV); Payback period; Discounted payback period; Internal rate of return (IRR); Modified internal rate of return (MIRR); Profitability index (PI) (Fabozzi & Drake, 2009; Ross et al., 2015). From these the Net Present Value (NPV) is the main investment evaluation technique since is the only one that satisfies four key criteria to support capital budgeting decisions:

- Consider all future incremental cash flows from the project;
- Consider the time value of money;
- Consider the uncertainty associated with future cash flows;
- Have an objective criterion by which to select a project (including mutually exclusive projects).

The NPV method is the one that will guide the financial manager into the investment that maximizes wealth, so when it is possible to compute it should always be used to make their decision. Usually, as there is the possibility of poor estimates, financial managers make use of several techniques since they will provide them additional information to support the results given by the NPV method (Fabozzi, Drake, 2009; Ross et al., 2015).

Taking all this information into consideration the methodology which will be developed will be a combination of a MCDA, where the MACBETH method will be used, with an investment appraisal, where the NPV method will be used. This methodology allows tackling all three key dimensions of the problem economic, environmental and social fulfilling the goal mentioned previously.

The remainder of this paper is structured as follows. Section 2 includes a description of the case study where the two alternatives, the current supply system via road tanker and the new pipeline system will be characterized and the problem scope will be defined. Section 3 includes the procedure developed to accomplish the proposed methodology, and then the results obtained from it are presented and discussed. Finally, section 4 includes the conclusions and some guidelines for future work.

2. Case Study

The jet A-1 supply chain has four main stakeholders which are relevant to the problem in study, these are: oil companies (product owners), Companhia Logística de Combustíveis (CLC), (possible operator of a new transportation system), TIEL – Transportes e Logística, S.A. (transportation company) and ANA (company responsible for airport management). In this section, the two alternatives evaluated in the decision making problem will be characterized and key information and data for our study will be presented.

2.1 Current Distribution System

Currently, the distribution of jet A-1 to Lisbon airport is done via road tankers. TIEL (transportation company) is contracted by the oil companies trough outsourcing contracts where a fixed transport fee is charged for each m^3 of product transported. The loading of the road tankers is done in CLC facilities, meaning that everyday trucks loaded with jet A-1 leave CLC facilities, in Aveiras de Cima, in direction to Lisbon airport, in Portela. Each truck completes more than one trip per day: it loads in CLC, then unloads at the airport and returns to load again. The route they take is via highway A1, hence it can be considered for the trip CLC – Airport – CLC a distance of approximately 120km (Figure 1).

Figure 1 - Road tankers Route

Each road tanker has 35 m^3 of capacity. In each shift a road tanker does 3 trips. The truck does 2 shifts per day with one different driver for each one. Each driver works 8 hour per day, 6 days per week, 24 days per month. Considering that in 2019, there were approximately 100 trips of 120 km done per day to enable the supply of jet A-1, it brings out several issues. Firstly, the amount of daily air pollutant emissions which impact both environment and human health. Therefore, the possibility of reducing the emissions generated by the current distribution system is key factor for the stakeholders involved. Additionally to the environmental impacts, there are other general concerns related with road distribution via road tankers. These include: delay in supply and public health safety. The first associated with the dependency on the highway which suffers from frequent traffic jam, as well as, the risk of highway unavailability in extreme situations. The second associated with the risk of accident, with road tanker, which can cause severe impacts to thousands of citizens which have to travel daily in that highway. Moreover, the general public complain about the mobility constraints and traffic caused by the hundreds of road tankers which travel daily in the highway (ECO Sapo, 2020; The Portugal News, 2019). Lastly, the recent driver's strikes, already mentioned above, is one of the main concerns of stakeholders and the one that triggered the study of a new pipeline system as alternative mode of transportation for the jet A-1 to Lisbon airport.

2.2 New Pipeline System

The development of a new pipeline system to supply jet A-1, that will connect CLC directly to Lisbon airport, is considered by the Portuguese government, as the best fitted alternative to mitigate some of the risks of the current distribution system. Rail could have been considered together with the pipeline, but the lack of existing rail infrastructure near Lisbon's airport makes it unfeasible. In the pipeline case, while it has high initial costs and being limited in terms of route, it is safer and has less environmental impacts while being the most cost efficient mode of transportation (Capiau, 2010; Pootakham & Kumar, 2010; Strogen et al., 2016). The introduction of the new pipeline system will eliminate the need for the daily 100 road tanker trips, which will mitigate some of the problems mentioned previously.

CLC, which is currently the company responsible for the multiproduct pipeline which connects Sines refinery and its installations and for the storage of all crude oil products transported in it, is the company which is on the front line to be responsible not only for developing the project, but also to operate the new pipeline system when finished. Therefore, in this case study it will be considered as the investing company, as well as, the operator of the pipeline. Meaning that, CLC will charge a transport fee to oil companies for each m^3 of product transported in the pipeline, as it currently happens with TIEL.

Currently, there is still scarce definitive information regarding the characteristics of the new pipeline system, however a preliminary characterization of the system was developed with a focus on its key components and design (ISO 13623, 2009; ISO 3183, 2019). From it the following information was obtained, the system will have an approximate length of 50 km to connect CLC directly to Lisbon airport, a diameter of 12 inches and a wall thickness of 9,53 mm. Additionally, it will be composed by: three pumps, where one will have a speed variator; emergency shutdown valves and sectioning valves; a pigging system for maintenance; a 3 Layer Polyethylene corrosion resistant coating and a cathodic protection; a leak detection system; a safety, control and communication system. Accordingly, despite the operation of the new system being simpler than the current system because the product flows directly from CLC to Lisbon airport with practically no need for workforce, the new system has more components to enable its operation thus making it more complex.

2.3 Problem Scope Definition

Considering the characteristics of both systems we can identify key factors for the decision making process regarding the three key dimensions identified previously. The economic dimension brings up two decisive parameters of the problem, profitability and transport fee which is the fee charged to oil companies for the transportation of jet A-1 from CLC to Lisbon airport. Regarding profitability, it has to be guaranteed for the investor company, which will be considered for the purposes of our study CLC, so that the investment on this project is attractive. In terms of transport fee, it can be identified as the main economic decisive factor of this problem because if the transport fee required to guarantee the investment profitability is higher than the current charged for the transportation via road tankers, oil companies would continue to ship the product via road tanker as it will be cheaper thus making the pipeline system needless in an economic perspective. So, the only way the investment is beneficial for both parties is if the transport fee decreases while guaranteeing CLC's profitability. However, in case this does not happen if the Portuguese government considers the new system essential for national interest, it can subsidize the project to overcome those problems. This is where the environmental and social dimension are as important as the economic one, because if the introduction of the new pipeline system leads to environmental and social benefits, like decrease in air pollutant emission, decrease social instability and increase reliability of supply it can be enough to make the Portuguese government to consider the new system essential for national interest and as mentioned above it the project is developed independently of the results of the economic analysis. All these decisive points raised regarding the problem justify the proposed methodology because the combination of the MCDA with the investment analysis will guarantee that all these points are tackled.

3. Methodology Implementation & Results

3.1 Multicriteria Decision Analysis

The multicriteria model construction is an iterative and didactic process, which follows a constructive socio-technical approach (Spackman et al., 2000). The inclusion of decision makers is vital and it is from them that we are able to gather the majority of information we need. Thus the process of building the model is done along with the decision makers and involves several doings, whose sequence in not unidirectional, but iterative and flexible, allowing for the introduction of adjustments whenever necessary, which are divided into three phases: Model Structuring; Determining criteria value functions and weights; Compute alternatives' global scores. The MCDA will be developed by applying the MACBETH method as mentioned previously. The implementation of the MACBETH method is done via M-MACBETH software application, which not only includes all the necessary tools to build the multicriteria model, but also functionalities to interactively analyze the sensitivity and robustness of the model's results. These tools are used for the structuring phase, to build value tree and criteria's descriptors, as well as, for ranking, scoring and weighting, and at the end to obtain alternatives' global scores.

3.1.1 Model Structuring

The data used in model structuring phase was obtained from a mixture of literature on the topic with semi-structured individual interviews we developed, with pre-defined questions, with each decision maker. The reasoning behind us opting for semi-structured interviews is that despite having pre-defined questions we have flexibility to approach more specific subjects according to each the decision maker area of expertise (Barriball & While, 1994).

The group which took part on the model structuring phase and which we made an individual interview with, was composed by the following individuals: Operations manager at CLC; Head of aviation at Galp, connected with the business of selling jet to airlines; Airport Operations Coordinator at Galp; Director at Galp, connected with various environmental projects in the company.

Model structuring begins with the construction of the value tree. From the individual interviews we identified what are decision makers main concerns regarding the current distribution system and what are the goals they want to reach from replacing the current distribution system of jet A-

1 via road tanker with a new pipeline system. From this information we identified the problem's evaluation criteria and built the following value tree (validated by the decision makers) (Figure 2), where the bold and red text represents the evaluation criteria identified.

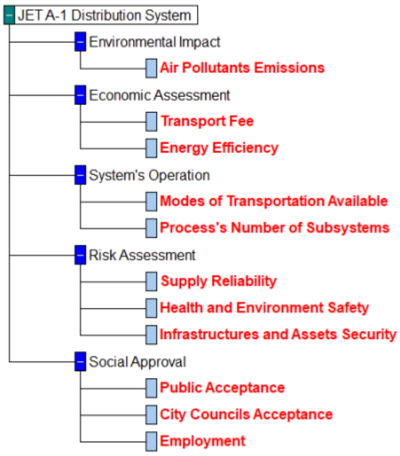
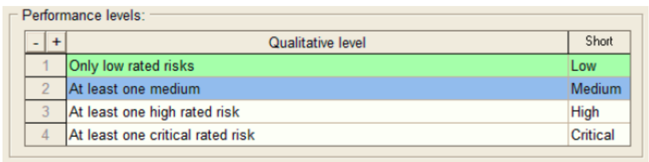


Figure 2 - Value tree. The red nodes correspond to the evaluation criteria.

Constructed and validated the value tree the next stage is to operationalize the evaluation criteria identified by building descriptors for each one of them. In this stage, it is essential to define for each criterion two reference levels, "good", which represents a level of unquestionable attractiveness and "neutral" which represents a level neither attractive nor unattractive. These levels are fundamental for criteria weighting, therefore we gave them special attention so that they were well defined. An example of a descriptor is given below for criterion "Supply Reliability". For the Reliability of Supply criterion we built a qualitative constructed descriptor based on the risk ratings of the hazards studied in the risk assessment (Figure 3). In the risk matrix approach we assess hazard's severity of consequences and its frequency, where we assign a numerical score to each one from 1-5. Finally, the risk level corresponds to the product between the scores of severity and frequency. Depending on the value obtained risks are evaluated as critical (25-16), high (15-8), medium (3-6), low (1-2).


Performance levels:

	Qualitative level	Short
1	Only low rated risks	Low
2	At least one medium	Medium
3	At least one high rated risk	High
4	At least one critical rated risk	Critical

Figure 3 - Qualitative constructed descriptor for criterion "supply reliability". **Caption: Blue level** – " Neutral" reference level; **Green level** – "Good" reference level

The final stage of model structuring is to characterize each alternative in order to identify or determine their performance on each of the criteria identified. Table 1 showcases the performances of both alternatives in each criterion, which were determined from a mixture of data gathered from the individual interviews and the literature on the matter.

Table 1 - Alternatives' table of performances (1) (Galp, 2018) (2) (Jaramillo & Muller, 2016) (3) (Soares, 2009)

Evaluation Criteria	Current system	New pipeline system
Air pollutants emissions	2.3 kg/m^3 (1) (2)	0.56 kg/m^3 (3)
Transport fee	3.90 €/m^3	1.67 €/m^3
Energy efficiency	8 kWh/m^3	2.08 kWh/m^3
Modes of Transportation Available	1	2
Number of subsystems	Multiple simple	Multiple complex
Supply reliability	Medium risk	Low risk
Health and environmental safety	Medium risk	Low risk
Infrastructures and Assets Security	Low risk	Medium risk
Public acceptance	Neutrality	Partial Approval
City councils acceptance	Approval	Approval
Employment	0	40

3.1.2 Determination of Criteria's Value Functions and Weights

When the model structuring is finalized, by validating both the value tree and the descriptors, the next phase is to construct the criteria's value functions, as well as, determine their weights, in order to enable us to compute the global score of each of the options considered. MACBETH introduces seven qualitative categories, no difference, very weak, weak, moderate, strong, very strong and extreme, which are used by decision makers to do a pairwise comparison between options. Generally, this phase is developed via decision conferences where all decisions makers are present. The goal is to promote discussion between them so that in the end we can collect consensual judgments. However, in our case this was not possible not only due to unavailability of all decision makers, but also due to the confidentiality agreements each decision maker have with their company. Therefore, we developed an approach similar to the DAI where personal computer-assisted interviews were done with each decision maker. From the individual interviews approach we collected each decision maker judgements on the pairwise comparison between performance levels in terms of their difference in attractiveness, in order to fill out the judgement value function matrix of each criterion. However, because the process of collecting decision makers' judgements was done through individual interviews instead of decision conferences, it was inevitable that for some pairwise comparisons different judgements were elicited. In these cases, we took advantage of a MACBETH's tool which is the possibility of selecting more than one category to measure the difference in attractiveness between levels. When this was not possible it was the facilitator responsibility to analyze the information collected from the interviews and select the judgment which better reflects the decision makers perspectives. From this procedure we obtain a final matrix for each criterion that best reflects the judgements elicited from the decision makers. Only when a consistent judgements matrix is obtained the software is capable to compute the criterion's value function. When obtained from the M-MACBETH software the value functions was validated by the decision makers and adjustments were made where necessary (Figure 4).

Figure 4 - Interval Scale for criterion "Supply Reliability" obtained from M-MACBETH

Figure 14 displays the interval scale for criterion “Supply Reliability” obtained from M-MACBETH which reflects the judgments elicited by the decision makers. The interval scale was validated without any adjustments since the decision makers agreed with the scores obtained for each performance level. The next step is to determine the weight for each criterion. Again the data collected previously enabled us to fill the judgement weighting matrix . As was the case for the value functions, whenever different judgements were elicited by decision makers the same process was taken. With this data the M-MACBETH creates the weighting scale, which once more has to be validated by the decision-makers and can be adjusted within a certain range (Figure 5).

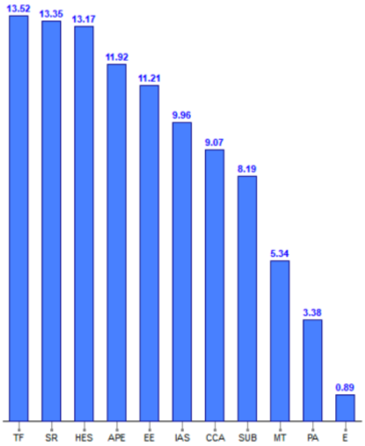


Figure 5 – Criteria’s Weights Histogram obtained from M-MACBETH. **Caption: TF** – Transport fee; **SR** - Supply reliability; **HES** – Health and environmental safety; **IAS** – Infrastructures and assets safety; **APE** - Air pollutants emissions; **SUB** – Process’s number of subsystems; **EE** – Energy efficiency; **CCA** – City councils acceptance; **PA** – Public acceptance; **E** – Employment; **MT** – Modes of transportation available.

From the individual interviews it was consensual that criteria “Transport fee”, “Supply reliability” and “Health and environmental safety” have the most important swings and the difference in attractiveness between them was almost none as showcased by their weights, 13.52, 13.35 and 13.17 respectively. The same can be said for criterion “Employment” but in the opposite way, since it was consensual that this criterion have the least important swing, hence having the lowest weight, 0.89.

3.1.3 Global scores and Sensitivity Analysis

Finalized the construction of the multicriteria model we are now able to obtain alternatives´ global scores from M-MACBETH software, which uses the value functions and weights determined previously and through an additive model computes each alternative's global score considering its performance in each of the evaluation criteria. These global scores are shown in Figure 6 below.

Figure 6 - Overall Thermometer

From these we can analyze that the option of replacing the current system with a new pipeline system has a much higher global score (104.38) than the option of keeping the current system as it is (-0.9). The negative value obtained for the current system alternative global score it is due to its performance in criteria “Air pollutants emissions” and “Modes of transportation available” which are below the “neutral” reference level. Which is in line with decision maker points of view since the current emissions are above acceptable and currently there is only one transportation mode available thus putting the supply of jet A-1 in danger as it happened with the road tanker drivers' strikes where there were no alternatives. Additionally, the M-MACBETH software is equipped with tools which showcase the evaluation criteria that had the greatest impact in this difference and which allow us to perform a sensitivity analysis, allowing us to do a more in-depth analysis of the results obtained. Figure 7 presents one of M-MACBETH’s tools (differences profiles), it exhibits the weighted difference in performance in each criteria between alternatives, as well as, the overall difference (105.28). We can analyze that the pipeline option has a better performance in seven criteria whereas the road tanker option only in four criteria. Besides having a better performance in more criteria it is also important to notice that these include the ones with higher weights, “transport fee”, “supply reliability” and “health and environmental safety”, hence contributing to the big difference in the global scores presented above (Figure 6). However, we can see that the main evaluation criterion that contribute for this difference is "air pollutants emissions" with a weighted difference of 35.97. Followed by the "transport fee" criterion with a weighted difference of 25.77 (Figure 7).

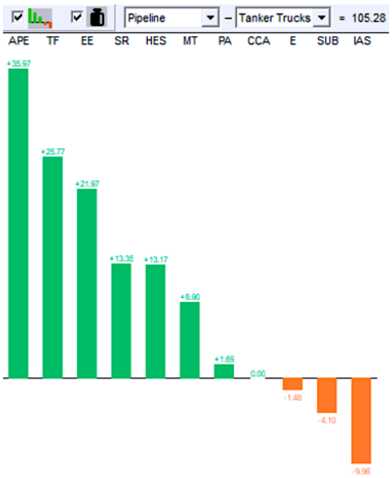


Figure 7 - Options' differences profiles

Then, the software also has the capability of developing a sensitivity analysis where it showcases for each criteria how varying the criterion weight from 0 to 100 influence the overall scores and which is the weight that makes the road tanker option more attractive than the pipeline option. However, in this case due to the really big difference between alternatives' overall scores the necessary weight variations in order to make the road tanker option more attractive are unrealistic because they are too large. Hence, confirming that the criteria´s weights correctly reflect the decision-makers preferences.

3.2 Investment Analysis

The investment analysis developed follows the NPV method, where the NPV is estimated and analyzed in order to access the profitability of the investment. However, in this analysis the NPV will not be enough to support the capital budgeting decision to be faced by CLC of investing or not in a new pipeline system to supply jet A-1 to Lisbon airport. As mentioned in the problem scope there is an additional decisive economic factor for this problem which is the potential transport fee charged to oil companies for the transportation via pipeline. Because, if CLC has to charge oil companies a transport fee higher than the one currently charged for the transportation via road tankers to reach the required return on the investment, oil companies would choose to continue to ship the product via road tankers as it is cheaper for them, and thus the pipeline system would be needless, considering merely the economic dimension of the problem. Therefore, the procedure developed will allow us to determine the NPV and transport fee for both scenarios, the one without the project (road tanker scenario) and the one with the project (pipeline system scenario), so that we are able to compare them and determine if the investment

on the new pipeline system is beneficial for both parties, operator (investor) and user(oil companies) of the system.

Firstly, to develop the NPV method there are two key components that need to be determined for each scenario, the cash flows of the project and the firm's weighted average cost of capital (WACC). In project evaluation, cash flows from assets are divided into three components, operating cash flow, capital spending and net working capital, in this problem's case the net working capital does not apply. Beginning with the road tanker scenario, its capital spending includes the purchase cost of the road tanker which is divided into two components the truck tractor and the jet A-1's tank , which is different from the ones which are used to transport diesel and gasoline because it has no compartments. The operational costs can be divided into two categories, vehicle-based and driver-based (Murray & Glidewell, 2019), and include: fuel, repair and maintenance, insurance, tires, tolls, salary, health insurance and fixed and administrative costs. In terms of the revenues, they are estimated by multiplying the transport fee (€/m^3) with the amount of jet transported (m^3). In the case of the pipeline system scenario, its capital spending are divided into two categories, the material and equipment cost and the labor cost, and include: pipe, pumps, speed variator, valves, cathodic protection and workforce. The operational costs in a pipeline system includes, the maintenance and repair, and other operational costs, and the energy costs. In terms of the revenues it is exactly the same as in the road tanker scenario.

Then regarding the firm's WACC, it represents the cost of capital for a company as a whole, so it can be interpreted as the overall return the company need to earn from its assets so that it is able to maintain its stock value. In investment appraisal WACC is the firm's required return that should be used to discount future cash flows (Reilly & Brown, 2011; Ross et al., 2015). Thus, we need to determine it for both scenarios. To compute the WACC we need to identify four parameters, cost of equity, cost of debt, market value of firm's equity and market value of firm's debt. In both scenarios, the cost of debt, the market value of firm's equity and the market value of firm's debt were obtained from the firm's financial data. Whereas, the cost of debt was estimated via the capital asset pricing model (CAPM). We obtained the following WACC for each scenario (Table 2)

Table 2 - Firms' WACC

	Road tanker (TIEL)	**Pipeline system (CLC)**
WACC	2.16%	0.38%

All the data on the parameters identified above was gathered from the literature or provided by the stakeholders involved in this dissertation, mainly CLC.

3.2.1 Pipeline System Scenario & Transport Fee

Starting by determining and analyzing the transport fee in both scenarios, since it is one of the required components to compute the NPV, we have two different approaches. In the road tanker scenario despite actual transport fee charged is a confidential value, CLC was able to provide us the average price in the industry which is equal to 3.90 €/m^3 of jet transported in each trip (120 km). However, in the pipeline system scenario the transport fee is yet to exist thus we had to estimate it. The procedure developed to estimate it has two main steps. The first one was to ask CLC, "as the investing firm what is the required rate of return it wants to attain from the investment in the pipeline system?", where the answer given by the firm was a required return of 11%. The second step is to estimate based on the investment cash flows what is the transport fee which needs to be charged so that a required return of 11% is obtained. Via this procedure we are able to obtain the transport fee which CLC will need to charge to oil companies in order to obtain the return on investment it wants. From this procedure and, accounting for all the scenario's cash flows and the required return of 11%, we obtained the result showcased in Table 3.

Table 3 - Estimative of pipeline system scenario transport fee and comparison with current transport fee

Scenario	Transport fee (€/m^3)
Pipeline system	1.67
Road tanker	3.90

This result clearly supports CLC to proceed with the investment in the new pipeline system because the transport fee charged will be decreased hence being more attractive for oil companies which will be able to decrease the costs it currently has with the transportation of the jet to Lisbon airport. The savings in transportation costs that oil companies are able to achieve with this change in mode of transportation will balance the initial investment that is required to introduce this new supply system showcasing how beneficial this investment could be. In this process more information on the investment was obtained (Tale 4).

Table 4 - Pipeline system scenario economic indicators

Indicator	Value
NPV	32.89 €/m^3
Payback period	10 years

We obtained, as expected, a positive NPV meaning that the investment increases company's value. Also, the 10-year payback period means that CLC will recover the initial investment cost on the pipeline system in exactly half of the lifetime considered for it.

3.2.2 Road tanker Scenario and Sensitivity Analysis

Despite all indicators being favorable to accept and go through with the investment in the new pipeline system there is additional relevant information regarding the road tanker scenario which can influence the results obtained above. This is related with TIEL seeing this new system as a threat to its business of transporting jet A-1, thus there is the possibility for the company to negotiate and give better conditions to oil companies which can lead to a change in the results and conclusions made previously. Hence, the investment appraisal for the road tanker scenario in TIEL's perspective will be presented and a sensitivity analysis will be developed with the goal of studying how competitive can TIEL be in relation to CLC in terms of the transport fee charged. From the data gathered regarding the scenario's cash flows and WACC (0.97%) we obtained the following results (Table 5).

Table 5 - Road tanker scenario economic indicators

Indicator	Value
NPV	5.81 €/m^3
IRR	33 %

These results showcase that for a transport fee of 3.90 €/m^3 the jet A-1 shipping business has been giving TIEL a great return on its investment. Additionally, it showcases that the company has a considerable margin to charge a cheaper fee while maintaining its business profitable. Therefore, the next stage is to develop a sensitivity analysis where some variables will be diverse, however instead of just studying its impact on the NPV we will also study the impact on the transport fee. The main goal is to analyze if TIEL is able to decrease the current transport fee charged to a value lower than the one obtained previously for the pipeline system scenario while maintaining its business profitable. In order to estimate the new values of transport fee, we will follow the same procedure developed for the pipeline system scenario, thus it will be assumed that TIEL'S minimum required return on the investment is 11%, as considered for CLC. Throughout the process of identifying and computing the road tanker scenario cash flows we came to the conclusion that the most impactful variable is the amount of trips the truck performs per shift because the increase in revenue from it its larger than the additional operational costs. Additionally, we identified the diesel cost as a key variable which alongside the number of trips can make a real change in the results obtained. Therefore, in the sensitivity analysis developed we varied the number of trips per shift and the diesel price. Considering these changes in both variables and the required return of 11%, we obtained the following result (Table 6).

Table 6 - Sensitivity analysis on number of trips per shift and diesel cost

Parameter	Base Scenario	Sensitivity Analysis
Number of trips per Shift	3	4
Diesel Cost (€/L)	0.25	0.15
	Result	
Transport Fee (€/m^3)	3.90	2.29

This result showcases that despite TIEL'S considerable margin to charge a cheaper fee while maintaining its business profitable as we saw in the initial results it is insufficient, even in more favorable conditions, to compete with the transport fee obtained for the pipeline system scenario. In this last result of the sensitivity analysis, we even obtained a transport fee much closer to that one but nevertheless the introduction of the new pipeline system will be more beneficial for oil companies as it will lead to minimize their transportation costs. Something that we can also conclude from these results is that even if TIEL attempts to optimize even more its current jet shipping business via road tanker in terms of its operation and costs it will always be difficult to compete with a new pipeline system since this type of systems are considered as the most cost effective to transport oil products (Herrán, de la Cruz, & de Andrés, 2010; MirHassani, Abbasi, & Moradi, 2013). These results strengthen the conclusions elicited previously for CLC to accept and go through with the investment in the new pipeline system because now we are able to add that there is no possibility for TIEL to charge a cheaper transport fee which would compromise CLC's investment without jeopardizing its own business.

4. Results Discussion and Limitations

4.1 Results Discussion

The combination of MCDA with an investment appraisal, enabled us to develop an overall appraisal to the project where all relevant aspects to the problem in study were tackled. We were able to focus not only on the capital budgeting decision for CLC via the investment analysis, where profitability and transport fee are the deciding factors, but also with the MCDA consider other factors, mainly subjective ones, which are difficult to introduce in an investment appraisal but have a big weight in the decision-making process of an investment of this type which involves important environmental and social aspects.

Aggregating all the results obtained from the methodology developed they thoroughly support the replacement of the current supply system with a new pipeline system considering the three key dimensions identified, economic, environmental and social. The main stakeholder's worries mentioned in the problem scope definition of this dissertation were the high investment costs associated with this type of project as well as the possibility of an increase in transport fee which would turn off the oil companies from this change. However, the results obtained from both the MCDA and the investment analysis showcased that despite the expected high investment cost, in its operations the pipeline system is more efficient than the current system in almost every key aspect, yearly costs, energy consumption, emissions and even risk, both in terms of supply and safety. Thus, leading to improvements in all dimensions, economic with the decrease in the transport fee charged, environmental with the decrease in air pollutant emissions and social with the decrease in risk, showcasing how beneficial this change can be to the stakeholders involved. The results obtained throughout this dissertation were in line with the information found in the literature which referred the pipeline systems as the most efficient mode of transporting oil products. However, as also mentioned in the literature this only applies for cases where large amounts of product are transported. This brings up a vital aspect to analyze which is, if the demand of jet A-1 continues at the same level it currently stands due to the pandemic state it is most likely that the transportation via road tanker is better and should be maintained. However, as it was shown from the results obtained, from a certain level of demand the pipeline system is undoubtably the best fitted method to transport the jet A-1 from CLC to Lisbon Airport.

A final remark, following the topic of product demand, is that the results obtained from the methodology developed are only fitted if the Lisbon airport system remains the same during the lifetime considered. It is known that the Portuguese government would like to expand the current Lisbon airport system with the introduction of a new airport which would support the current airport in Portela. However, this possibility was not considered in our study due to the large uncertainty related with that topic. Despite that we are aware that the decision makers have to take that possibility into account in their decision because the introduction of a new airport would completely change the results we obtained in our study mainly due to the decrease on the amount of jet to be transported to Portela airport. A system with a 12 inch pipe diameter like the one we considered in our study would no longer be efficient because it would be too large for the amount of product transported. Thus, if the new pipeline system project and the investment on it are done, there will need to be a guarantee from the Portuguese government to the investing firm that the Lisbon airport system or the amount of product transported remains the same so that the system is still profitable.

4.2 Limitations

Throughout the development of the dissertation we were faced with some limitations that led us to adapt some aspects of the procedure we initially planned. In this section these limitations will be identified and explained in detail.

Firstly, in the characterization of the new pipeline system we were not able to go into much detail because there is a lot of information about it which still raw, since it is in a phase where stakeholders are still discussing if it should be done and how it should be done thus there are many uncertainties surrounding it. Leading us to focus mostly on the components which were key for our problem like the diameter and wall thickness.

Regarding the MCDA, despite the inclusion of the decision makers being a vital part to its procedure, this inclusion is a complex and difficult process which led to some problems along the way and to some constraints in our model. Firstly, we were not able to interview every stakeholder that we intended, mainly someone from ANA (airport perspective) and someone from an environmental organization (due to the environmental implications involved in this type of project). Secondly, we were not able to do decision conferences to obtain the decision makers judgments, due to limitations imposed by the pandemic state and personal agendas. Meaning that everything was done via individual interviews and there was not any discussion between decision makers on their perspectives.

Lastly, we faced some limitations on the gathering of data regarding some parameters. Primarily, the data we obtained initially regarding the demand of jet A-1 was completely compromised due to the pandemic state. In 2020, the demand of jet A-1 suffered a large decreased and it is still unclear when airports will be fully operational, thus the values used for future demand have a lot of uncertainty associated with them. Taking this into considerations, we used data of what CLC expects will be the demand in future years as they anticipate that demand will return to the same values of 2019 in about 4 years and then a constant growth as it was the case before the pandemic state. Finally, due to the confidentiality or scarce actual information on some parameters we had to use the average values from the industry, for example the road tankers transport fee. And for some cases they had to be estimated from the average values of the industry like the maintenance and insurance costs on road tankers and maintenance and repair, and other operational costs on the pipeline, which were estimated based on the Aveiras-CLC pipeline costs. Additionally regarding the topic of gathering information, in some cases we had to use certain methodologies to obtain the information we needed, where unfortunately we were not able to go into much detail since they were not the focus of this dissertation. One of this cases was the risk matrix approach used to characterize both alternatives in the risk criteria of the multicriteria model. This approach was not studied in as much detail as it could have been, however a complete study on the system's risks must be done in the future where more data is considered. The same can be applied to the more technical side regarding the pipeline characterization and dimensioning where we just focused on the parameters necessary for our study but this topic can and should be in the future studied in more detail.

Despite these limitations we were able to overcome them and achieve the goals proposed in the beginning of this dissertation. However, this leaves some gaps and improvements that can be done in future works in order to obtain even more robust results, these future works will be mentioned in the next section.

5. Conclusion and Future Work

The introduction of a new pipeline system to replace the current distribution system of jet A-1 to Lisbon airport is a complex problem due to the involvement of multiple stakeholders with different goals and worries and also because of the implications this change can make to the industries involved. Therefore, the dissertation's methodology combined an investment analysis and a MCDA and fulfilled its goal of gathering the necessary information and data to promote an informed decision.

In the MCDA, we were able to develop a consistent multicriteria model composed by all problem's key criteria and which reflected decision makers perspectives. From it, decision makers identified the economic and risk criteria, "transport fee", "supply reliability" and "health and environmental safety", as the most important. Additionally, in the ones that had more impact on the difference between alternatives, the environmental criteria, "air pollutants emissions" and "energy efficiency" are highlighted, where the first one had the highest weighted difference between alternatives of 35.97. Accordingly, the results obtained from the multicriteria model constructed showcased a clear advantage for the new pipeline system alternative when compared to the current distribution system, since the overall scores were of 104.38 and -0.90, respectively. Thus, despite the limitations we faced throughout this process we were able to obtain robust results and achieve our goal of including social and environmental aspects in the decision making analysis.

In the investment analysis, we analyzed both profitability and transport fee because they were identified in problem definition as the two key economic factors for the decision-making process. Profitability in operator's (investor) perspective and transport fee in user's (oil companies) perspective. We evaluated both scenarios, the one without the project (road tanker scenario) and the one with the project (pipeline system scenario). Despite the results showcased that the investment is profitable in both scenarios, the transport fee of 1,67 €/m^3 in the pipeline system scenario is clearly more favorable for the user than the one currently charged of 3.90 €/m^3. Additionally, we developed a sensitivity analysis to study the competitiveness of the road tanker scenario in terms of transport fee. The results showcased that even in more favorable conditions the minimum transport fee obtained was of 2.29 €/m^3 meaning that the pipeline system scenario is still more beneficial for oil companies. Thus, the capital investment on a new pipeline system to supply jet A-1 to Lisbon airport should be accepted since it economically benefits both parties interested.

In conclusion, the combining results of both methods thoroughly support the decision of replacing the current distribution system with a new pipeline system to supply jet A-1 to Lisbon airport. The results consistently showcased that the pipeline system outperforms the transportation via road tankers mainly due to its higher operational efficiency which leads to a decrease in energy consumed, air pollutant emission and transport fee. Additionally, it mitigates the risk of drivers' strike while being the safest mode of transportation equipped with advanced safety and control systems. This proves what we found in the literature regarding the pipeline system being the most fitted mode of transporting large quantities of oils products. Thus, from a certain level of demand of jet A-1 the pipeline system is the best fitted method to transport the jet A-1 from CLC to Lisbon Airport.

Future work

We had some limitations throughout the application of the methodology, mainly related with its social dimension and the difficulty to obtain specific data on some matters. Therefore for future work we suggest the following. Decrease uncertainties associated with some parameters of both alternatives. Mainly in the new pipeline system where there is a lack of information on some design characteristics like route. When this information is available alongside with specialized studies on matters like environment, mechanical, civil, risk, etc., consistency and robustness of both models can be improved. Additionally, in the MCDA the addition of airport's (ANA) and an environmental organization perspectives to the model, which we were not able to obtain, could be relevant because they are two perspectives which can have a significant impact on the decision-making. Finally, the next step is to gather all decision makers, which we were not able to do via the decision conferences, in order to discuss the results obtained, understand if there is any final necessary adjustments and lastly make use of the information gathered to support their decision.

References

Baltussen, R., & Niessen, L. (2006). Priority setting of health interventions: the need for multi-criteria decision analysis. *Cost Effectiveness and Resource Allocation*, *4*(1), 14. https://doi.org/10.1186/1478-7547-4-14

Bana e Costa, C. A., & Vansnick, J.-C. (2008). A critical analysis of the eigenvalue method used to derive priorities in AHP. *European Journal of Operational Research*, *187*(3), 1422–1428. https://doi.org/https://doi.org/10.1016/j.ejor.2006.09.022

Bana e Costa, C., De Corte, J.-M., & Vansnick, J.-C. (2011). *Chapter: MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique)*. https://doi.org/10.1002/9780470400531.eorms0970

Bana e Costa, C., Lourenço, J., Chagas, M., & Costa, J. (2008). Development of Reusable Bid Evaluation Models for the Portuguese Electric Transmission Company. *Decision Analysis*, *5*, 22–42. https://doi.org/10.1287/deca.1080.0104

Barriball, K., & While, A. (1994). Collecting data using a semi-structured interview: a discussion paper. *Journal of Advanced Nursing*, *19 2*, 328–335.

Belton, V., & Gear, T. (1983). On a short-coming of Saaty's method of analytic hierarchies. *Omega*, *11*(3), 228–230. https://doi.org/https://doi.org/10.1016/0305-0483(83)90047-6

Belton, V., & Stewart, T. (2002). *Multiple Criteria Decision Analysis: An Integrated Approach*. Kluwer Academic Publishers.

Beria, P., Maltese, I., & Mariotti, I. (2012). Multicriteria versus Cost Benefit Analysis: A comparative perspective in the assessment of sustainable mobility. *European Transport Research Review*, *4*, 137–152. https://doi.org/10.1007/s12544-012-0074-9

Capiau, T. (2010). *An economic analysis of pipeline transport in Flanders An economic analysis of pipeline transport in Flanders*. Universiteit Gent.

Donegan, H. A., Dodd, F. J., & McMaster, T. B. M. (1992). A New Approach to AHP Decision-Making. *Journal of the Royal Statistical Society. Series D (The Statistician)*, *41*(3), 295–302. https://doi.org/10.2307/2348551

ECO Sapo. (2020). Abertas candidaturas para oleoduto de abastecimento ao aeroporto de Lisboa. Retrieved April 15, 2020, from https://eco.sapo.pt/2020/02/17/abertas-candidaturas-para-oleoduto-de-abastecimento-ao-aeroporto-de-lisboa/

EIB. (2013). *The Economic Appraisal of Investment Projects at the EIB*.

Fabozzi, F. J., & Drake, P. P. (2009). *Finance: Capital Markets, Financial Management and Investment Management*. Wiley.

Galp. (2018). *Rotulagem de Energia Elétrica 2018*. Retrieved from https://casa.galp.pt/sites/default/files/faqs/rotulagem_energia_eletrica_2018_0.pdf

González-Prida, V., Barberá, L., Viveros, P., & Crespo, A. (2012). Dynamic Analytic Hierarchy Process: AHP method adapted to a changing environment. *IFAC Proceedings Volumes*, *45*(31), 25–29. https://doi.org/https://doi.org/10.3182/20121122-2-ES-4026.00005

Herrán, A., de la Cruz, J. M., & de Andrés, B. (2010). A mathematical model for planning transportation of multiple petroleum products in a multi-pipeline system. *Computers & Chemical Engineering*, *34*(3), 401–413. https://doi.org/https://doi.org/10.1016/j.compchemeng.2009.11.014

ISO 13623. (2009). *Petroleum and natural gas industries — Pipeline transportation systems. ISO 13623:2009*. Geneva, Switzerland.

ISO 3183. (2019). *Petroleum and natural gas industries — Steel pipe for pipeline transportation systems.ISO3183*. Geneva: International Organization for Standardization.

Jaramillo, P., & Muller, N. Z. (2016). Air pollution emissions and damages from energy production in the U.S.: 2002–2011. *Energy Policy*, *90*, 202–211. https://doi.org/https://doi.org/10.1016/j.enpol.2015.12.035

MirHassani, S. A., Abbasi, M., & Moradi, S. (2013). Operational scheduling of refined product pipeline with dual purpose depots. *Applied Mathematical Modelling*, *37*(8), 5723–5742. https://doi.org/https://doi.org/10.1016/j.apm.2012.11.009

Murray, D., & Glidewell, S. (2019). *An Analysis of the Operational Costs of Trucking : 2019 Update*. Virginia.

Pootakham, T., & Kumar, A. (2010). Bioresource Technology A comparison of pipeline versus truck transport of bio-oil. *Bioresource Technology*, *101*(1), 414–421. https://doi.org/10.1016/j.biortech.2009.07.077

Reilly, F. K., & Brown, K. C. (2011). *Investment Analysis & Portfolio Management* (10th ed.). Cengage Learning.

Ross, S. A., Westerfield, R. W., & Jordan, B. D. (2015). *Fundamental of Corporate Finance* (11th ed.). McGraw-Hill Education.

Soares, C. D. (2009). *Environmentally Harmful Subsidies: Identification and Assessment*. 1–26.

Spackman, M., Dogson, J., Pearman, A., & Lawrence, P. (2000). *"Multi-Criteria Analysis Manual."* NERA Publications.

Strogen, B., Bell, K., Breunig, H., & Zilberman, D. (2016). Environmental , public health , and safety assessment of fuel pipelines and other freight transportation modes. *APPLIED ENERGY*, *171*, 266–276. https://doi.org/10.1016/j.apenergy.2016.02.059

The Portugal News. (2019). Fuel pipeline for Lisbon airport an "excellent decision." Retrieved April 15, 2020, from https://www.theportugalnews.com/news/fuel-pipeline-for-lisbon-airport-an-excellent-decision/49869

Tudela, A., Akiki, N., & Cisternas, R. (2006). Comparing the output of cost benefit and multi-criteria analysis: An application to urban transport investments. *Transportation Research Part A: Policy and Practice*, *40*(5), 414–423. https://doi.org/https://doi.org/10.1016/j.tra.2005.08.002

von Winterfeldt, D., & Edwards, W. (1996). *Decision analysis and behavioral research*. Cambridge University Press.

Yedla, S., & Shrestha, R. M. (2003). Multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi. *Transportation Research Part A: Policy and Practice*, *37*(8), 717–729. https://doi.org/https://doi.org/10.1016/S0965-8564(03)00027-2