Application of Linear Programming Technique in Science Research and Practical in Vietnam Oil Filter Enterprises

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Abstract:  
The objective of the paper is the applied research of linear planning in scientific research and in practice in the Vietnamese oil refining enterprises. The more scientific the industry develops, the digital economy requires that scientists and businesses need to access new knowledge, big data and improve the efficiency of production and business to minimize losses. To achieve the above objectives, linear planning is an effective tool.

Keywords: Linear Programming Technique, Vietnam

1. Introduction

Digital economy is becoming a development trend of all countries, including Vietnam. According to economic experts, one of the mandatory requirements for digital economic development in each country is the need for high-quality human resources with knowledge of information technology, especially deep training. major in Maths - News. In fact, the countries with developed economies in the world today such as the US, Japan, Korea, Germany ... all have a large team of experts in Math - News, well-trained. The universities in these countries are also very interested in and invest in the training of Math and News teams to serve the job requirements of the recruitment market and meet the requirements of the country's economic development. That is also the reason why these countries produce many large-scale enterprises with global influence such as Microsoft, Apple, Samsung ...

Linear planning is a mathematical tool used in studying the method of finding the minimum or maximum value of a linear function by a number of variables, satisfying a finite number of constraints represented by a system of equations and inequality, linear equations. The software is built based on the linear planning tool that supports the establishment of linear planning models in the refineries, and at the same time solves the linear planning problem to produce the results of the flow structure. products in the factory.

The general equation for a problem with the number of constraints m and the number of variables n is described as follows

Maximum function

$$ Z = \sum_{j=1}^{n} c_j X_j, \forall \sum_{j=1}^{n} a_{ij} X_j \leq b_j \ i = 1 \div m $$

Minimal function

$$ Z = \sum_{j=1}^{n} c_j X_j, \forall \sum_{j=1}^{n} a_{ij} X_j \geq b_j \ i = 1 \div m $$

Currently, the dedicated linear planning program for the petrochemical industry is provided by: Honeywell Hi-Spec Solutions (RPMS - Refinery & Petrochemical Modeling System), Aspentech (PIMS - Process Industry Modeling System), Haverly (GRMPTS), Schneider Electric (Spiral Suite) and Princeps (PrincepsLP). In which, more than 75% of the world's refineries use PIMS software to support plant operations.

LP is used in many different industries
- Calculation of alloy composition in the metallurgical industry;

- Optimizing the mixing ratio in the food industry, for example producing feed from several ingredients at different raw material prices, while ensuring quality requirements (nutritional value);

- Optimization of raw materials in the cement industry;

- Update fleet mission plans for airline companies;

- Optimizing production in the car industry.

In the oil and gas industry, the linear planning model used to optimize refinery operations has been practically proven to provide high economic benefits and is widely used around the world. Some important fields in the oil refinery industry apply linear planning models [4, 5]: Design and configuration of the refinery; selection and evaluation of crude oil materials; short-term and long-term operation planning; evaluation and verification of investment projects on oil refineries; evaluating and verifying processing agreements and product structure change contracts; assessing and examining new technologies; control, optimize plant operations; product mix; managing stockpiling of goods; optimization of raw material supply, production and transportation in the refining industry.

In Vietnam, when the factory or plant is shut down, the calculation of the breakdown loss is usually done based on the statistical method and calculating the difference of production volume at the end of the month of breakdown compared to month before or against the plan set out at the beginning of the month. As such, the plant / company manager only knows the loss at the end of the reporting cycle, thus causing a certain delay in the plant operation and operation.

In the scope of the study, the authors applied a linear planning model to calculate the loss when there is a plant shutdown incident in the refinery. By establishing a linear planning model for the base case and the plant outages by the monthly reporting cycle, the authors determined the difference in returns between the outages and the downs. This base and value is referred to as the factory loss in the month of the incident. This model is built on the self-developed software of the Vietnam Petroleum Institute.

Linear planning, technology workshops, oil refineries.

The method used to calculate economic losses is based on a monthly plan model. However, the refinery is a dynamic object, so it is necessary to update continuously to ensure the accuracy of the established model to best reflect the actual plant operation.

The monthly plan model is a popular tool that allows an oil refinery to make the most appropriate operational decisions and / or actions to correct changes in the market.

In the world in general and in Europe in particular, refineries have used linear planning models to build monthly operation plans, evaluate crude oil, operate and optimize refineries, inventory management, management and economic loss calculation in cases of shutdown so that leaders have timely instructions to maximize profits, minimize losses for the factory [8 - 10]. The use of the monthly model also enables refiners to respond quickly to unusual incidents of emergency shutdowns or assist in decision-making of day-to-day business operations.

Optimal calculation by linear planning model helps the refineries to make timely and convincing decisions to reduce losses to the plant when the downtime occurs to deal with problems, with any workshop but specifically 3 main workshops CDU, RFCC and CCR. Each factory has its own technology configuration, standards applied to products are not completely the same, so it is necessary to build a linear planning model for each factory and based on this model to calculate losses and optimized for the factory.

The base case linear planning model is built on actual operating data and will be corrected for some outages. The difference in profit between the plant shutdowns and the establishment case is considered a plant loss.
2. Build a linear planning model for the base case

2.1. Literature review

The main technology workshops of a typical refinery considered in this study include: CDU, NHT, CCR, KTU, RFCC, LTU, NTU, PRU, ISOM, LCO HDT. The schematic diagram of the refinery is shown in Figure 1. Propylene will be used as a feedstock for the polypropylene production plant.

Figure 1. Technological diagram of a typical refinery

Background information for building linear planning models is as follows:

- The raw material of the refinery is crude oil mixture with the density of 0.826. Processing capacity 4,708,409 barrels / month (~ 1,039 m³ / hour):

- General process material balance is established based on data on crude oil properties and computational material balance of technology workshops provided by the designer. The material balance of the mixing process to create the final product is optimized for the purpose of meeting product quality regulations;

- Fuel used in the plant from sources:
  + Gas products (fuel gas) generated from workshops in the factory;
  + DCO oil from RFCC, consumes about 50,313 barrels / month (~ 11.11 m³ / hour).
Manufactured products meet current quality standards.

2.1.1. The goal function
The target function used is the maximum profit function, where:

\[ \text{Profit} = \sum (\text{product price}) \times (\text{amount of product}) - \sum (\text{raw material price}) \times (\text{amount of material}) \]

2.1.2. Model building parameters and constraints
The linear planning model is built:

- The constraints on the physical balance of intermediate products across the workshops, including product flow capacity and processing equipment capacity. Equation of material balance:

\[ (\text{Production volume} + \text{consumption for workshops}) \]
- raw materials = 0
- Product mix diagram of the refinery
- Product quality constraints will comply with the factory's product quality specifications;
- The constraint on fuel demand for the plant: the amount of DCO used as fuel for the plant is about 50,313 barrels / month (~ 11.11 m3 / hour);
- When mixing intermediate product lines, the properties of the end products are usually related to the linear law with the properties between the ingredient lines. However, there are properties that do not comply with this rule (such as RVP, viscosity ...), so it is necessary to convert these properties to the blending index to be able to mix according to the linear equations. The blending index of the ingredient stream and product line will follow the linear mixing rule, where the blended ingredient and product quantity is calculated by volume. The blending indices are calculated using the following blend formula:

\[
\text{Index} = \text{RefIndex} \times \left( \frac{\text{Number} + \text{RefConst}}{\text{RefNumber}} \right)^{\frac{1}{\gamma}}
\]

\[
\text{Number} = \text{RefNumber} \times \left( \frac{\text{Index}}{\text{RefIndex}} \right)^{\gamma} - \text{RefConst}
\]

Inside
- Number: Value of the property;
- RefIndex, RefConst, RefNumber, \( \gamma \): Constants (depending on properties).

2.1.3. Linear and realistic planning model results
Product structure between the results of solving the linear planning model made and actual factory data
The error between the results of the linear planning model and the actual factory data <1% shows that the linear planning model reflects the reality quite accurately and is reliable enough to be the basis for the assessment.

2.2. Building a linear planning model for cases of shutdown of technology workshops
To assess the economic loss of shutting down a technology workshop in an oil refinery, the linear planning model needs to be adjusted a number of parameters, specifically:
Converting the maximum operating capacity of the workshops from daily to monthly reporting cycle assuming 1 month will correspond to 30 days;

Any workshop X stopped working y days, the working capacity (maximum) constraint is calculated by the formula:

Operational capacity constraint

- The model must ensure all components are mixed. In the event of an excess of intermediate products, these products should be brought to the factory's intermediate product tank. According to design data, intermediate product tanks are designed for 4 days of normal plant operation. Therefore, in the event that the workshops are shut down for less than 4 days, it is still possible to ensure that the other workshops operate normally and the intermediate products can be stored in these tanks;

- The results from the linear planning model including product structure, profitability and capacity of the workshops will be compared with the base case in order to calculate the economic losses in the event of a shutdown.

In the case studies, downtime has been chosen as the longest number of days that the workshops can shut down and the CDU capacity is not lost much. This is the duty of the production dispatching unit in the refinery. During an incident, it is necessary to consider intermediate components storage tanks for materials of RFCC, naphtha, gasoline-blended intermediate workshops ... In case the breakdown is longer, use a linear planning model to determine the best solution to minimize losses.

According to actual operating data at domestic refineries, factories that often have problems that have to stop working include CDU, CCR and RFCC. Average downtime is 3 days / month. As for RFCC workshop, due to the complexity of technology and operation, it takes 3 to 5 days for each shutdown to troubleshoot and run again. Therefore, in the research scope of the topic, the authors will consider 3 cases of stopping the workshop:

- Stop operation of CDU workshop 3 days / month;
- Stop operation of CCR workshop 3 days / month;
- Stop operation of RFCC workshop 5 days / month.

For each specific case, the model will offer the best option, also the one with the least economic loss. This option could help keep the current plant's operating capacity and residual intermediate products would be stored in intermediate tanks or would reduce the plant capacity accordingly. Additional declarations for the linear planning model for each case the workshop is shut down, specifically:

- Stop operation of the atmospheric distillation plant for 3 days:
  + CDU workshop capacity constraints: 4,237,568 barrels / month

- For the shutdown of other workshops (CCR, RFCC), the linear planning model will run optimally and make a decision to keep the operating capacity of the CDU (intermediate products will be contain intermediate products and go to processing when the plant is running again) or reduce CDU capacity accordingly. Therefore, the CDU workshop capacity constraint in the LP model will be less than or equal to the maximum capacity of the workshop (≤ 4,708.409 barrels / month). Specifically:
  - Stop the reforming workshop for 3 days:
    • CDU workshop capacity constraint: ≤ 4,708.409 barrels / month;
    • Reforming workshop capacity constraint: ≤ 529,446 barrels / month.
  - Stop the workshop of catalytic cracking for 5 days:
• CDU workshop capacity constraint: ≤ 4,708.409 barrels / month;
• RFCC workshop capacity constraint ≤ 1,742,404 barrels / month.

3. Calculation results

3.1. Stop the operation of the CDU workshop for 3 days

With additional constraints settings when the CDU plant is shut down for 3 days, the linear planning model solves the problem of maximizing profit and recommends the operating capacity of each plant in the plant.

The shutdown of the CDU workshop will cause a domino effect to stop the whole plant for 3 days and lead to a 10% decrease in capacity, except for NHT, CCR and ISOM (capacity decreases by 4%). The reason is that in the base case, the excess amount of raw gasoline as raw material for the banks is due to the capacity limitation of the bank, CCR and ISOM (balance of 51,169 barrels / month). This amount of gasoline will be sent to the M92 petrol blend. In the case of a 10% reduction in CDU capacity (CDU stops working for 3 days / month), the amount of raw gasoline still meets nearly 96% of the capacity of the factory of the central bank. The capacity of the CCR and ISOM workshops therefore also decreased.

According to the above results, when the CDU plant was shut down for 3 days, the capacity of the factories decreased and caused a loss of about 5.3 million USD in profit in the month of the incident, equivalent to 1.77 million USD / day.

The 3-day shutdown of CDU workshop as the scenario also causes the output of other products to decrease, except for M95 gasoline. A decrease in CDU capacity during the month reduces the amount of raw gasoline used to blend M92 (in this case, the amount of raw gasoline used for blending is zero) resulting in a decrease in M92 output and high octane constituents. to prioritize M95 blending, resulting in increased output of M95.

3.2. Stop the operation of CCR workshop for 3 days

Similar to the shutdown of the CDU plant, the 3-day shutdown scenario of Reforming (CCR) will lead to the NHT, ISOM and LCO HDT workshops also shut down due to the lack of hydrogen supply. In the case of a CDU workshop keeping the same operating capacity, only reduce the capacity of the NHT, CCR and ISOM workshops by 10% compared to the base case. The LCO HDT workshop did not decrease its capacity although still stopped operating for 3 days because the normal operating capacity is only about 60% of the design capacity, so there is still enough margin to ensure the capacity to handle LCO oil from the storage. when operating again. In this case, the output of products such as diesel, fuel oil, Jet A1 jet fuel does not change, only the total output of gasoline decreases due to the reduction of the output of reformate and isomerate. M92 gasoline output increased significantly due to increased production of low-octane gasoline blending components, namely, raw gasoline (whole naphtha).

In case the CCR workshop stops operating, the M92 gasoline output increases very high (Table 8) and may exceed demand for the month or orders already available. Therefore, in order to minimize losses in this case, the plant’s sales team must boost consumption of M92 gasoline.

With the optimal operation of the plant, CCR workshop stopped working for 3 days will cause a loss of about 1.34 million USD in the month of the incident, equivalent to 447 thousand USD / day.

3.3. Stop the operation of RFCC workshop for 5 days

The RFCC workshop plays a very important role, so shutting down this plant causes huge losses to the refinery. When the RFCC workshop is shut down for 5 days / month, the linear planning model solves the optimal problem and gives the answer about the operating capacity of the workshops in the respective refinery.

Thus, the shutdown of RFCC workshop has a great impact on the plant's operation. Workshop capacity decreased by 11.32 - 16.67% compared to the base case.
In this case, similar to the reduction in the capacity of the CDU and CCR workshops, the capacity of the workshops both decreased, leading to a significant reduction in production output of products and a loss of about 9.4 million USD / month, equivalent to 1.88 million USD / day. However, if in the event of a shutdown of the RFCC facility, the atmospheric distillation residue (which is the material for the RFCC) is stored in either the atmospheric sludge tank or the crude oil tank (in the case of excess atmospheric distillation residue), more than the storage capacity of the atmospheric sludge tank) the plant losses will be significantly reduced.

A comparison of losses in plant shutdowns shows that the shutdown of the RFCC workshop caused the most losses to the plant, followed by the CDU plant and the plant shutdown. CCR causes the least damage.

The linear planning model has calculated the optimal solution to minimize losses in cases of shutdown of the refinery's technology workshops. These options include: keeping the capacity of the CDU workshop and putting intermediate products in intermediate product tanks for further processing after the plant is back into operation or having to reduce the capacity of the CDU workshop accordingly. However, losses can be further reduced if the refinery adopts measures for the fastest and most accurate fault diagnosis (for example using CFD models) that reduce downtime.

4. Conclusion

The linear planning model for refineries is built to calculate the physical balance of the technology workshops and product lines, to optimize operations under normal operating conditions. and shutdowns to minimize the loss to the refinery. Under the hypothetical scenarios, the down-operation scenario of the RFCC plant causes the most losses, followed by the CDU workshop and the shutdown of the CCR plant causing the least loss to the refinery. The linear planning model developed by the Vietnam Petroleum Institute can be applied to calculate the losses for the shutdowns of different workshops in the oil refinery; is the basis for building the optimal operation plan and minimizing damage in the event of a failure to shut down the technology workshops of the refinery.

References

