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A Mathematical Model in Optimization Production Programming for Oil Refinery

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Abstract- This Chapter is focused on the production programming optimization of production modes concerning crude oil barrel unloading, storage, blending and feed to Crude Extract Units (CEU). Kochi Refinery Company Limited (KRCL) is receiving its crude oil through a pipeline, which is linked to a docking station to oil barrel or any other tankers unloaded. The unloading programme of these tankers is defined at the corporate level and cannot be changed easily. Thus, for a given Programming horizon, the number, type, arriving and departure times of the oil tankers. The model offers the crucial programme for the system in accordance with the given conditions and the optimal programming cost calculated. The crucial program, if it is feasible, must follow the proposed suitable unloading days for barrel and the offered current rates among offers and tanks, among storage and among tanks and plants, for keeping the optimal production scheduling given by the model results. Furthermore, this model can be used as a workable tool, not only for supporting the shipment planning, also, for manifesting system infeasibilities and for crucial decisions concerning investments in storage and pumping systems. The purpose is to offset the demand while the inventory volumes and the pumping system capacities are not violated. The shipment plan considers being realizable in terms of production.

Keywords— Production Programming, Optimal Programming, Crucial Program, Optimization

I. INTRODUCTION

Kerla Refinery Company Limited (KRCL) gets the thing crude oil from a pipeline that is connected to docking station an oil ship, which are associated with KRCL. The capacities of each are 13,800, 6,000, and 3,000 tons, along with any other tankers that are being discharged. These tankers' unloading schedule is set at the corporate level and is difficult to change [1]. Thus, within a specified scheduling horizon, the volume, classification, arrival, and departure schedules of the oil tankers are predetermined. [2].
The focus of this paper is on optimising the production schedule of operating modes associated with the distribution, blending, storage, and unloading of crude oil ships to Crude Extract Units (CEUs). The archetype suggests a strategic approach for the process based on the established optimal operating cost and the given parameters.

The strategic operation must, whenever feasible, align with the recommended unloading daylights for ships and the recommended drift tariffs between ships and tanks, as well as between storage and charging tanks and between tanks and shrubberies, in order to ensure the optimal production schedule as determined by the model results. This model can also be a helpful tool for detecting system infeasibilities, aiding shipping planning, and making strategic investment decisions un pumping and storage systems [3], [4], and [5].

The objective is to meet the demand while remaining within the constraints of inventory levels and the pumping system's capabilities. The shipment plan must be practical in relation to production. It is essential to verify the shipment plan and the associated consumption for the shrubs in accordance with the production schedule to ensure that supply occurs on time. Furthermore, the model will aid in this critical process and ascertain whether the shipment design can truly align with production needs or not [2], [6] and [7].

II. PROBLEM FORMULATION

A multistage system that includes ships, storage tanks, charging tanks, and CEUs is illustrated by the

regularity outline for this production schedule optimization model, as shown in figure (1). Within a specified scheduling timeframe, crude oil vessels arrive at the refinery docking station, which is designed to accommodate only one ship for unloading at any given time. Each vessel will have a designated departure date determined by the planning level, which must not exceed the arrival date of the next ship. Unloading operations may commence on the day a ship arrives, in accordance with the model's suggested optimal outcomes. This aligns with the current state of the system under examination. Given that the planned arrival date of the next ship coincides with the maximum departure date of the previous vessel, the completion of unloading for a ship should occur no later than one day prior to the maximum departure date established at the projection level. This arrangement enables the subsequent ship to potentially initiate unloading upon its arrival date [8], [9], [10], and [7].
At the docking station, crude oil is transferred into storage tanks. Afterward, the charging tanks obtain crude oil from these storage tanks. It is essential that every batch of crude oil in the charging tank aligns with a predetermined mixture of blended crude oil, as detailed during the planning stage for the scheduling target.

Each tank's achievement of this mixed composition range is controlled by taking into account the measurable equilibrium of the residual volume as well as the multiple inflows and outflows from the tank, each of which has a distinct composition over time. The CEUs then transport the mixed crude oil from the charging tanks, switching between different types of blended crude oil as needed for each CEU.
Finally, it is important to remember that when a CEU is being supplied by a charging tank, it should not be receiving input from any storage tank at the same time, or vice versa [11], [12], [13], and [14].

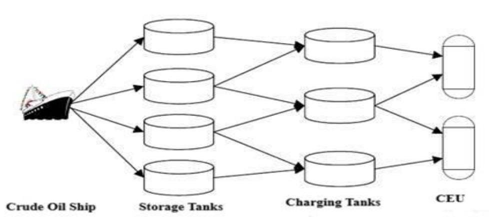

Figure 1. A Multistage system of CEUs

Objective of the Study

Taking into explanation the framework of this multistage procedure and the timetabling of ship arrivals, as well as the limitations on equipment capacity and the concentration ranges of essential components in crude oil, this analysis aims to ascertain the operating variables necessary for cost minimization [15].

- The duration of time that each vessel remains at sea following its arrival.
- The time required for unloading each ship.
- The procedure of transferring crude oil from ships to storage facilities occurs at a specific rate.
- The rates at which crude oil is assigned and blended from storage tanks to charging tanks are being analysed.
- The arrangement of crude oil blending types is to be adjusted in each CEU, following the optimal changes in mode transitions.
- Inventory quantities of storage and charging tanks.
- The rates at which the crude extraction unit is charged satisfy the demand for every CEU.
- The ensuing regulations governing operations are to be followed [21].
- Within the scheduling timeframe, every vessel designated for unloading must arrive at and depart from the docking station.
- Should a ship not arrive at the docking station, it will be unable to unload the crude oil.
- When a ship exits the docking station, it is not capable of continuing the unloading process for the crude oil.
- The vessel is allowed to begin the unloading process on the date it arrives.
- The ship is incapable of unloading by its designated departure date. The only exception is the last ship.
- During the operation of the charging tank as it charges one CEU, the introduction of crude oil into the charging tank is prohibited, and the same applies in the opposite scenario.
- Each charging tank can provide service to a maximum of one CEU at any given time interval.
- Each CEU is assessed a fee for just individual blended crude oil at a particular time recess.

In contrast, the following operational limitations need to be satisfied.

- The requirement for each CEU across designated time periods
- Equipment potential, boundaries: tank size and pumping efficiency
- Each blended crude oil exhibits quality restrictions that are determined by the range of concentrations of its constituent components.

III. MODEL FORMULATION

The model's goal is to reduce operating costs for the entire system that is shown. Its structure, which makes use of broad notation and a MILP formulation, insinuates that it may be proficient to solve a general problem in this sector. Binary and continuous variables are combined with the system network to create the multi-period MILP model.

The assumptions for the proposed model are outlined below;

- The ideal integration is expected for each charging tank while it receives different types of crude oils, and superfluous blending time within the tank is not needed before it transfers to the CEU.
- Only a single docking station for the unloading of crude oil is taken into account.
- The characteristics of crude oil are dictated by the concentration of vital components that are either present in the crude oil otherwise in the blended crude oil. In most cases, sulphur is recognized as individual of the crucial elements for distinguishing concerning types of crude oils.
- The duration allocated for the transition is overlooked, as are the transient flows produced during the startup or shutdown phases when a transition occurs.

For the proposed scheduling paradigm, a consistent differentiation is used in the specified slating prospect. The choice of the extent of apiece discretized time period requires a compromise concerning operational accuracy and computational workload [12], [17] and [18].

IV. NUMERICAL EXAMPLE

Examine the following scenario: two crude ships are scheduled to arrive on days 1 and 5. Ships 1 and 2 carry 1,000,000 barrels of crude oil A and B, individually, and their unloading should be finished by day 8. One CEU is required to process one million barrels of diversified crude oil x and y, respectively. Crude oil quality is determined by the weight fractions of sulphur, which are 0.06 for crude oil and 0.01 for crude oil A. The B. Crude oil mixes x and y are two types of mixers made by combining two crudes. While y's sulphur concentration should be between 0.045 and 0.055, x's should be between 0.015 and 0.025. Crude oil A and B have storage tanks with initial capacities of 250,000 and 750,000 barrels, respectively. On the other hand, the charging tanks for crude blend x and y have beginning amounts of 500,000 bbl. Inventory expenses, ship harbouring costs, ship sea in the offing costs, and CEU trade fees for crude oil mix charge mode changes are the costs associated with this issue. The system details for the numerical example are displayed in Table (1).

Table 1 Crude oil production planning Unit

Unloading Ship (in days)			8
Number of Ship arrivals			2
Number of Ship	Arrival Time	Amount of crude oil	Unit of Crude oil Component
Ship 1	1	100	0.01

Ship 2	5	100	0.06
Number of	Storage Tanks		2
Storage Tanks	Capacity	Original Oil Amounts	Unit of Crude Oil Component
Tank 1	100	25	0.01
Tank 2	100	75	0.06
Number of	Charging Tank		2
Charging Tanks	Capacity	Original Oil Amount	Unit of Elementary Component
Tank 1	100	50	0.02 (0.015-0.025)
Tank 2	100	50	0.05 (0.045-0.055)
Number of CEUs		1	
Unit Costs of Ship	Operational	Unloading cost Ship wating cost	8 5
Tank inventory unit	Cost	Storage Tank Charging Tank	0.08 0.05
Unit			
Maximum Charge Storage Tank	of Ship to	50	
Maximum Charge Tank to Charging	of Storage Tank	40	
Maximum Charge Tank of charging	of Storage Tank at	40	

Barrels x 10,000 and barrels per time recess x 10,000 are the units of measurement for volumes and flow rates, respectively. The sea awaiting and unloading expenses are expressed in US$ x 1,000 each time interval day, while the changeover costs are expressed in US$ x 1,000. The cost of a tank inventory unit is expressed as US dollars x 0.1 per barrel of oil. As a result, US$ x 1,000 will be the ideal value.

As seen in the designs below, we can depict the provided data in a flow network.

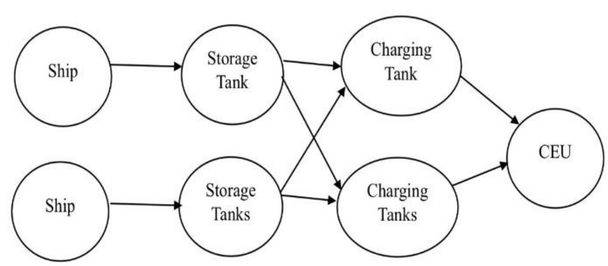

Figure 2 Oil proceeding network at KRCL

In the numerical example, ship 1 outsets to empty proceeding day three for the current model. Table (2) compares the best beginning date for unloading is determined by both models. Compared to the other model that takes this operation into account on a daily basis, that is one more day 2. For ship 2, however, both begin unloading on day 7.

Table 2 Optimal unloading from time for Ships

Ships	MILP Model	X Model
1	3	2
2	7	7

Given that the existing model's ideal operating schedule should result in higher overall inventory costs, the scenario may be contributing significantly to the discrepancy between optimal values. However, as table (2) shows, the sea waiting expenses (US$5,000) for the current model are one day more than those for the X model.

There were 331 constraints, 192 single variables, and 36 discrete variables in the optimization model table (3). The optimization model was made up using IBM OSL [19] and the General Algebraic Modelling System (GAMS) [20]. By taking into account the binary variable data structure, the number of variables and constraints was decreased. Table (3) displays the finest results produced by the X model and compares them ahead of time with the optimal outcomes of the current model.

Table 3 Comparisons between the best outcomes and the current model

Objects	MILP Model	X Model
Optimal values	217,667	206950
Equations and constraints	331	552
Single variables	192	337
Discrete variables	36	116
Passage	1695	4393
Operational term	17.1	5.21

All of the optimal objective assesses generated by the X model as results are less than the subsisting model consequences, as shown in table (3). According to the X model's mathematical justification, it actually handles more equations and constraints than the models now in use; However, because the X model has achieved greater cost reductions while handling the identical operational scheduling problem, its precision and optimal value findings are superior to those of the current model. Additionally, the advancement in computing has prevented the model's machine time for each example from increasing much in proportion to the growing number of equations and limitations.

According to the results show in table (1), The X model yields more optimum outcomes for the numerical case, indicating an overall savings in operational costs of US$10,717 (which represents a 4.92% reduction relative to the obtainable model) throughout the 8-day scheduling timeframe.

V. CONCLUSION

In this paper provides a comprehensive explanation of the specifications related to the challenges of managing and optimizing operational costs in an oil refinery, particularly concerning the scheduling of unloading, storage, blending, and supply of crude extraction units. It details the mathematical formulation of the optimization production planning model in algebraic terms. The primary objective function aimed at minimizing costs, as outlined in equation table (1), incorporates substitution costs, unloading costs, and inventory costs. Furthermore, each equation, constraint, and variable necessary for the models is discussed in depth, often specifying their individual characteristics. The chapter also illustrates various methods for employing this X model to resolve planning challenges, emphasizing the complementary restrictions that must be applied to cater to a range of preferences.

In this paper has also illustrated the detailed analysis of the X model, effectively addressing the same questions that [88] employed to clarify their model. It has referred to this model as the "Existing model" to set it apart from the X model. A comprehensive comparison of the results from both models has been undertaken, underscoring the differences in their outcomes. Despite the X model's ability to handle additional equations and constraints, its ideal values for minimizing overall operating costs have been found to be lower than those of the "Existing model." Moreover, it has been shown that the attributes of the X model facilitate its adaptation to various challenging situations, such as the requirements specified by [12] in their example. Conversely, the "Existing model" was developed to operate within a singular solution framework, rendering it less precise than the X model in addressing these types of scheduling challenges, even though the majority of its conclusions in this chapter seem to follow a similar optimal path.

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