Transportation optimization model of oil products

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Massive oil product transportation is necessary to maximize all efforts from the point of origin (refineries) to the point of destination (depots). To address the oil transportation optimization problem, an integer mathematical programming model was created in this study. It is focused on obtaining refineries-to-depots optimal assignments by making cost minimization and distance minimization the objective functions. The strategy used is to run the programme through the I-Log programme. The relevant data was chosen from a few actual case studies. In order to attain the optimal refinery-to-depot assignments with the lowest total transportation distance and total transportation cost, the study's findings are therefore highly realizable.

INTRODUCTION

According to the council of supply chain management professionals (CSCMP), logistics is a component of supply chain management and includes all operations related to the movement and transformation of commodities from the extraction of raw materials to the end user as well as information flows (Handfield and Nichols 1999). And up to 50% of a product's overall logistics expenditures might be attributed to transportation expenses (Bauer, 2002). How to handle transportation operations efficiently has become one of the key aspects for oil businesses to survive and sustain competitive advantages in an increasingly competitive global environment. The oil business engages in a very broad spectrum of vertically integrated activities, from oil and gas discovery to refining and distribution. Figure 1 in general illustrates a high level view of the oil industry supply chain.

The main oil firms typically locate their refineries near to the depots, turning the depots into a hub for consumer distribution. The location of the consumers is mostly taken into account when deciding whether to establish a depot. Hill (2003) asserts that the sales and marketing divisions typically foresee the facility location strategy. The business will then consider its ability and capacity to meet the customer's needs. The business will create its overall strategy planning.

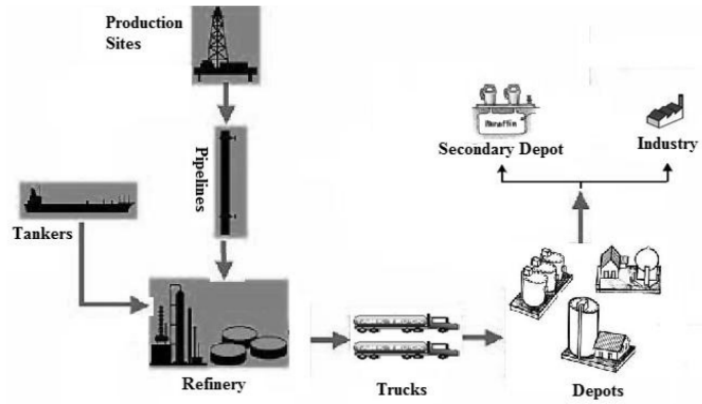

Figure 1. Oil industry supply chain.

The most important predictor factor is the type of car; some models are far more likely to fail emissions testing than "ordinary" vehicles. Out of a total of 52 car models, 5 of the 14 models that performed the worst were produced by foreign corporations or their joint ventures with Chinese businesses (Chang and Ortolano, 2008). The wide size range of particles produced by fleets, including ultrafine particles, can be assessed using the complete set of tailpipe particle emission parameters offered for various vehicle and road type combinations (measured in terms of particle number). These emission factors are especially useful for regions that may lack the funding to conduct measurements or the measurement data necessary to calculate the region's emission factors (Keogh et al., 2009).

The pipelines and storage tanks used in oil refineries are full of petroleum products. Included are storage tanks at retail gas stations, tanks for home heating oil, lubricant storage at car repair shops, propane tanks for use in a variety of applications, and terminals for oil refineries located all over the world (Tahar and Abduljabbar, 2010). Recent studies in operations research and management science have focused on modeling refineries' food chains, with only one part of the chain, such as crude logistics, being described in the literature (Neiro and Pinto, 2004; Reddy et al., 2004). In order to choose the best location for the terminals in relation to client distribution sites, Hughes (1971) puts up a network model. The effective methods for filling and emptying storage tanks at oil terminals (Christofides et al., 1980). The text omits discussing the terminal profits as well as the transportation costs related to loading and unloading these storage tanks. Agent-based crude purchase and short-term crude oil scheduling from port to refinery tanks and distillation unit based on simulation (Cheng and Duran, 2004; Chryssolouris, 2005; Julka et al., 2002). Supply chain management (SCM) simulation research at IBM and virtual logistics and talk about topics connected to strategic and operational SCM, distributed SCM simulation, and commercial SCM simulation software. External the refinery environment (Banks et al., 2002). (Kleijnen, 2005).

This work seeks to optimise the conveying assignments from refineries to depots from a mathematical perspective by presenting a series of equations to mimic various aspects of real transportation. The reduction of both transportation distance and expense is the goal in the end. The main presumptions are as follows:
1) All oil produced at refineries must be transported to its final destination.
2) The same number of trucks that travel from refinery to depot return from depot to refinery.
3) Each truck arrives at a depot as early as possible and departs as early as possible.
4) All vehicles are stationed at refineries, are unrestricted in number, and travel with their full loads.

THE PROPOSED MODELS

Model foundation

When solving a type of programming problems known as linear programming (LP), the objective function that must be maximized as well as the relationships between the variables that relate to resources, or constraints, are linear.

An LP model's formulation can be a time-consuming and challenging undertaking. The inappropriate collection of variables being used or the wrong relationships between the variables being built might lead to an incorrect model. An effective model formulation follows several rules. A set of decision variables, a set of parameters, an objective function, and a set of constraints make up every LP.

A minimization problem of an LP written in the matrix form is:

$$\text{Minimize} \quad Z(X) = CX = \sum_{j=1}^{n} C_j X_j \qquad \text{----------(1)}$$

Subject to $AX = B$

$X \geq 0$ ----------(2)

Where

The constraint coefficients for rows 1 through m in the matrix A, which has dimensions m✖n, are individually represented by n coefficients. The decision variables' column vector consists of the variables X_1,X_2,..., and X_n. The parameters of the constraints are represented by the row vector (C), which is a (n✖1) matrix or a column vector, and the coefficients of the objective function are represented by the (1✖n) matrix (C).

A numerical vector, X, that satisfies all constraints and sign restrictions, is a workable solution to this issue. A feasible solution that minimizes the goal function, Z(X), among all feasible solutions is known as an optimum feasible solution (or an optimum solution). According to Murthy's (1983) proof, the above LP has an optimal feasible solution if and only if X(y)≥ 0 for every homogeneous solution y that corresponds to that LP. Bernard Kolman (1993) demonstrated that if m n, or if the number of equations exceeds the number of unknowns, a homogeneous system of m equations in n unknowns always has a nontrivial solution.

Model construction

The proposed transportation models in the upcoming subsections will be built on a fundamental Winston model (2004). A set of n demand locations and a set of m supply points are where a good is sent from and from which it is shipped. A variable cost of C_i□ is incurred for each unit created at supply point I and transported to demand point j. X_i□ is the quantity of units transported from supply point I to demand point j. resulting in the transportation model as follows:

Minimize $\sum_{j=1}^{n}\sum_{i=1}^{m} C_{ij}X_{ij}$ ---------(3)

Sub to : $\sum_{j=1}^{n} X_{ij} \leq S_i$ (i=1,2,....,m) (supply constraints) --------(4)

$$\sum_{i=1}^{m} X_{ij} \geq D_j \text{ (j=1,....,n)} \quad \text{(Demand constraints) -------(5)}$$

$$X_{ij} \geq 0 \text{ (i=1,2,...,m; j=1,2,...,n)} \quad \text{------(6)}$$

By adding up all products of cost per unit with the quantity of units transported for each origin-destination (i-j) pair, the objective function seeks to minimize the cost of transportation. According to the supply restrictions, nothing transferred from any supply point S_i to any destination may exceed the amount of supply that is currently available. The entire amount of supplies supplied from all origins to a specific demand point cannot exceed the amount that is required by that destination D_j. This is also true for the supply limitations. The non-negativity criterion is the final set of restrictions. As a general rule, it can be seen in the supply and demand restrictions that supply cannot exceed what is available and that demand can only be satisfied up to what is actually demanded.

The following definitions are specific to the models that will be built.

Index

i	refineries
j	destinations where oil production reach
p	product type

Decision variable

X_{ij}	Is the integer number of trips taken to transport a product from origin i to destination j.

Parameters

C_{ij}	Distance between refinery i and destination j.
D_j^p	Processing capacity of product p at destination j.

S_i^p Total M³ for product p at refinery i

V^p M³ capacity of vehicle transporting product p

A homogenous product must be carried from several origins to various destinations in a typical transportation problem while keeping the overall transportation cost to a minimum. Assume there are n demand nodes and m supply nodes. The jth demand node has a need for D□ unit, whereas the ith supply node can supply S_i units of a particular product (Figure. 2).

In the oil sector, there are a set of m refineries, each of which can process $S_m\ M^3$ of oil daily at a set of n depots, each of which can process $D_n\ M^3$. More generally, there are a group of m refineries, each of which sends $S_m^p M^3$ of product p to eight depots, each of which has $D_n^p\ M^3$ of product p processing capacity.

A cost of C_{ij} is incurred for each unit of product conveyed from the i^{th} supply node to the j^{th} demand node. The challenge is to find a workable solution that minimizes overall transportation costs while conveying all of the available quantities without exceeding the capacity or demand restrictions of the receiving node.

In order to achieve the volume needs while keeping transportation costs to a minimum, the model assigns the appropriate number of trucks to each route.

Find a practical method for moving the available goods a minimum haul distance overall to each of their intended destinations.

By first focusing on the oil transportation issue, the transportation model can be made considerably simpler and easier to understand. As previously seen, the refineries serve as the sources of supply, and the depots serve as the locations to which oil will be transported. The capacity of the oil that can be stored in the depots and at the refineries is regulated. The challenge is figuring

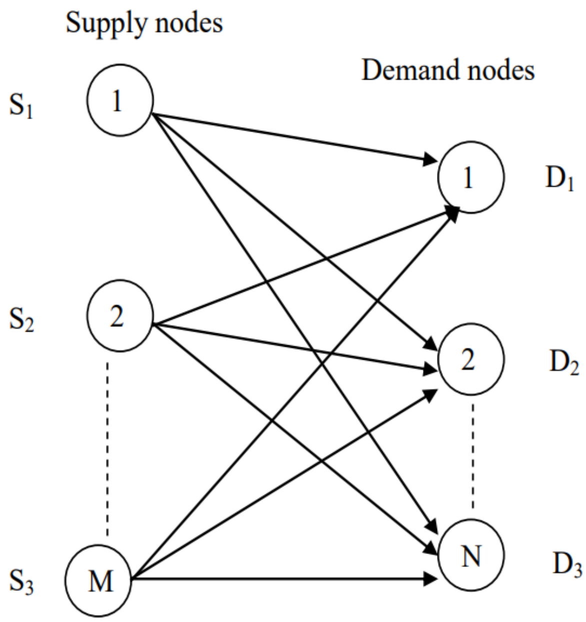

Figure 2. Origin-destination transportation network, supply nodes.

out how to get the oil from all the refineries to the closest depots while minimising overall transit. The main goal of the model is to determine the ideal refinery-depot assignment in order to reduce overall costs.

Let X ij be the number of vehicle trips to transport oil productions from refinery i to depot j through a distance of C_{ij} . Thus model can be written as the following:

Minimize Z= $\sum_{i=1}^{m}\sum_{j=1}^{n} C_{ij}X_{ij}$ --------- (7)

Subject to V $\sum_{j=1}^{n} X_{ij} = S_i$, i = 1,…,m (supply constraints), --------(8)

V $\sum_{i=1}^{m} X_{ij} \leq S_j$, j = 1,…,n (demand constraints), --------(9)

$X_{ij} \geq 0$ and integer ∀ i,j

Where

X_{ij}	Number of vehicle trips from i to j,
C_{ij}	Distance between i and j,
D_j	Processing capacity of depot j,
S_i	Supply at refinery i,
V	Capacity of the tanker

Oil is delivered from refineries to depots over the shortest possible distance according to the target function. The two sigmas following each other in the double summations signify that the two variables are multiplied before their products are combined together. The total transportation distance for the specific I and j is calculated by multiplying the number of trips made to deliver the oil between refinery I and depot j by the distance between them. The m equalities that make up the supply limitations are each for a different refinery. The total amount of oil produced by each refinery must equal the sum of the number of trips made from that refinery to the depots multiplied by the tanker's size. The equal sign for these restrictions also means that all of the refined oil needs to be sent out. However, due to demand limits, which total n, the quantity of oil that may be processed by a given refinery cannot exceed its processing capacity. The remaining two restrictions are that the decision variables cannot be negative and that the number of trips must be an integer.

Table 1. Oil production for the refineries.

Refinery name	Symbol	Oil output (M^3 /year)	Oil output (M^3 /week)
AL-Duara	I	21590321	415198
Baeiji	J	7216548	138779
Total production	T	28806869	553978.25

Data collection source

Oil production

Table 2. capacity for the depots.

Depot	Latefia	Meshahda	Resafa	Kut	Khanqeen	Ramadi	Falahat	Baquba	Total
s y m b o l	A	B	C	D	E	F	G	H	T
Capacity (M^3)	501208	512534	385109	85800	9910	123744	43324	46156	1707785

A pair of refineries in the middle of Iraq are chosen. The state of Iraq's capital city's ALDura refinery transports some of its oil production to depots (Resafa Depot, Meshahda depot, Latefia depot and Kut depot). Iraq's northern Beji refinery transmits its oil production to (Khanqeen depot, Ramadi depot and Baquba depot). For these refineries, data on oil output for the year 2006 was acquired. To obtain reasonably accurate quotes, contacts were made and facilities visits were done. This was accomplished in 2010.

Every single seventh depot provided the oil marketing organisation with their actual production capacity (SOMO). Another depot was chosen since their combined capacity is less than the total amount of oil produced by the two refineries (ALDura refinery and Beji refinery) that were chosen. At AL-Anbaar, there was the closest depot (Falahat depot). Now, the eighth depots' combined capacity was greater than the amount of oil that the two refineries could process.

Table 1 depicts the yearly cubic meter of the commodities for the two refineries, and Table 2 capacity for the depots.

Table 3. Origin/destination distance matrix C_{ij} in miles.

i / j	A	B	C	D	E	F	G	H	I	J
A	-	63	41	62	104	92	63	67	20	157
B	63	-	23	125	64	88	57	55	39	118
C	41	23	-	103	95	79	48	39	20	135
D	62	125	103	-	144	166	139	115	82	217
E	104	64	95	144	-	146	117	34	101	214
F	92	88	79	166	146	-	27	180	85	119
G	63	57	48	139	117	27	-	207	57	90
H	67	55	39	115	34	156	131	-	70	248
I	20	39	20	82	101	85	57	70	-	157
J	157	118	135	217	214	119	90	248	157	-

ORIGIN-DESTINATION DISTANCE ESTIMATION

The origins were the refineries and the destinations were the depots. These distances were mostly actual miles by traversing to all the facilities in their respective locations (Table 3).

Results

The output from the computer-run integer programming models is shown in this section. Tables display the information needed as input for programming runs. The original locations of the refineries and depots are used to give the output for the oil transportation problem. The outcomes display the ideal refineries-to-depots assignments, which indicate which refinery will send its oil to which depot and in what quantity, hence reducing the overall transportation distance.

Table 4. Truck type Information.

Truck types	Capacity M^3	Speed miles/h	Cost $/miles
Small truck	35	55	10
Big truck	40	45	15

Table 5. Values for load time.

Refinery	Small truck	Big truck
I	30	55
J	35	50

Table 6. Depot's Information.

Depots	Earliest departure time	Latest arrive time
A	360	1080
B	400	1150
C	380	1200
D	340	900
E	420	800
F	370	1070
G	320	700
H	410	1100

Input Parameters

The primary issue is with the goods that need to be transported; the primary product is oil, which is regarded as a waste product. Below, Tables 4 and 5 offer information about the different sizes of trucks, Table 6 provides the earliest departure and latest arrival times for each depot, and Table 7 displays the shipment that will be transported by truck from a refinery back to a depot.

Log outputs

After we ran the programme, we received three solutions with three objectives. the best solution, which was the third option with an objective 388080 dollars. The ideal values for the earliest unloading time and latest unloading time in minutes for each route are shown in Table 8. Table 9 displayed the potential values of route and truck count for each route and each truck type.

We also obtained a chart on the CPLEX statistics in Figure 3 using the outputs from the I-Log programme; the vertical axis of this chart is the value of the objective, and the horizontal axis is time in seconds. The figure emphasizes the integer values discovered throughout the search and displays the fluctuation of the best node and best integer values.

(1) The green line depicts the progression of the Best Integer value, or the best integer value that could be obtained for the aim.

(2) The red line depicts how, as you move from one node to another, the best value of the open nodes that are still open (which isn't always an integer) changes over time. This establishes a limit for the ultimate answer.

(3) The yellow point designates a node that contains an integer value. In the CPLEX log, these points typically match the stars (asterisks). View the CPLEX Log page as well.

Every second, the discrete frame's values are dynamically changed to reflect how the algorithm is performing. The values in the General frame are constant and represent the model attributes.

Table 7. Shipments that will be carried back from a refinery to a depot.

Origin	Destination	Total volume (M^3)	Origin	Destination	Total volume (M^3)
A	B	300	E	A	123
A	C	250	E	B	234
A	D	350	E	C	143
A	E	145	E	D	78
A	F	300	E	F	107
A	G	125	E	G	98
A	H	250	E	H	115
B	A	185	F	A	201
B	C	200	F	B	157
B	D	221	F	C	169
B	E	263	F	D	212
B	F	197	F	E	104
B	G	220	F	G	201
B	H	180	F	H	99
C	A	143	G	A	215
C	B	178	G	B	147
C	D	258	G	C	149
C	E	221	G	D	190
C	F	106	G	E	114
C	G	190	G	F	210
C	H	110	G	H	199
D	A	75	H	A	181
D	B	135	H	B	137
D	C	245	H	C	139
D	E	283	H	D	180
D	F	155	H	E	124
D	G	260	H	F	160
D	H	165	H	G	221

Table 8. Values for earliest unloading time and latest loading time.

	Values for earliest unloading time		Values for latest loading time	
	Small truck	Big truck	Small truck	Big truck
< A, I, 20 >	412	442	1028	998
< A, J, 157 >	567	620	873	820
< B, I, 39 >	473	507	1077	1043
< B, J, 118 >	564	608	986	942
< C, I, 20 >	432	462	1148	1118
< C, J, 135 >	563	610	1017	970
< D, I, 82 >	460	505	780	735
< D, J, 217 >	612	680	628	560
< E, I, 101 >	561	610	659	610
< E, J, 214 >	689	756	531	464
< F, I, 95 >	504	552	936	888
< F, J, 80 >	493	527	947	913
< G, I, 87 >	445	491	575	529
< G, J, 75 >	437	470	583	550
< H, I, 70 >	517	559	993	951
< H, J, 248 >	716	791	794	719

Table 9. Values for possible truck on route and truck on route (solution 3).

	Values for possible truck on route		Values for truck on route	
	Small truck	Big truck	Small truck	Big truck
< A, I, 20 >	1	1	48	1
< A, J, 157 >	1	1	0	0
< B, I, 39 >	1	1	42	0
< B, J, 118 >	1	1	0	0
< C, I, 20 >	1	1	37	0
< C, J, 135 >	1	1	0	0
< D, I, 82 >	1	1	43	0
< D, J, 217 >	1	0	0	0
< E, I, 101 >	1	0	36	0
< E, J, 214 >	0	0	0	0
< F, I, 95 >	1	1	30	0
< F, J, 80 >	1	1	6	0
< G, I, 87 >	1	1	32	0
< G, J, 75 >	1	1	6	0
< H, I, 70 >	1	1	33	0
< H, J, 248 >	1	0	0	0

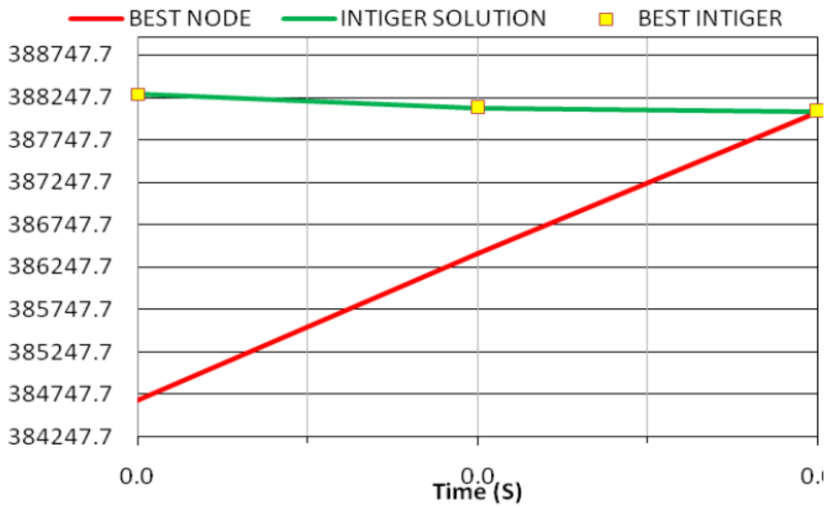

Figure 3. Chart on the CPLEX Statistics page showed the objective value.

Refineries - depots assignment

The goal is to determine the best refinery-to-depots assignment such that the overall transportation distance and cost are reduced, given the oil supply from Table 1 and the depot capabilities from Table 2. The columns in Table 10 above labeled "No. of trips X_{ij}" display the ILOG output of the integer programming for this model. These are actually the values of the decision variables, X_{ij}, which depicts how many trips the trucks will make to transport all of the available oil from each refinery, which serves as the origin, to the depots, which serve as the destinations (one way), in order to minimize both the overall distance traveled and the overall cost.

Total Capacity	1707785 M^3
Total supply	415198 M^3 /Week
Total transportation distance is	669 Miles
Total transportation cost	388,080 $

Table 10. Number of trips, distance and cubic meter from two refineries to depots in Baghdad and Beji.

Origin	AL-Dura				Beji			
	No. of trips X		Distance (miles)	Volume (M^3)	No. of trips X		Distance (miles)	Volume (M^3)
	Small truck	Big Truck			Small truck	Big truck		
Latefia	48	1	20	1720	0	0	0	0
Meshahda	42	0	39	1466	0	0	0	0
Resafa	37	0	20	1206	0	0	0	0
Kut	43	0	82	1318	0	0	0	0
Khanqeen	36	0	101	898	0	0	0	0
Ramadi	30	0	95	942	6	0	80	201
Falahat	32	0	87	1039	6	0	75	185
Baquba	33	0	70	1142	0	0	0	0
Total	301	1	514	9731	12	0	155	386

DISCUSSIONS

According to the aforementioned findings, the shortest feasible route for the transportation of 415198 M3 of oil every week between the two refineries and the eight depots is 669 miles, or what is referred to in linear programming as the Z value. The large commodity must be transported using at least 314 weekday truck trips. This figure is obtained by multiplying the 302 oil trips to the AL-Dura refinery—the total—by the 12 tanker trips to the Beji facility.

The data displayed in the table above make it abundantly evident that the refineries in the north and center transfer their oil to the stockpiles in Baghdad, Al-anbaar, Kut, and Diala. 9731 M^3 of oil in total are carried from the AL-Dura plant. Beji is the other refinery, and it has received 386 M^3 in deliveries.

Even if the eighth depots' combined capacity is 1707785 M^3, a total of 9731 M^3 of oil is sent there, leaving roughly 1698000 M^3 underutilized. The refinery at Beji is closer to Ramadi and Falahat depots than is AL-Dura refinery, so it is better to deliver oil from Beji since the goal is to reduce transportation costs rather than shipping oil from AL-Dura refinery solely to satisfy capacity needs.

There are 302 trips overall that travel to the Baghdad depots, while 12 excursions go to the Beji facility. At each of the depots in Al-Dura, there will be a daily average line of 8 trucks during the seven days of operation. The first refinery depot (Resafa) reveals that it requires 37 trips to transport 1206 M^3 of oil over the course of a week. For this modest Resafa facility, 3 trucks per week are anticipated to exit the mill, which is hardly a busy situation. When compared, the Latefia depot, where 48 fully filled tanker trucks depart from this location each week for their final destination, might be said to be busier because more than 5 trucks depart from there every day.

When it comes to distance, it took 514 miles to transport 9731 M^3 of oil to the Baghdad depots, but only 155 miles to transfer 386 M^3 to Beji. Although the amount of oil going to AL-Dura is 25 times greater than that going to Beji, the distance is only 3.3 times greater. This is because the cluster of depots in the Baghdad area are closer to their refinery (AL-Dura) than those in the Beji area, which are more dispersed from their designated depots. Khanqeen has the greatest transportation distance—101 Miles—to the Baghdad depots.

It has been noted that the eight depots' combined capacity is around 1292587 M3 greater than the combined oil deliveries from the two refineries. It is reasonable to assume that none of the depots operate at full capacity as a result, despite the fact that the management claimed that their facilities were operating at capacity. The implication of this is that the distance traveled from the sources is never given top priority when the governing bodies assign capabilities to these destinations.

If the two refineries assigned to Baghdad and Beji by the proposed model have not yet reached their maximum output capacity, increasing oil production is one approach to reduce inefficient transportation. It makes reasonable to authorize a future refinery near the Baghdad region if the depots are operating at full capacity.

Conclusions

The ideal refinery-to-depot assignments are discovered. The least expensive form of transportation was discovered through this investigation. Two refineries that are part of a cluster transport their oil to depots from the center in Baghdad, Iraq, and Beji, Iraq. The AL-Dura refinery had a total capacity of

1707785 M^3 and a weekly output rate of 415198 M^3. The capacity of the designated two depots, which included the other refinery at Beji, was 167068 M^3 per week and 138779 M^3 per week. The entire transit distance and expense for completing the aforementioned assignment are 669 miles one way and 38,080 dollars each week, respectively.

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