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Crude Tanker Scheduling Simulation Model-A Case Study

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ABSTRACT

The crude oil imports of about 16 million tonnes are currently arranged from the Middle East countries and are available for lifting at different ports in West Asian Gulf. This imported crude has to be transported to several refinery port locations along the Indian coast. For this operation, a fleet of tankers is deployed. This study attempts to analyse the existing tanker scheduling system with a view to optimising the utilisation of the tanker fleet, for fleet augmentation and for facilities planning. A simulation model of the system in GPSS has been constructed, validated and tested. The model has then been used to measure the impact of changes in facilities, demand/supply inputs, decision rules etc. on system performance. The model should be found to be a useful operating and planning tool and with suitable modifications, is capable of Application in a variety of similar situations elsewhere in the world.

I. INTRODUCTION

Annual crude oil imports into the country are currently of the magnitude of 16 million tonnes. Bulk of these imports are arranged from the Gulf countries and are offered for lifting at ports such as Kharg Island, Lavan Island, Rastanura, Das Island, Fateh etc. This imported crude has to be transported to several refinery port locations all around the country, e.g. Wadinar in extreme North West, Bombay, Goa, Cochin, Madras, Vizag, Haldia etc. For this transport operation, a fleet of tankers chartered from Shipping Companies is deployed. The fleet comprises about 20 vessels which are of different carrying capacities, standard lengths and other attributes. The heterogenous composition of the fleet, the varying demands at refinery port locations, the fluctuations and uncertainties in supply schedules at load ports, the disparities in refinery ullages and lack of a formal M.I.S. make the system operation a complex exercise. The onset of monsoons and draft variations at ports add yet another complexity into this operation and make the task of scheduling and of optimal utilization of fleet a difficult one. In the maze of these complexities and uncertainties, how to improve the utilization of the tankers and optimise the expenditure on freight is the focal point addressed by the study. To have an idea of the magnitude of freight involved, it may be mentioned that the existing annual expenditure of this operation is on the order of $150 million.

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II. OBJECTIVES

A. To study and analyse the existing crude tanker scheduling system and construct a tanker scheduling model with a view to optimising the tanker fleet utilization on continuing basis.

B. To use the computer model for facilities planning, for fleet augmentation and/or fleet reduction etc.

C. To draw out and update a monthly tanker schedule with changes in inputs based on optimal fleet size with reference to demand and supply position changes, drafts obtaining and current inventories.

III. THE RESEARCH METHODOLOGY

On a careful examination of the tanker scheduling system and the uncertainties associated with its different components, it was clear that simple queuing, L.P. or waiting line models had no place in the scheme of things. The dynamics of the System and the adjustment of tanker schedules to new demand, supply, draft and tanker availability situations could more aptly be reflected in the simulation model of the System.

Consequently, a model in GPSS V was constructed and coded. The model was validated by equalizing a number of model generated outputs with real life data independently compiled with respect to the same parameters for the system for the same period. The model finally emerged as a tool that could be used for planning or for ascertaining tanker schedules based on optimal fleet utilization for a given set of input parameters.

IV. OPERATING BACKGROUND

A. Currently, the crude oil is imported from Rastanura, Lavan Island, Kharg Island, Das Island and other West Asian Gulf ports to 6 discharge ports viz. Wadinar, Bombay, Cochin, Madras, Vizag and Haldia. Additionally, crude is also offloaded at Bombay LPO during off monsoon season and Sikka (near Wadinar) during monsoon season. This is so because the high tide conditions at Bombay LPO during monsoon prevent double banking of vessels. Unloading at Bombay LPO or Sikka is necessary for two reasons viz. (i) due to inadequacy of on-shore storage tanks at various ports/refineries locations and (ii) port drafts are not adequate to accept berthing of tankers with a DWT exceeding 50,000 tonnes in some cases.

Currently, the following preferential routes are assumed for the movement of tankers between load ports and discharge ports:

From Rastanura	to Butcher Island (Bombay) to Bombay (LPO-Storage Vessel) to Wadinar to Cochin to Madras-Haldia
From Lavan Island	to Madras-Haldia (exception-Bombay or Sikka LPO)
From Kharg Island	to preferentially Madras Haldia
From Das Island & Other Ports	No set pattern, will depend upon individual cases.

B. Loadings at Ports

Because of draft and length overall constraints, daughter vessels are used for transfer of the crude at Cochin, Vizag and Bombay (from LPO to Butcher Island or elsewhere) as necessary.

Ordinarily, loading is done at a single port. Only when a full tanker load is not available at first port of call, supplementary loading may be done at another port. Similarly, when only a small quantity is left over as balance against a contract, two-port loading may be resorted to make up a full tanker load.

C. Loadport/Supplier

Out of the total import requirements of 16 million tonnes per year a substantial tonnage is tied up in firm contracts, the balance is imported on a spot basis depending upon inventory levels/monthly requirements.

For the Term Contract quantities, the quantity lifted up to a particular date, balance available as of that date, pro rata monthly availability for the next few months, additional requirements or offers, if any, for a particular period etc. are taken into consideration before deciding on the quantity to be lifted from a particular supplier at a particular load port. The tanker nominations and lay days at load ports are checked with the supplier about a month in advance after ascertaining availability of respective tankers for loading.

Similarly, the spot purchase requirement for each month is also computed for the next 3–4 months. However, since spot purchases are influenced by International Market conditions, very often the decision relating to spot purchases is taken at short notice. Although approximately 30–40 days notice may be available for liftings in most cases, liftings may require to be done within a week or 10 days in other cases. Therefore, the system has to be capable of taking care of such liftings from loadports and for assigning vessels for such liftings.

In the case of spot purchases, the justification to buy a particular quality or quantity of crude, will largely depend upon the prices prevailing in the international market at the appropriate period. Therefore, although Arab Crude is generally acceptable to all refineries, a situation may arise that could force acceptance of crude of a different grade or the one available in special parcel sizes and as such the allocation of a vessel to lift this cargo has to conform to the unique requirements of the loadport. The other important factors would be the laydays within which the parcel has to be lifted and whether ullage is available at the refinery which is being allocated to receive this cargo.

D. Discharge at ports

Ordinarily entire crude contents of a vessel are discharged at a single port. An exception is the Madras-Haldia combination who share the discharge. This is resorted to in view of the ullage and draft constraints at Haldia. other ports could also be paired occasionally to meet emergent situations.

Discharge Ports/Recipients. In the case of allocating a vessel to the discharge port, the factors taken into consideration are:

- The current crude inventory at the receiving location
- The current demand at that location
- The acceptability of the vessel at that location consistent with the (i) Draft (ii) LOA or Length overall (iii) Beam (iv) Pumping Rate (v) Cargo
- The type of crude and the acceptability by the refinery.

E. Tankers

The vessels available in the system may be categorised as follows:

- Time chartered vessels with the Industry.
- COA (Contract of Affreightment) vessels including daughter vessels used for lighterage operations at various ports
- Non-COA vessels
- All other Indian Flag Vessels
- Foreign Flag vessels which may have to be inducted into the system.

The vessels under the category of Time Chartered and COA are entitled to payment for 365 days of the year regardless whether or not they are used for all the 365 days. This is a firm commitment to the vessel owners.

In the case of non-COA vessels, payment is made for the period for which the vessel is actually used. This payment is made on 'cost plus' basis as in the case of COA vessels. In addition to the above, vessel owners are also entitled to claim pro rata dry docking expenses based on the number of days the vessel was in service with the Oil Industry.

While deciding on allocation of a vessel, in addition to considering various factors such as draft, beam, loading capacity, LOA, acceptability at loadport, acceptability at discharge port etc. the relative cost of the voyage by various vessels is taken into consideration and the cheapest vessel is used to the extent possible and to the extent available. Such relative cost has been arrived at based on several parameters such as bunker consumption, speed, size of the vessel, pumping rate, cost recovery factor and standing charges etc. mutually decided for each class of vessels and continually updated from time to time.

F. Allocation of Vessels

In the last week of each month, the position of all vessels in the system is reviewed. This review indicates the availability of vessel for loading a cargo at a load port on a desired date. It indicates whether the vessel is suitable to go to the loadport and the proposed discharge port, whether it will meet the required laydays, or meet the desired arrival date at the discharge port etc. The review also indicates as to whether any vessels are free for deployment/loading and whether any vessels allocated for a particular loading cannot meet the requirement and therefore have to be substituted. Depending on this review the vessels are reallocated for loading cargo in the forward month.

Normally authorisations from the suppliers would be available at time of review and vessel nominations can then be firmed up. However, in order to take care of changes in laydays, changes in nomination by suppliers particularly at short notice, non-confirmation or delay in confirmation of laydays by suppliers, changes in operating condition or need at the refinery/location, changes in the availability date of vessel for a variety of reasons etc., it may become necessary to alter particular allocation of vessel to load/discharge port and thereby revise the nomination with the supplier.

For this purpose an industry Coordination Committee meets once a month to draw up a plan for the next month and thereafter it meets industry members once a week to review and update supplier's confirmation, vessel availability, refinery exigencies & problems etc. and reallocate the vessel to loadport/disport as required. This may also involve diversion of full or part cargo meant for one port to another.

One of the important factors to be taken into consideration in allocating a vessel to a loadport is to ensure that it meets the supplier's layday nomination and port requirements. If the vessel comes ahead of the nominated laydays it will have to wait and if it comes later than the nominated laydays it may still have to wait until the supplier is able to take it pu on an out of turn basis.

V. THE MODEL

The model comprises 4 separate routines each closely interfacing the other. The broad functions of each of the 4 capsules are set out in the Schematic flow charts appended on appropriate pages and are described below:

A. Supervisor Routine

The Supervisor Routine (Figure 1) functions like a scheduler and books or assigns tankers to specific tasks. This is in fact the 'brain' of the model. The booking is done everyday. The task includes handling of all activities after a tanker is booked to reach a destination and before it is released after loading and/or unloading of crude. The allocation of the tanker, of course, has to be done based on a number of considerations such as drafts at concerned ports, LOA, Beam, tanker availability, its empty or loaded status, the tanker characteristics etc.

The supervisor routine reviews the status of each tanker everyday. All the tankers are checked sequentially and allocated to the load or discharge port, if they are available for booking and berthing. While doing this allocation, it has been assumed that other things being equal, the cheapest available tanker amongst those awaiting assignment has to be given priority in the matter of allocation. A tanker gets assigned to discharge port if it is carrying crude and to load port if it is empty.

While doing the discharge port assignment, the assumption made is that the discharge port with the lowest current inventory of crude would be given the highest priority, port with next lowest crude inventory is given the next priority and so on, subject of course to constraints of crude acceptability.

Similarly while selecting a load port, the one with the highest pro rata outstanding supplies will have preference over another with relatively lesser pro rata quantities available for lifting.

In either case, the other ground rules of assingment viz. allocation and transportation remain valid, e.g. these are subject to port and vessel sizes, drafts, LOA, beam etc. Cognizance has been taken of the current operating constraints such as a particular refinery not receiving any imported crude except in small quantities, emergency situations or exigencies at refineries and some ports to receive supplies jointly with others.

B. Discharge Ports Routine

The operations of discharge ports are simulated by the macro-DISPO-Daily Monitoring of Discharge Port Operations. The Macro is called separately for each discharge port. In this macro, pseudo transactions are created everyday. These transactions update the inventory of crude to the extent of daily demand, the daily demand being derived from monthly demand. if the stock is found below minimum acceptable inventory, discharge port flag is set on or else pseudo transactions are terminated. A prior check is made as to the acceptability of crude by a refinery at a particular discharge port.

C. The Load Port Routine

The operations of the load port are simulated by the macro (LOPO-Daily Monitoring of load port operations). The macro is called separately for each load port. In the LOPO, pseudo transactions are created everyday. The liftable supplies for the month are worked out in advance based on pro rata outstanding supplies. A load flag is kept 'on' until the scheduled supplies from the port for the month/period have been exhausted. The inventory of crude and pro rata outstanding supplies available for lifting at load ports are updated when the tanker leaves port.

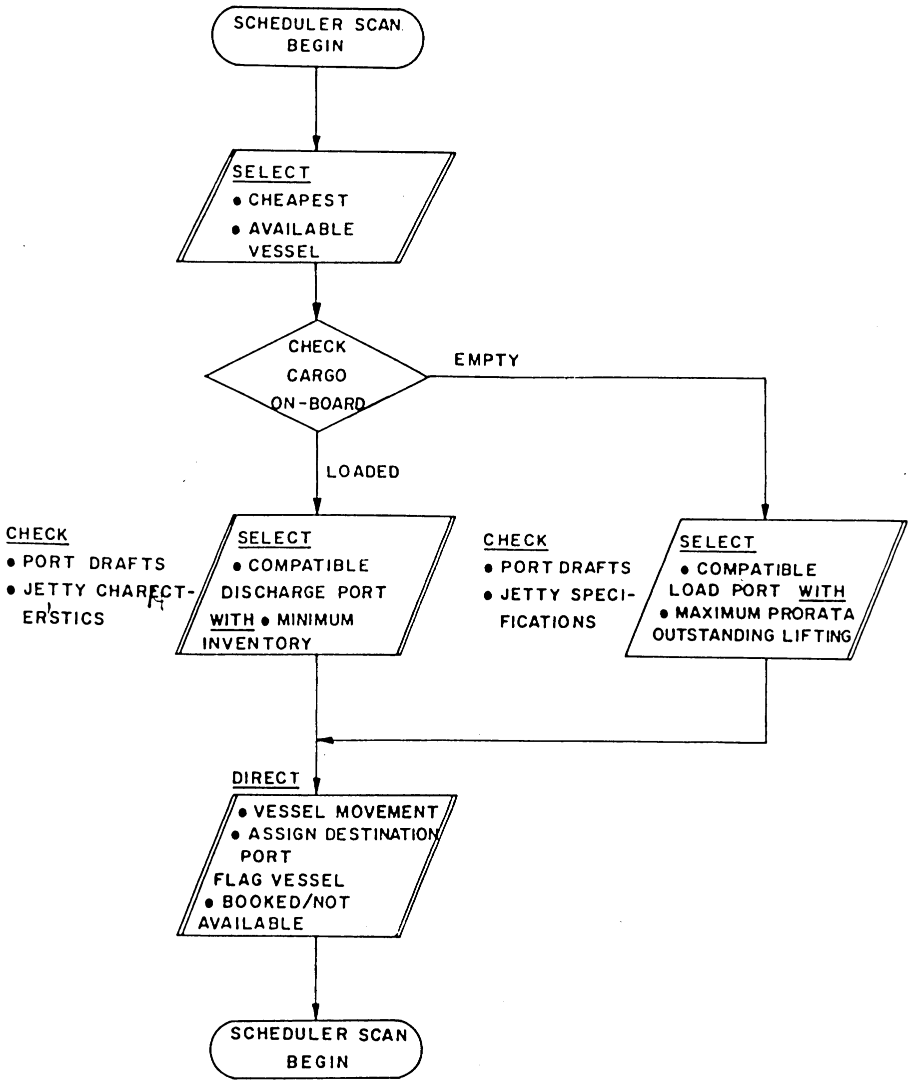

Figure 1. Supervisor Routine

D. Tanker Vessel Servicing Routine

This is simulated by a macro called 'TAKER' (Figure 2). In this macro, pseudo transactions are generated, everyday. The tanker attributes e.g. current location, crude contents etc. are attached to them. The 'pseudo' transactions do not affect the tanker state until tanker is 'booked'. At the instance of supervisor routine, which books the tanker and assigns a task either to deliver crude to a discharge port or load crude from a load port, the tanker is set to move. The first pseudo transaction that encounters a booking is used to complete the task of loading or unloading and release it thereafter. The subsequent pseudo transactions do not influence the tanker state. While performing the task, the limitations of port ullage in case of discharge port and limitations of tanker capacity in case of load port are built into the program.

From the foregoing, it is clear that the supervisor routine is the one which really 'drives' the model and provides a linkage between the various subroutines. it is the one that occupies a focal place in the scheme of things.

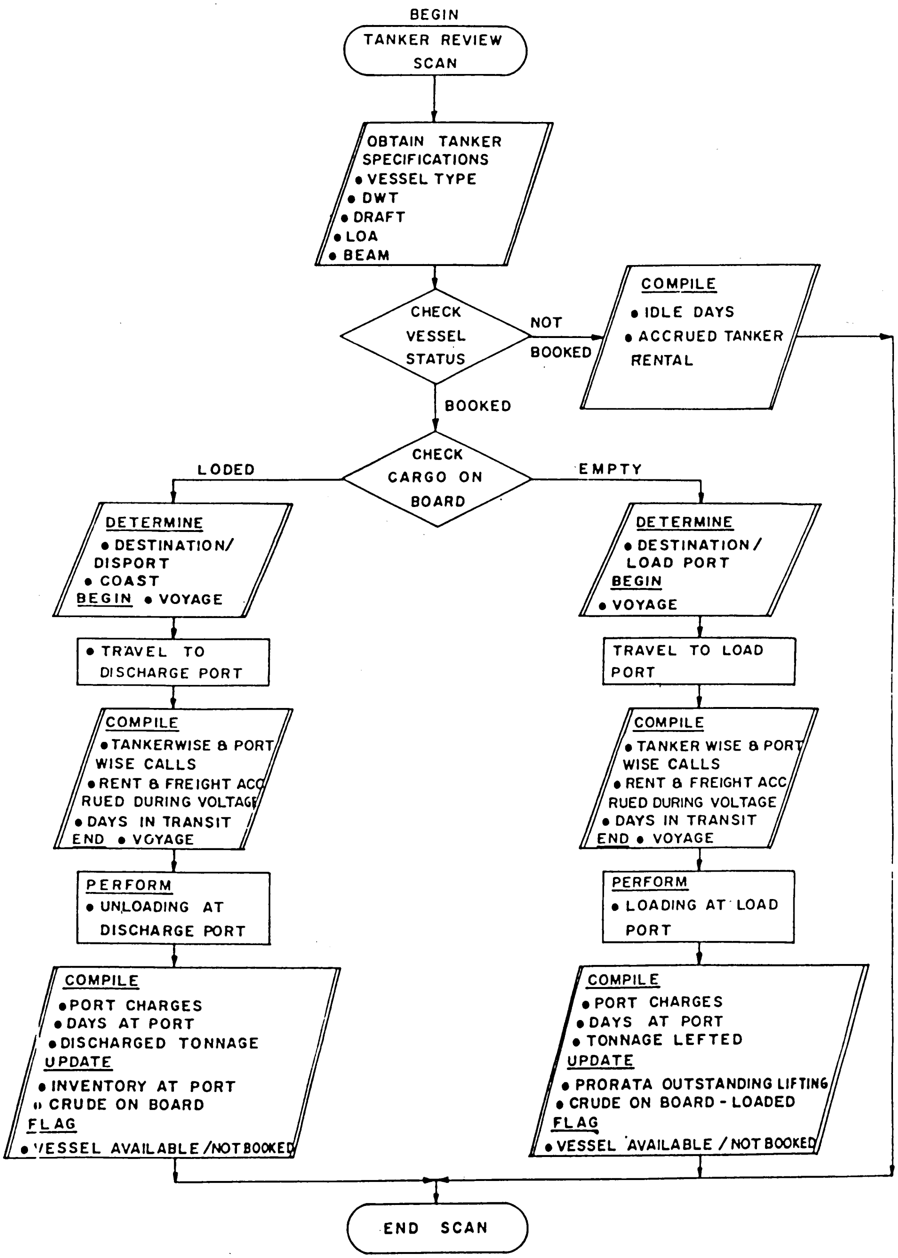

Figure 2. Tanker Service Routine

VI. INPUTS TO THE MODEL

The following principal inputs have been inducted into the model:

Crude Demand Matrix

This matrix sets out the monthly crude demands at each port location. This relates to Indian Ports.

Crude Supply Matrix

This matrix contains for each of the 12 months the supplies of crude available for lifting at each port location. This relates to ports in Gulf.

Inventory Holding Matrix

This matrix comprises information relating to the crude inventory holding capacity or ullages at port locations. Ullages at discharge ports only have been considered.

Minimum Inventory Matrix

This Matrix contains inventory required at each discharge port location in order that the concerned refinery would not have to shut down for want of crude.

Vessel Characteristics Matrix

This matrix contains for each vessel its carrying capacity, LOA, beam, draft, pumping rate, ballast, bunker etc.

Draft Matrix

This matrix contains the draft conditions for each of the twelve months operating at various port locations, i.e. both load and discharge ports.

Route Matrix

This matrix contains the information regarding length of the route, journey time, maximum permissible speed etc.

Port facilities Matrix

Here information relating to each port such as the draft obtaining, kind of vessels that could be berthed, number of hose connections, number of tugs, number of pilots and service times for various operations is set out.

Cost Matrix

This matrix contains information relating to per day rental costs for each of the vessels engaged in crude transportation. Costs details contained in this matrix include per day cost for 'in transit', 'at ports', and 'waiting for berthing'.

VII. INITIALIZATION ROUTINE

The purpose of this routine was to feed data relating to tanker status, refinery crude inventory load port liftings, refinery consumption, drafts etc. that had been carefully collected for the period that was simulated by the model.

VIII. MODEL VALIDATION

In order to validate the model, the following outputs were generated after running the Model for a month:

a) The number of trips made by various vessels during a year. Further the trips were broken up by vessel as well as by port.
b) The total tonnage lifted and discharged.
c) The total vessel rentals and freight charges incurred.
d) The tanker utilisation and detentions.
e) Crude Inventory status at discharge ports.

The information relating to above items was also measured independently for the system for the same period to be used as a basis for comparison and validation. After a large number of trials and repeated computer iterations, it was possible to debug the model and validate it. This, by far, was a difficult and arduous exercise. The end result of this exercise was a model equivalent to the real life system available as a convenient device where System performance could be tested under a given set of operating conditions or vessel and facility attributes.

IX. MODEL RESULTS

In this phase of the project, the model after testing in the validation phase, was used to predict the impact of several changes that the management was intending to effect in the crude tanker scheduling system. Several 'what if' questions were posed to the model by feeding appropriate data or program changes and the answers found by running the model in each case. The results were classified in two broad headings. One set of results was relevant for day to day operations. Here a recommended optimal tanker schedule was the output. The second set of results relate to the impact of changes in facilities, rules of working or tanker fleet etc. on tanker performance and were immensely useful for planning purposes-both for tactical and strategic planning.

The model results of the second category are shown at a glance in table 1.

A careful study of the table will bring out the following:

i) That as the system is worked out with lesser number of vessels, the vessel ulitisation goes up, idle days are reduced and the overall freight also decreases. (cases 1 to 3).
ii) As the transit time of tankers is reduced, the tanker ultilisation goes up and resulting freight decreases. In fact as the transit time is reduced further, this trend continues. (cases 4 & 5).
iii) Even for enhanced crude lifting and discharges performed by the vessel, the same fleet of tankers is found adequate (Case 6). This is further confirmed by the resulting freight remaining identical with the base case (Case 1). Only if the crude liftings and runs are further increased as in case 7, that the freight element goes up steeply but the fleet size is still adequate to handle this increased traffic.

TABLE 1

PERFORMANCE STATISTICS OF TANKERS

(Simulated Period = 1 month)

Case Description	Busy* Tanker Days	Number of Port Calls Made	Crude in Transit at start of simulation	Crude Lifted	Crude Dis-charged	Crude in Transit at End	Bunker Freight and Rental			TOTAL
							At Port	in Transit	Waiting for Berthing	
1. System as it is operated currently	266	29	674	870	838	706	1.24	5.55	5.76	12.55
2. Two vessels withdrawn from the system	317	35	674	870	970	574	1.39	6.38	4.47	12.24
3. Four Vessels withdrawn from the system	342	38	674	870	1095	449	1.48	6.82	2.78	11.08
4. Transit time by 1 Day on all Routes	240	29	674	870	838	706	1.24	−.83	6.13	12.20
5. Transit Time reduced by 2 days on all routes	213	29	674	870	838	706	1.24	−.09	6.51	11.84
6. Crude run and crude liftings increased by 10%	266	29	674	957	838	793	1.24	5.55	5.76	12.55
7. Crude run and liftings increased by 20%	353	37	674	1044	1144	574	1.54	7.10	4.71	13.55
8. Crude run and liftings increased by 20% and 4 vessels withdrawn	360	40	674	1043	1095	622	1.58	7.40	2.34	11.32

* TOTAL AVAILABLE TANKER DAYS EQUAL 400.
ALL CRUDE QUANTITIES IN THOUSAND TONNES
ALL RENTALS IN MILLION US DOLLARS

iv) The trial run reflected in case 8 presents a very interesting spectacle. In this case the model has been tested by increasing the liftings and crude runs by 20% and simultaneously reducing the fleet size by 4 vessels. As will be noticed the resulting tanker utilisation is the highest and the accrued freight is amongst the lowest. The idle time of vessels is also the lowest.

X. CONCLUSION

In the foregoing paragraphs only the important components of this work have been set out. An effort has been made to describe some of the more interesting modules of the simulation model which grapple with a complex segment of crude oil transport operations at the country level. The utility of the model is in two regards-one it brings out an optimal scheduling plan based on dynamic parameters which could be fed into the model from time to time; two it provides an important aid to the planners by predicting the performance of the tanker operation as a consequence of changes in facilities, fleet size, operating rules and the like. The model has been coded in a general purpose language and with suitable modifications is capable of universal application embracing widely different operating environments. It could run in most mainframe/super mini computer systems supporting GPSS.