MS-E2177 Seminar on Case Studies in Operations Research 2019

Neste

Final Report

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2 Introduction

2.1 Background

Petroleum refining is by far an old method to extract useful, and therefore valuable, products from crude oil. The importance of the oil refining industry measured in its size and strategic role increased dramatically since the use of oil for lamps fuel (i.e. kerosene) production in the 19th century to these days. Some of the most important technical frontiers in the oil refining business stand on Supply Chain Management (SCM) as the services become more globalized, as well described by Jacoby [1]:

"The globalization of the industry is forcing suppliers to respond with global service and more robust international logistics capabilities ... As suppliers globalize, the cost of shipping internationally is forcing them to reevaluate their supply chains, sometimes replacing their raw material sources and reconfiguring their intermediate processing activities and locations. While this presents opportunities for local suppliers, it can also threaten them."

In an oil refinery, among the most important SCM decisions are the procurement decisions of raw material (i.e. crudes) meeting multiple objectives such as profit, oil specifications, possible liabilities and so on. Nevertheless, feedstock procurement is not an activity that can be directly accounted for by cost management, as long as the costs depend on different features, such as quality. This is further explained by Ocic [2] in:

"...this is a process industry where a full slate of products, differing in quality and by use value, is obtained from a single feedstock on a single unit. Relating the basic feedstock costs to all products, and observing their individual quality as obtained on a particular processing unit, does not, in fact, present the real causality of costs for a single product. All the products cannot be evenly treated from the aspect of production motive. Namely, within a product slate, we can recognize the products, on

account of which the production process is organized, as well as by-products, which are inevitable, in a process. These products must not be treated in the same way from the aspect of charging the costs to their carriers."

Neste is a Finnish oil refinery and marketing company with a strong focus on renewable energy products. The company was founded in 1948 with the goal of securing Finland's refined fuel demand. Neste has a headquarter in Espoo and more than 5000 employees in over 14 countries. Neste's largest shareholder is the Finnish government which owns over 35% of the company's shares [3]. In 2017, Neste had a 1,1B€ operating profit and a 13,2B€ revenue. From this revenue, oil products generated 8,5B€, marketing & services create 3,9B€, and renewable products 3,2B€ (there were also over 2,6B€ eliminations from the revenue). The company is the world's largest producer of renewable diesel. In 2017, Neste's renewable segment produced approximately the same operating profit as the larger oil products segment [4].

Neste has two main oil refineries in Porvoo and Naantali with an additional joint venture for base oil production in Bahrain. The total oil refining capacity is over 15 million tons per year. Neste's renewable diesel production facilities are located in Porvoo, Singapore, and Rotterdam. Their total production capacity is 2,6 million tons per year. Marketing & services unit sells petroleum products and related services directly to end-customers [4]. Porvoo's refinery has four production lines and Naantali's refinery has one.

Introducing additional petroleum naphtha affects the blending qualities requirement and, as a consequence, alters other feedstock quantities in the optimal solution. The decision to purchase and introduce additional naphtha is recurrent for Neste production unit process due to suppliers offers or market conditions. The quantities of naphtha available for purchasing are discrete with batches being an integer number of halves of a vessel. Naphtha specifications (e.g. heavy and light) have different implications for the decisions regarding the price and embedded qualities. Additionally, naphtha price fluctuation affects the feasibility and optimality of the purchase decision. Ultimately, the availability of other crude oil products, inventories available for them, and market prices for final products affect the possibility and feasibility of introducing naphtha.

Renewable products	Oil products	Marketing & services
Revenue 3,2B€ Operating profit 476M€ Total capacity 2,6 million tons Production in Porvoo, Singapore and Rotterdam	Revenue 8,5B€ Operating profit 650M€ Total capacity over 15 million tons Refineries in Porvoo and Naantali + base oil joint venture in Bahrain	Revenue 3,9B€ Operating profit 69M€ Sells petroleum products and related services to end-customers

Table 1: Summary of Neste's segments

2.2 Motivation

Neste's SCM department seeks to maximize the total profit from the oil refineries by establishing an optimal feedstock procurement. This is accomplished through the optimization performed in a monthly basis which depends on the 15-months Sales and Operation Plan (SOP), utilizing the models implemented in AVEVA Spiral Suite software (Spiral). One of the major challenges from the SCM is to verify the prices and quantities of some supplementary feedstocks evaluated after the SOP. The schematic representation of Neste's refinery operation system is presented in Figure 1.

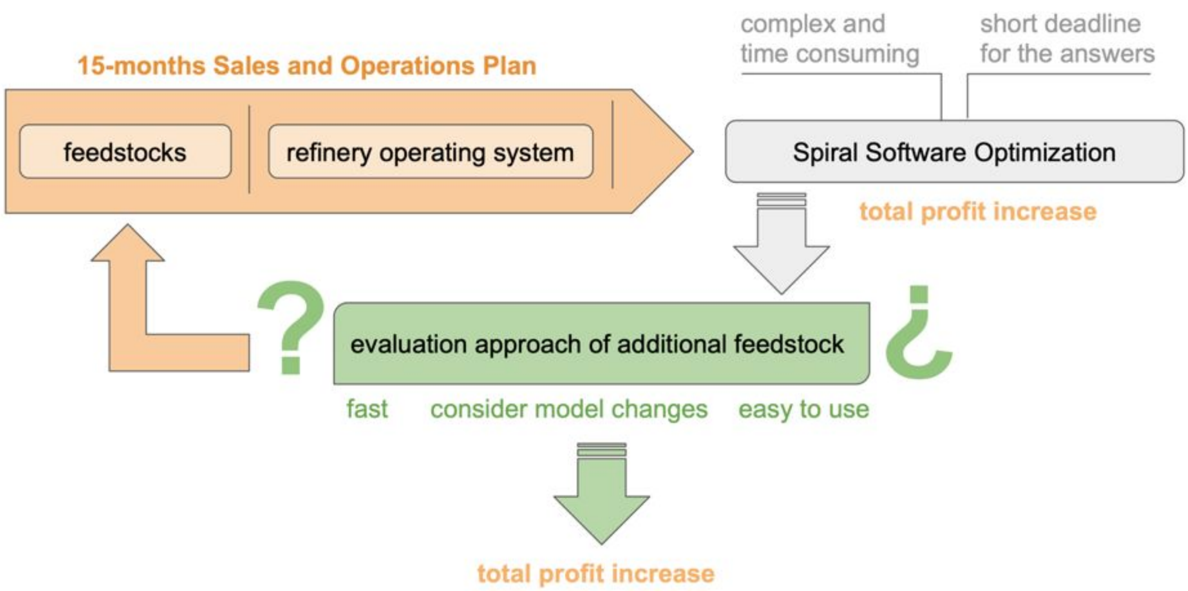

Figure 1: Neste Refinery Operation System

In general case, the problem requires the consideration of all crude oil feedstocks combination in the blendstock. However, considering this project's time frame, the analysis scope will be limited to two chemicals, light and heavy naphtha. Considering the current solution, the decision process is made based on the Excel tool taking into account current market prices for different naphtha qualities and inventories of other crude oil qualities. The Excel tool is fast, convenient and practical to use, compared to the use of the full Spiral optimization mode.

Regardless the convenience and efficiency of the developed tool, the company has aimed the analysis towards the quality improvement which can be potentially performed in two directions. In one hand, ones can focus on the upgrade of the Excel mechanism implying the improvement of the decision-making process through optimization tools, establishing the optimal process of data collection and, possibly, reasonable Spiral model simplification. On the other hand, once the decision has been made, further investigation may be carried out to understand the effect of various sources of uncertainty on the solution obtained.

2.3 Objectives

The formulation of the project's objective appeared to be quite a challenging task by itself. The difficulties were caused by the necessity to decide in which direction the research will be pushed toward. This arrangement required pre-investigation of the most feasible approach regarding the limitations established by the course and company targets. After several meetings with the representatives of the SCM and discussions on the feasible approach satisfying the requiring time frameworks and efforts, the decision was made to give up on the first approach related to the modification of the current solution despite its promising perspectives. The challenges that may occur while improving the existing optimization tool are related to the necessity of total and profound knowledge of the model features the scale of which indicates this task being infeasible within the relatively short time period of the course. Thus, in accordance with the company interests and course limitations, the team ended up concentrating on the development of another approach for the post-optimality analysis.

Table 2: Research Objective and Tasks

OBJECTIVE:	the development of post-optimality analysis tool that can be applied to make a decision about the additional purchase of naphtha

Major tasks:

Task 1: broad literature review

Task 2: analysis of the existing Excel solution

Task 3: formulation of the post-optimality tool

Task 4: experimental illustration

The objective was pursued through several interconnected tasks divided into analytical and experimental parts of the project. A key assignment is a broad literature review underlying the project relevance and justifying the feasibility of approaches developed. Another important concept is the analysis of the existing Excel's solution to identify the points to be improved along with familiarizing with the model description. Finally, the formulation of the post-optimality tool improving the decision-making process with the experimental illustration. The schematic representation of the objectives is presented in Table 2.

3 Literature Review

3.1 Refineries planning under uncertainty

Refinery planning aims to improve the performance of economic optimization which provide planning solutions that are near optimal when stochastic parameters change. Thus, apart from the stochastic modeling lying on the basis of this idea, the robust optimization is employed to prevent a large deviation of the solution from the optimal one. The refinery planning problems can usually be represented by non-linear models (NLP) or mixed-integer nonlinear models (MINLP) and mixed-integer linear models (MILP) in the case of discrete decisions. The approaches of dealing with optimizing in the presence of uncertainties may be split into the following categories Stochastic programming, Robust programming, Fuzzy programming, and stochastic dynamic programming. The full list of techniques according to the classification illustrated in [5] is given in the Figure 4.

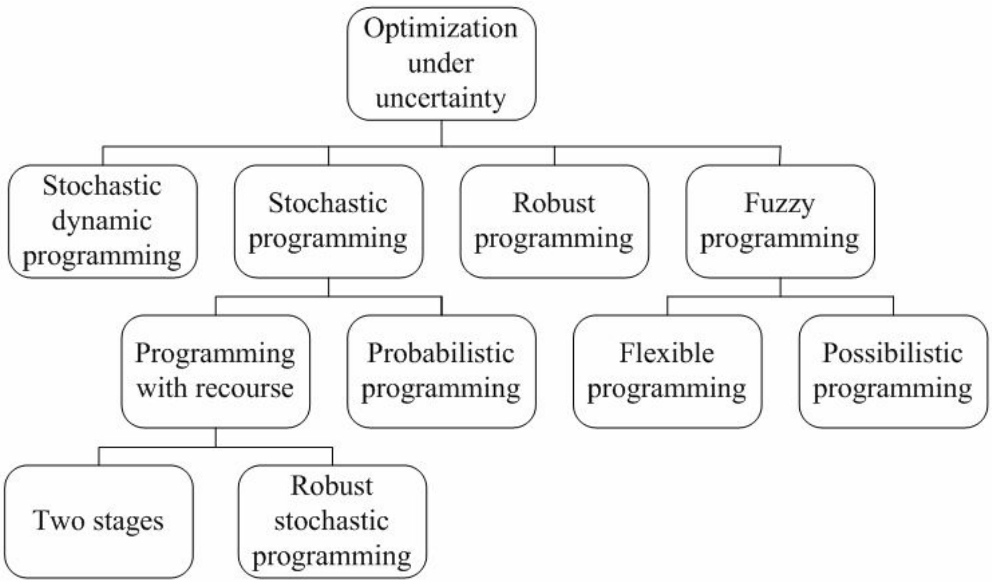

Figure 2: Approaches for dealing with uncertainty

Additionally, [5] indicates that nearly half of the observed refinery planning papers utilized a stochastic programming approach in their modeling techniques. In particular, Ribas et al. in [6] developed a two-stage stochastic model (stochastic programming) and min-max regret model and max-min model (robust programming) to address exogenous (external) and endogenous (internal) uncertainties for operational planning of oil refineries. Ribas in [6] developed two-stage stochastic model (stochastic programming) and min-max regret model and max-min model (robust programming) to address exogenous (external) and endogenous (internal) uncertainties for operational planning of oil refineries using different risk profiles. In this case, the stochastic approach corresponds to the risk-neutral attitude while robust approach represents the risk-averse attitude.

According to Jonsbraten [7] the uncertainty can be classified as external (exogenous) and internal (endogenous), depending on the point-of-view of process operations. Meanwhile, Abdallah Al-Shammari in [8] classified uncertainty based on its source in the process. Thus, he derived clusters such as

- Model-inherent uncertainty due to inaccurate estimation of model parameters such as kinetic constants;
- Process-inherent uncertainty due to variations in process parameters such as temperature and flow rate;
- External uncertainty such as changes in feed stream availability, as well as in demand and price of the product;
- Discrete uncertainty such as equipment availability.

3.2 Post-optimality analysis

Once the optimal solution for the refinery planning problem has been obtained, further investigation may be devoted to the analysis of the solution behavior under the parameters variation. The term "post-optimality analysis" is commonly used to understand the effect of the parameters' perturbations. According to [8] it consists of two main concepts sensitivity and stability analysis.

The sensitivity analysis is mainly associated with the determination of the Lagrange multipliers describing the change in the Objective Function (OF) responding to the variations in the right-hand side coefficients. As an example, [9] applied sensitivity analysis as one of the key concepts to perform marginal value analysis for the refinery planning model. Another illustration [10] describes the process of obtaining additional economic information of the fuel gas system through the marginal value analysis applied to the MILP model for multi-period optimization of fuel gas scheduling.

The stability analysis aims at defining maximum variations limits for the parameters within which the optimal solution or basis remains unchanged. Along with sensitivity analysis, this method helps understand the effect of the uncertainty in the model. Wendell In [11] described the tolerance approach providing a decision-maker with an effective methodology to obtain a maximum-tolerance percentage within which selected coefficients may vary from their estimated values (within a priori limits) while still retaining the same optimal basic feasible solution. The alternative approach is given by Arsham in [12] who develops the process of Construction of Sensitivity Regions which allows for any dependent, independent, multiple changes in both the right-hand side values and the cost coefficients of linear program models to have unique solution. He extends the approach in the construction of sensitivity region to maintain the degenerate vertex for models with the degenerate optimal solution as well as maintaining the multiple solutions for the models with non-unique optimal solutions [13]. In [14] Al-Shammari proposes post-optimality analysis to study the effect of uncertainty or variation in model parameters on the optimal solution of linear target calculation model predictive control. Additionally, Al-Shammari and Ba-Shammakh [8] used a modified tolerance approach to compute the allowable variation limits for individual and simultaneous variations within which the operation levels remain optimal for the simplified refinery model formulated as an LP problem.

4 Data & Methods

The model to be optimized includes a crude distillation unit and more than 40 process units in addition to inventories, blenders and other process equipment. More than 90 materials can be imported to the refinery, and more than 100 material types can be produced. The resulting optimization model consists of approximately 22,000 equations and 22,000 variables with about 77,000 non-zero elements. Some of the equations are non-linear, but no integer variables are included in the model.

Neste's optimization model is solved by Spiral® software in which the first optimization analysis with values known by the time the planning is performed. Operational short-term purchases options then occur after this first step of a relatively long-term plan when the post-optimality analysis can be insightful. As explained in the previous sections, the problem to be solved should count with punctual analysis (i.e. for specific feedstocks) to support purchase in the spot market. Under these conditions, the post-optimality analysis can bring good insights into the sales department with almost no time commitment - mainly when counting with a systematic approach. Analysis objects (i.e. Sensitivity Analysis and Robustness Decisions) designed for the most important feedstocks or the most frequent emergent purchases can help managers to replicate the proposed methodology in future experiments.

Oil intakes, i.e. feedstocks in general, offers can happen in between planning periods forcing Neste's SCM team to analyze emergent offers to seek good deals. The conditions of those offers fluctuate as the prices of oil benchmarks (e.g. Brent price) change and along with suppliers' capacities and their market power. Recurrently different Naphtha qualities (i.e. heavy or light) prices are in focus as emergent offers take place hence Naphtha acquisition poses as a good example for the study. Focusing on the emergent demands, the analysis hold in this project helps managers from supply chain and sales teams to have a consistent decision when it comes to feedstock prices and quantities to buy.

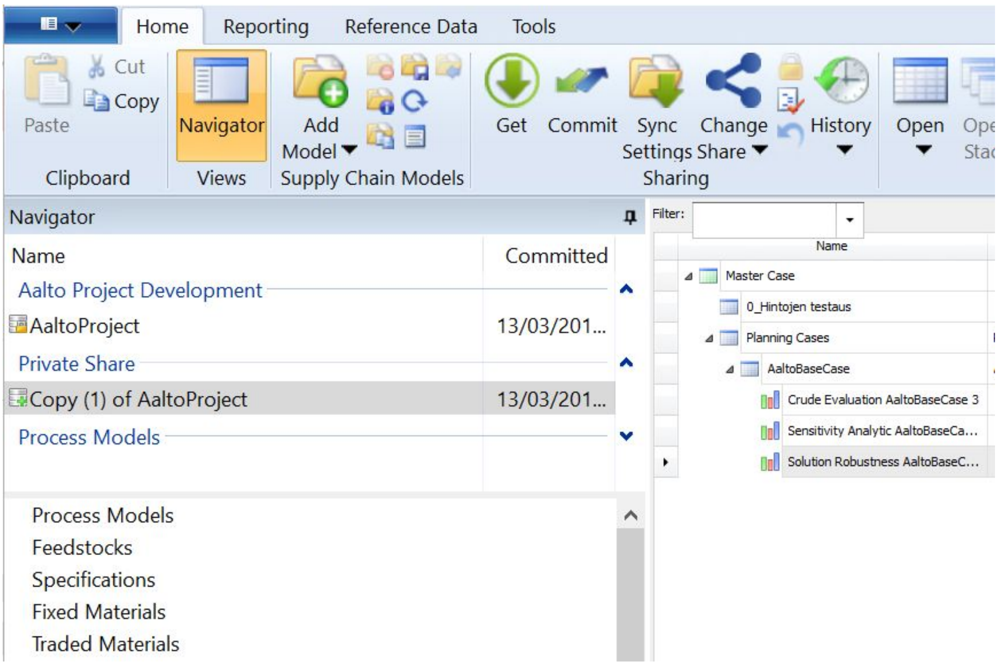

Figure 3: Spiral Software

The sensitivity analysis held accounts with twelve scenarios being 6 made by fixed values of Light Naphtha (LN) quantities and 6 of Heavy Naphtha (HN) quantities. Values for LN are set with 5,000 tons of difference between each scenario, i.e. from 0 to 25Ktons. Values for HN are derived from the optimal values found for each scenario from 1 to 6 where just LN is fixed. Additionally, the Base Case (BC) represents the optimal solution in which purchase analysis does not take place. All scenarios are described in Table 3.

Table 3: Scenarios description

	Scenarios (Fixed Values for Light or Heavy Naphtha)												
Variables	**Base Case**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Light	20,121.7	25,000.0	20,000.0	15,000.0	10,000.0	5,000.0	0.0	-	-	-	-	-	-
Heavy	2,942.3	-	-	-	-	-	-	0.0	3,015.5	6,451.9	8,291.7	10,931.4	13,599.4

Decision robustness can be considered from two perspectives: model robustness and solution robustness [15]. The first one relates to the degree that the model keeps near feasibility in all scenarios while the second relates to the changes in the optimal solution throughout several scenarios. Following these concepts, we proceed with the study aiming the solution robustness referring to measures such as maximal regret. Noticeably, this project aims to analyse the robust in order to assess the solution stability, a proper robust optimization is left for future work.

Bearing this in mind, the less the solution changes along with the different scenarios, the more robust it is. The solution robustness accounts for the different OF values when the optimal solution of one scenario is considered in another scenario. Then for example, if scenario 2 robustness is assessed against the scenario 1, the optimal solution for HN (and for all other feedstock but LN) in scenario 1 is repeated in scenario 2 and the scenario 2 is then optimized assuming a fixed value for HN. In other words scenario 2 (LN = 20Ktons) with the HN fixed to the optimal value for scenario 1 (LN = 25Ktons). For the sake of clarity, results are further discussed in the next section where a numerical experiment serves as a practical illustration.

5 Results

Table 4 shows the main takeaways of the post-optimality approach for the scenarios previously described. All scenarios (including the base case) are compared in terms of a robust approach pairwise. This way managers can derive the impact of changing purchase strategy from one scenario to another, assuming other variables (i.e. HN or LN) remains the same. As an example, take scenario 4 with an optimum of 0.397 M$ and values of LN and HN respectively equal to 10Ktons and 8.3Ktons. If the solution for this scenario (i.e. HN = 8.3Ktons) is used in e.g. scenario 6 (with LN = 0Ktons) the OF reduces more than $ 60,000 to 0.325 M$. Nevertheless, if scenario 4 is compared with scenario 1, the solution turns to be infeasible which makes sense as with a level of 8.3Ktons of HN, forcing the purchase of 25Ktons of LN would lead to a constraint violation such as capacity, unit parameter, product specification, or other. Comparisons between scenarios {1,2,3,4,5,6} with scenarios {7,8,9,10,11,12} do not take place as they are trivially either infeasible (whenever 2 different equalities are assumed to the same value) or equal to the scenario's optimal solution (when the scenario is compared to itself).

Table 4: Robustness analysis

				Robustness Decisions Optimized by Scenario (M$)											
				1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
Scenario	Fixed Variable(s)	Fixed value	Optimal Values	LN = 25K	LN = 20K	LN = 15K	LN = 10K	LN = 5K	LN = 0K	HN = 0K	HN = 3.0K	HN = 6.5K	HN = 8.3K	HN = 10.9K	HN = 13.6K
Base Case	-	-	0.459	**Inf***	0.458	0.426	0.389	0.353	0.317	0.455	0.458	0.436	**Inf**	**Inf**	**Inf**
1	HN*	0K	Inf	**Inf**	0.455	0.421	0.385	0.349	0.313						
2	HN	3.0K	0.458	**Inf**	0.458	0.426	0.389	0.353	0.318						
3	HN	6.5K	0.430	**Inf**	0.437	0.430	0.394	0.358	0.322						
4	HN	8.3K	0.397	**Inf**	**Inf**	0.419	0.397	0.361	0.325						
5	HN	10.9K	0.365	**Inf**	**Inf**	0.267	0.385	0.365	0.329						
6	HN	13.6K	0.333	**Inf**	**Inf**	**Inf**	**Inf**	0.352	0.333						
7	LN*	20.4K	0.459							0.456	0.458	0.431	**Inf**	**Inf**	**Inf**
8	LN	20.2K	0.458							0.455	0.458	0.435	**Inf**	**Inf**	**Inf**
9	LN	18.1K	0.440							0.444	0.448	0.440	0.424	**Inf**	**Inf**
10	LN	17.1K	0.425							0.437	0.442	0.438	0.425	**Inf**	**Inf**
11	LN	12.0K	0.391							0.400	0.404	0.409	0.409	0.391	**Inf**
12	LN	7.1K	0.357							0.364	0.368	0.373	0.376	0.376	0.357

* *LN* *Light Naphtha*
HN *Heavy Naphtha*
Inf *Infeasible*

Note: all presented values obfuscated and are representative

5.1 Numerical example

As a matter of checking the robustness value the comparison between scenarios 3 and 4 is taken as an example - i.e. values for HN from scenario 3 and LN from scenario 4 -, we can see how the neighbors comparisons performed in Table 5 where red values represent a loss in respect to the OF and green values stand for increments. It is expected that the OF increases when moving to the left neighbor (assuming the optimal values of HN and LN for scenario 3) with value equal to 0.430 as that would be the optimal value for scenario 3. What remains not straightforward is that in the comparison scenario 3 to scenario 4 we obtained a better profit by increasing the purchase of LN and not altering HN levels whereas for scenario 5 the profit comes when the HN purchase level reduces and LN increases. Summing up, the DM should read Table 5 one move at a time (either increasing/decreasing LN or increasing/decreasing HN) then attributing the difference of OFs to the difference in the respective feedstock level. This way stability and sensitivity analysis can help DMs to have an effective way of measuring the fair price to buy/sell any feedstock.

Table 5: Numerical example for the robustness analysis

				Robustness Decisions Optimized by Scenario (M$)					
				1	*2*	*3*	*4*	*5*	*6*
Scenario	Fixed Variable(s)	Fixed value	Optimal Values	LN = 25K	LN = 20K	LN = 15K	LN = 10K	LN = 5K	LN = 0K
Base Case	-	-	0.459	**Inf***	0.458	0.426	0.389	0.353	0.317
1	HN*	0K	Inf	**Inf**	0.455	0.421	0.385	0.349	0.313
2	HN	3.0K	0.458	**Inf**	0.458	0.426	0.389	0.353	0.318
3	HN	6.5K	0.430	**Inf**	0.437	0.430 ←	**0.394**	→ 0.358	0.322
4	HN	8.3K	0.397	**Inf**	**Inf**	0.419	0.397	0.361	0.325
5	HN	10.9K	0.365	**Inf**	**Inf**	0.267	0.385	0.365	0.329
6	HN	13.6K	0.333	**Inf**	**Inf**	**Inf**	**Inf**	0.352	0.333

* *HN* *Heavy Naphtha*
Inf *Infeasible*

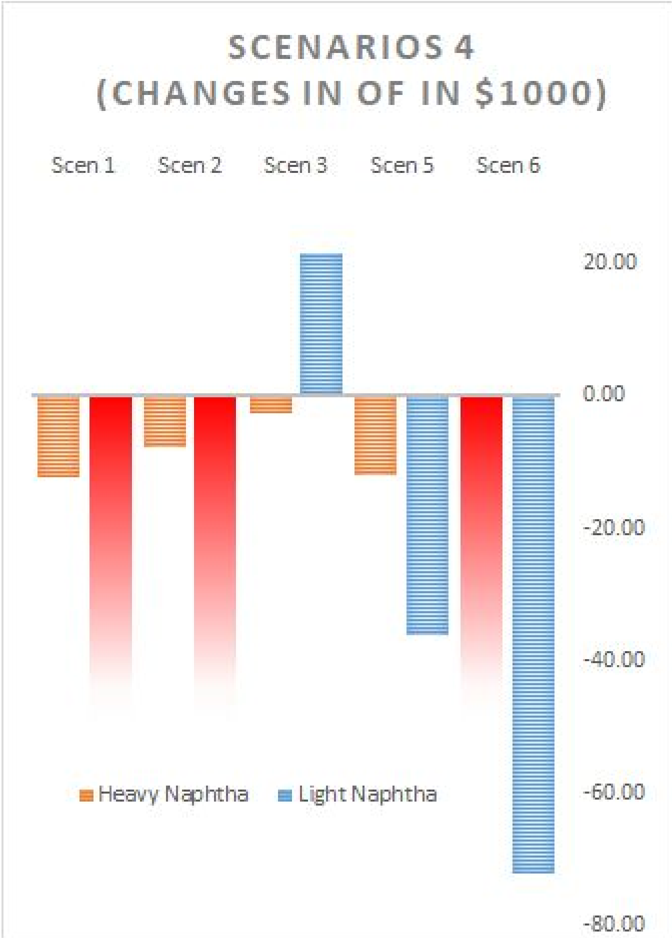

Figure 4: Comparison between changes in Heavy Naphtha and Light Naphtha strategies from scenario 4

Figure 5 shows the case that scenario 4 is compared to the others in terms of the changes of either LN quantities, horizontal move in Table 5, or HN, vertical move in Table 5. It can be seen in scenario 4 that a purchase of 5 Ktons of LN can increase profit in about $ 21,620, what makes the max price for LN acquisition equal to 260 + 21,620/5,000 = $ 264.32.

Therefore, it is not recommended to change the value of HN, unless if sold for a higher value than it was bought, but a good profit can come from changing the quantity for LN from 10Ktons to 15Ktons. An estimate for the prices (for buying or selling) is presented in Table 6.

Table 6: Possible prices from scenario 4

		Ref Price	*260*	
	Max Price (Buying/Selling)			
Scenarios	B/S	HN	B/S	LN
1	Sell	261.49	Buy	0.00
2	Sell	261.49	Buy	0.00
3	Sell	261.49	Buy	264.32
5	Buy	0.00	Sell	267.26
6	Buy	0.00	Sell	267.21

6 Discussion

6.1 Reflection on literature

The literature review showed that there is considerable amount of information related to the stochastic and robust optimization for the refinery planning comparatively to the post-optimality analysis. Considering the latter, the definition of these terms vary depending on the author preferences, mainly describing the marginal value analysis that usually represents the variations of two approaches combination: sensitivity and stability analysis.

The possibility of finding the application for one of these terms for some specific case still seems to be relatively high regarding it within the post-optimality topic. However, there we have found just a few examples of these techniques applications for the case of refinery planning optimization. Thus, the research in this project may fill this gap to reinforce the connection between the existing theoretical models on post-optimality methodology and the illustrations of their application to the real cases.

6.2 Assessment of the results

The initial goal defined by the Neste SCM team was to improve the decision-making process about the penetration of the supplementary refinery feeds, in particular, heavy and light naphtha in the refinery system to increase the company profit. As a result, we proposed a tool for marginal values analysis applied for the Spiral model representing the refinery operation system. This tool is based on the concepts of post-optimality approaches such as sensitivity and stability analysis and uses the computational resources provided by spiral suite software.

We have developed the methodology allowing, once the optimal solution for the model is determined, to identify the possible monetary outcomes for the different scenarios representing various combinations of the light and heavy naphtha quantities to be bought as an additional supply. This study aimed to provide an illustration of applying this tool for performing post-optimality analysis in the case of company interest. This technique is performed by studying the effect of the varying the parameters of light and heavy naphthas, such as quantities on the optimal solution.

The final output of the project is the tool allowing to make a theoretical conclusion based on applying Spiral software techniques to the real problem. The parameters under investigation were defined by the SCM team which implies the fulfilment of the company interests. Apart from that, the results may be used as an illustration of post-optimality analysis for the refinery operation system, which may help to fulfil some gaps in the literature as discussed in the section above. Meanwhile, despite the specific choice of the parameters to be studied, this methodology proposed may be generalized to any number and kind of additional refinery feeds in the system increasing its relevance.

Regardless of all the benefits of the methodology, due to time restrictions, it is defined as a basis for further conclusions to be made. Hence, further development could help to develop more specific and user interests oriented tool, as well as the possible software realization automating all the theoretical processes. Furthermore, another possible improvement of the decision-making system based on the upgrading of the existing Excel tool can be also performed in the future.

7 Conclusions

The main objective of the project was to develop an optimization-based valuation process for refinery feedstock supply. Currently, Neste makes this decision with an Excel-tool that has some factors to be improved. After conducting a literature review and iterating several possible approaches the method implying utilization of Spiral embedded tools was chosen. Neste uses Spiral software already to model the refinery planning system which makes it a suitable tool for the purpose.

This approach shifted the projects focus to a deep dive in Spiral's functionalities including sensitivity and robustness analysis. One key result was the discovery of relevant features that Neste had not fully utilized. These features were used to build a preliminary recommendation model for the naphtha purchasing decision. This model can be used to see the optimal purchasing quantities for different naphtha qualities at different prices. The tool also shows the additional profit/loss when new purchases are made guiding further purchasing decisions as well.

Perhaps the most important result of the project is the ability to produce a novel way of utilizing and expanding on the results obtainable with the current model through post-optimality analysis. Even though our model will not be implemented directly to production it can guide Neste in the development of a similar model not only for the naphtha decision-making but also for several other products.

8 Appendix

Appendix 1

Risk table is below:

Risk	Probability	Effect	Impact	Plan to mitigate risk
Team member inactivity or dropout	Low	Other team members need to cover or the person being absent works remotely	Low to medium	Clear schedules, project manager's authority, and informing possible absences well in advance
Too large workload	Medium	Not all objectives will be reached, the results will be inadequate, or work-hours increase drastically	Medium	Frequent communication with Neste and having a clear plan towards the most feasible direction. In case it seems unreachable the willingness to pivot
Challenges in using the Spiral software	Low	Delays on the progress of the project	Medium	Having a low threshold to reach out to Neste in case of problems. Using the Spiral help page and search.
The final model does not satisfy customer needs	Medium	The final model will not provide value, however, the report and literature review might have produced useful results	Medium	Frequent communication with Neste and ensuring that the model developed is relevant and valuable for Neste

Table 7: Risks associated with the project

Appendix 2

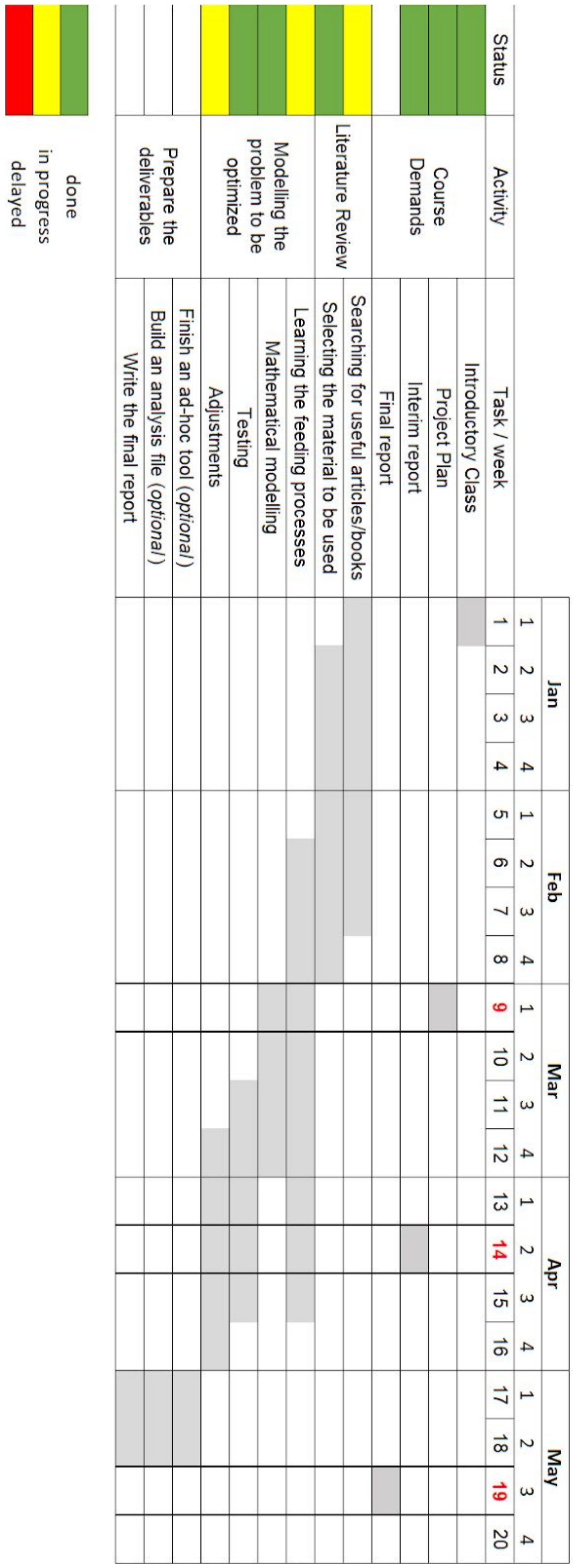

Figure 5: Updated schedule

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10 Self Assessment

The project focus shifted quite a bit from the initial project plan. The main reason for this shift was the discovery of the range of functionalities already built in Spiral software. These functions allowed us to narrow our focus on the parts of the project that both provide the most value for Neste but that are also most feasible to do within the limited timeframe. This means that the mathematical modeling and programming parts from the original project plan were changed to a more detailed analysis of the existing software. Sensitivity and stability analysis were chosen as the most feasible approach.

The risks presented in the original project plan changed a bit during the course and two of the risks realized to some extent. Before we even submitted our project plan, one of our team members dropped. Also, the infrequent meetings with the company hindered our progress in the first half of the project, but that was understandable since our contact person was sick for several weeks. We reacted to the risks accordingly and the effects were minimized: we contacted other people inside Neste who were able to help us forward until our initial point of contact was back in full strength.

Due to the change in our approach, the initial schedule presented in the project plan was not relevant anymore. At the time of the interim report we, however, updated the schedule to better fit the new focus of the project. We managed to follow this schedule neatly without any notable issues.

The project execution was not ideal in the first half of the project due to several potential approaches considered simultaneously, communication challenges with the client, and delays in accessing the Spiral software. However, in the second half of the project with the more focused approach we managed to execute more effectively. The regular catch-ups with the client, working together as a team, and a feasible approach were all necessary for successful execution.

Initially, the amount of work seemed quite large, but after focusing the scope the workload was manageable even after one person dropping from the team in the first weeks. Also, open communication with the client helped us to avoid excessive struggling with the program on our own and focus on productive activities.

The project was successful in several ways, but most importantly, it was successful since we managed to provide valuable results and insights for the client. Instead of a separate system or Excel file, the client can use their existing systems to develop our approach further and to implement it. The parts of the project that were less successful, were initial project planning, initial communication with the client first and the first half of the project in general.

Our team had an approach that we all tried to grasp the bigger picture and have a comprehensive view on the problem. Even with this approach, a slight challenge was that one of us was most competent in using the Spiral tool giving him more responsibility and making him less replaceable in case of absence.

The teaching staff provided us with relevant feedback throughout the course, and they had a really constructive approach which made receiving feedback enjoyable. There is not much they could have done differently since the course is in any case mostly independent work with the client organization.

Client organization did great job throughout the spring. Most of the challenges with communication could have been overcome earlier if we had just realized faster to have several points of contact for help. One recommendation for the client, would be to have the laptop ready with basic software such as Excel ready in the first meeting so that the project would have a productive start.