Original Research Article

Accessing and Distributing Petroleum Products in E-Commerce Environment

ABSTRACT

The e-commerce environment is changing the dynamics of doing business rapidly but very often transportation problems hinder customer satisfaction. This paper seeks to minimize the cost of accessing and distributing petroleum products in e-commerce environment. The 0-1 mixed integer linear programming (0-1 MILP) model was used to model the statement of problem: the simulation results suggest that increase in petroleum product demand increases total cost of operations and it can be minimize by reducing the cost of distance covered to access and distribute products. Besides a well-integrated activity of vehicles used for accessing and distributing scheduling plan into e-commerce pace of executing business may improve customers' satisfaction.

Keywords: E-commerce, Petroleum Products, 0-1 MILP

1 INTRODUCTION

Businesses in the twenty-first century are experiencing tremendous changes in doing business powered by the internet. Nowadays, business firm can share products data, information, advertisement, new business strategies and products, new product unveiling date etc. with other business (B2B) or customers (B2C) very quickly or fast via the internet. Businesses using the internet to sell their products accrued these advantages: (i) speed to the market: quick respond to changing market conditions, (ii) cost reduction of doing business: reduces business errors, decreases the use of labor and paper, provides better product tracking and delivery and cutting acquisition time, (iii) flexibility: custom interface between a company and its different clients, and (iv) shortening of the product delivery time (Lankford [1]). The first three advantages can be achieved during the business transaction on the internet but the last one involves other activities like transportation, product handling, traffic management and others. One way of shortening product delivery time is to schedule effective ways to transports goods from warehouses, manufacturing or distribution centers to customers by optimizing the frequency of transport and selecting cost efficient transport route (Ying & Dayong [2]).

Transportation optimization problem in e-commerce environment has been studied widely and further researches are still ongoing. Chen [3] proposed convective transportation model to optimize logistics distribution problem in e-commerce. His results suggest that network convective distribution model reduces transportation cost, very effective and consumes less logistic resources compared to single convective distribution. Li et al. [4] applied mutilate-goal vehicles scheduling problem to investigate how time impact product delivery in e-commerce logistics distribution. Their results show that customers prefers to receive products they ordered online mainly in the afternoon with smaller width of time window. Customers' preference of receiving products with smaller width of time mounts enormous pressure on transportation companies. Yang & Li [5] used vehicle routing problem with time window (VRPTW) to study vehicle scheduling problem under e-commerce environment. They used clustering analysis to analyze the problem and their simulation results revealed that VRPTW optimizes cost better than the traditional vehicle routing problem. Daly & Cui [6] identified transportation issues along waterways in China as a serious problem hindering e-logistics management in China.

Uzar & Catay [7] studied the distribution planning problem of bulk lubrication at BP Turkey. The problem involves the distribution of different lube production from a single production plant to industrial customers using a heterogeneous fleet. Their objective is to minimize total transportation related cost. They model the problem as a 0–1 mixed integer linear program with the first approach being a linear programming relaxation-based algorithm while the second is a rolling –horizon threshold heuristic. Using a real-data of BP Lubes logistics, they found that both variant of the rolling horizon threshold heuristic are able to provide good result very fast. Onut et al. [8] work on heterogeneous fleet vehicle routing model for solving liquefied petroleum gas distribution problem a case study in Turkey. Using real world data obtained from LPG Operating Company, their optimal solution aided in scheduling and assigning vehicle route daily.

Avella et al. [9] address a daily petrol delivery problem using a heterogeneous fleet of tanks trucks. They assumed that the tanks are either completely full or completely empty and developed a formulation and branch-and-price algorithm. To test the performance of their approach they used a real-world data consisting of twenty-five customers and six tank trucks of three different types. Dondo et al. [10] worked on managing distribution in supply chain network focusing on downstream petroleum product. They developed a vehicle routing problem in supply chain management (VRP-SCM) to optimize complex distribution system. The VRP-SCM system allows two or more vehicle to visit a given location to perform a pickup and/or delivery operations and vehicle route may include several stops. Using a mixed integer liner programming (MILP), they solved the VRP-SCM problem which relies on a continuous- time representation. The approach provides a very detailed set of optimal vehicle routes and schedules to meet all products demand at minimum total transportation cost.

The papers reviewed mainly focused on distribution optimization routing problem but in this paper the optimization routing problem seeks to minimize the cost of accessing and distributing petroleum products in e-commerce environment. Such optimization routing problem can be solved using 0–1mixed integer linear programming (0–1 MILP) model. The simulation result indicates that; (i) OMC's petroleum product demand increment, increases vehicle usage strategy and further increases total cost of accessing and distributing products, (ii) total cost of accessing and distributing petroleum product increment is mainly contributed by distance covered cost to access and distribute product, and (iii) strong integration of vehicle accessing and distributing scheduling plan with e-commerce speed may improve customers' satisfaction. The rest of the paper is organized as follows section two defines the problem and 0–1 MILP mathematical model while section three deals with the simulation results and discussions. Section four concludes with the findings, future research and limitation of the paper.

2 STATEMENT OF PROBLEM

In general Oil Marketing Companies (OMC) can procure petroleum products from Oil Refinery Company (ORC) can be depicted as shown in figure 1. At first, OMC's places and order via the internet, ORC acknowledges receipts of the order and forwards it to their logistics department to access and distributes petroleum product demand from ORC's different storage sites. Petroleum products (gasoline, gasoil, LPG, kerosene) are stored at different sites (site A: gasoline, site B: gasoil, site C: LPG, site D: kerosene) to optimize storage capacity and to develop strategic usage of product at these sites. ORC vehicle warehouses are located at zones closer to the storage sites. Per OMC's petroleum product order ORC is faced with strategies to optimize the cost of accessing and distributing petroleum product to OMC's filling stations as shown in figure 2.

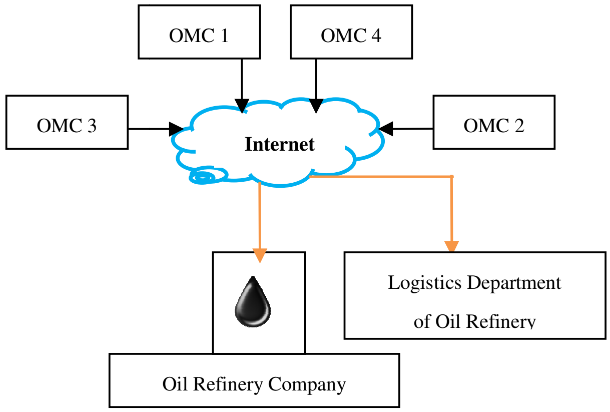

Figure 1, OMC Ordering Petroleum Products Online

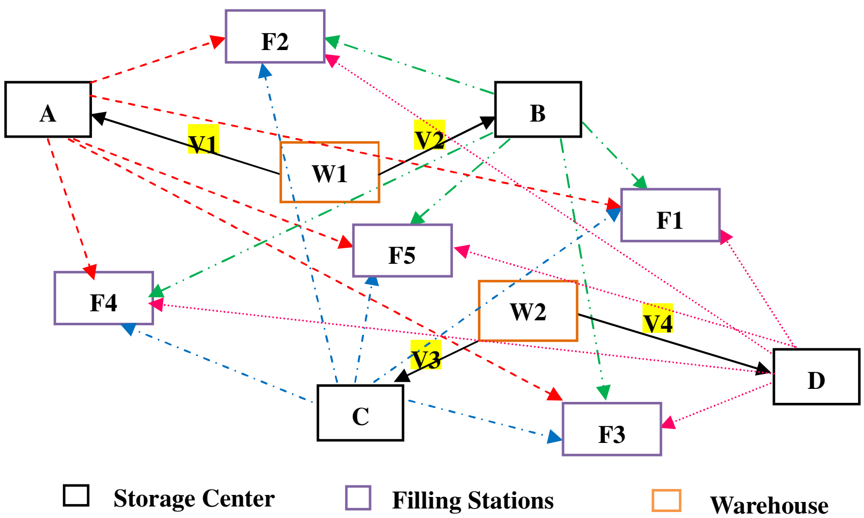

Figure 2, ORC Accessing and Distributing Petroleum Products

The problem of statement can be solved using 0–1 MILP model (Uzar & Catay [7], Onut et al. [8], Avella et al. [9], Dondo et al. [10]). In developing the vehicle route to optimize the cost of accessing and distributing petroleum products these assumption were taken into consideration: the model does not account vehicle delivery delay penalty cost example traffic disruptions, stopover at pervious stations, vehicle breakdowns, loading vehicle with petroleum product etc. Besides, ORC vehicles can access petroleum products from its storage site daily, no limitations to the quantity of product tons vehicle can access and there are no queues at storage site during product loading. Vehicle dispatched from a warehouse after completing its accessing and delivery route cycle can be park at the nearby warehouse and it can be used to deliver any kind of petroleum products. The cost of purchasing the petroleum product is not considered in the cost minimization structure of accessing and distributing the petroleum product. The next paragraph touches on the 0–1 MILP mathematical model, refer to appendix for the nomenclature.

2.1 0–1 MILP Mathematical Model

The 0–1 MILP mathematical model is constructed by combining distances between warehouse, storage sites and filling stations, petroleum products characteristics and demand, vehicle capacity and weight and the cost encompass accessing and distributing petroleum product in e-commerce environment.

$$min \sum_{v=1}^{W1} \{(d_A * n_A * \$0.50) + (d_B * n_B * \$0.45)\} \quad + \quad \sum_{v=1}^{W2} [(d_C * n_C * \$0.6) + (d_D * n_D * \$0.65)] + \sum_{v=1}^{V} \sum_{s=1}^{S} \sum_{z=1}^{Z} \{ \$15 * n_T + (DC_{PV} * D_{SZ})\} \tag{1}$$

Subjected to:

$$\sum_{v=1}^{W1} \sum_{v=1}^{W2} W_V \leq 1 \qquad \forall\, v \in V \tag{2}$$

$$W_V = 1 \qquad \forall\, v \in V \tag{3}$$

$$\sum_{v=1}^{V} WW_{V12} = 1 \qquad \forall\, v \in V \tag{4}$$

$$\sum_{v=1}^{V} WW_{V21} = 1 \qquad \forall\, v \in V \tag{5}$$

$$\sum_{v=1}^{V} XX_{VP} = 1 \qquad \forall\, p \in P \tag{6}$$

$$\sum_{p=1}^{P} (TL_{PVS} * UW_P) \leq \sum_{p=1}^{P} WC_V * DV_{VP} \qquad \forall\, v \in V, \forall\, s \in S \tag{7}$$

$$\sum_{p=1}^{P} (TL_{PVS} * UV_P) \leq \sum_{p=1}^{P} VC_V * DV_{VP} \qquad \forall\, v \in V, \forall\, s \in S \tag{8}$$

$$\sum_{v=1}^{V} TUL_{PZV} \geq \sum_{v=1}^{V} DEM_{PZ} \qquad \forall\, p \in P, \forall\, z \in Z \tag{9}$$

$$Q * NV_{ZV} \geq TUL_{PZV} \qquad \forall\, p \in P, \forall\, v \in V, \forall\, z \in Z \tag{10}$$

$$\sum_{v=1}^{V} NV_{ZV} \leq 1 \qquad \forall\, z \in Z \tag{11}$$

$$NV_{ZV} \leq 0 \qquad \forall\, v \in V, \forall\, z \in Z \tag{12}$$

$$\sum_{v=1}^{V} \sum_{z=1}^{Z} NV_{ZV} \leq 9 \qquad \forall\, v \in V, \forall\, z \in Z \tag{13}$$

$$\sum_{v=1}^{V} \sum_{z=1}^{Z} FFSV_{ZV} = \sum_{v=1}^{V} \sum_{z=1}^{Z} DV_{VP} \qquad \forall\, p \in P \tag{14}$$

$$\sum_{v=1}^{V} \sum_{zp=1}^{ZP} LFSV_{Z'V} = \sum_{v=1}^{V} \sum_{zp=1}^{ZP} DV_{VP} \qquad \forall\, p \in P \tag{15}$$

$$FFSV_{ZV} \leq NV_{ZV} \qquad \forall\, v \in V, \forall\, z \in Z \tag{16}$$

$$LFSV_{Z'V} \leq NV_{ZV} \qquad \forall\, v \in V, \forall\, z \in Z \tag{17}$$

$$F_{VZ'Z} \leq NV_{ZV} \qquad \forall\, v \in V, \forall\, z \in Z \tag{18}$$

Equation set 1 is the objective function of the 0–1 MILP mathematical model and the aim is to minimize the cost of accessing and distributing petroleum products in e-commerce environment over a whole accessing and distribution planning horizon. The cost incurred mainly arises from vehicles distance covered to access and distribute petroleum product and fixed cost. The cost equation comes in three parts, the first two parts covers the cost of accessing petroleum products form storage sites while the last part describes the cost of distributing petroleum products to OMC's various filling station. Constraint set 2 state that vehicles $\boldsymbol{v}$ are dispatched once from warehouse 1 and 2 and that of constraint 3 captures vehicles $\boldsymbol{v}$ starting point that is ORC's warehouses. Constraint sets 4 and 5 describes how vehicles assigned to access and distribute petroleum products ends their route course (for example vehicle dispatched from warehouse *1* ends its routes course at warehouse *2*). Vehicles used to access and distribute petroleum products are vehicles that can accommodate every petroleum product characteristics as shown in constraint 6.

Constraint 7 and 8 states that the total load of vehicle $\boldsymbol{v}$ (i.e. the amount of petroleum product transported by a vehicle) cannot exceed the vehicle maximum volumetric and weight capacity respectively. That of constraint 9 assumes that the total amount of petroleum product $\boldsymbol{p}$ delivered to each filling station z must always satisfy filling station demands. Since $\boldsymbol{TUL_{PZV}}$ is the amount of petroleum product $\boldsymbol{p}$ delivered by vehicle $\boldsymbol{v}$ to filling station z, constraint 10 establishes that the condition that a delivery operation performs by vehicle $\boldsymbol{v}$ at filling station z can only take place if the vehicle $\boldsymbol{v}$ has been assigned to filling station z and $\boldsymbol{Q}$ acts as delivery upper boundary.

Constraint set 11 makes sure that every filling station z can at most be visited by a single vehicle during the planning horizon and the storage sites acts as a pure petroleum product lifting site as captured by constraint set 12. Constraint set 13 ensures that most vehicle $\boldsymbol{v}$ loaded with petroleum products can visit at most nine (9) filling stations while constraint sets 14 and 15 captures the route constraint of vehicles $\boldsymbol{v}$ visiting exactly one filling station first z and exactly one filling station last z' respectively. Constraint sets 16 and 17 state that a single filling station z can be visited first / last by vehicle $\boldsymbol{v}$. Finally constraint 18 state that vehicle $\boldsymbol{v}$ must visit filling station z before visiting filling station z'.

3 SIMULATION ANALYSES AND DISCUSSION

The developed 0-1 MILP model is simulated based on warehouses distance to storage sites, warehouse vehicles types and characteristics, petroleum products characteristics, distance between storage sites and filling stations, and filling station petroleum products demands. The Generalized Algebraic Modeling System (GAMS) software (Rosenthal (2014)) 64-bits, CPLEX 24.3.3 and an Intel (R) Pentium (R) 987 CPU 1.50-GHz, 4.00-GB RAM computer was used to analyze three different cases of accessing and distributing petroleum products to ascertain the robustness of the 0-1 MILP model and tables 1 to 5 capture the assumed parameters used.

Table 1

Warehouse Vehicle Characteristics

	Vehicle Characteristics				
Warehouse 1 & 2 house	Vehicles	Volume (m^3)	Weight (kg)	Loading Products (m^3)	Distance Unit Cost (km/hr)
5 Vehicles (V1-V5)	**V1, V2, V3**	25	20000	6000	0.45
	V4	20	15000	5000	0.38
	V5	18	12000	4000	0.25

Table 2

Distance between Warehouse and Storage Sites

	Storage Sites

Warehouse	A	B	C	D
W1	6	5	-	-
W2	-	-	4	7

Table 3

Petroleum Products Characteristics

	P1	P2	P3	P4
Weight (kg)	3.86	3.03	2.03	4.80
Volume (m^3)	0.015	0.020	0.005	0.030

Table 4

Distance between Petroleum Product Storage Site and Filling Stations

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
A	105	25	115	30	58	77	85	198	295	365	280	188
B	18	33	108	152	28	357	248	146	23	197	305	99
C	125	142	27	44	98	248	121	272	72	303	185	19
D	29	172	17	114	87	72	178	221	34	208	325	08

Table 5

Filling Stations Demand of Refined Petroleum Products

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
P1	1000	800	1500	950	1050	1200	700	900	850	1000	1000	950
P2	1000	1000	700	1450	1000	600	1000	850	650	750	1090	870
P3	900	1200	1100	850	1250	800	950	800	1050	1000	1200	820
P4	1040	850	950	1300	1200	400	1100	1000	800	750	800	800

3.1 Three Cases of Accessing and Distributing Petroleum Products

Case 1

Considers OMC's ordering two petroleum products (gasoline and LPG) in e-commerce environment to be delivered to 10 filling stations.

Strategy: Per OMC demand, ORC can allocate a vehicle each from its warehouses to access and distribute the petroleum products (gasoline and LPG) to the 10 filling stations. The total cost of accessing and distributing OMC's demand is **$1302.90** and the planning route for each petroleum product is shown in figure 3. The strategy satisfies each filling station petroleum product demand leaving a surplus which can be used to fuel vehicles.

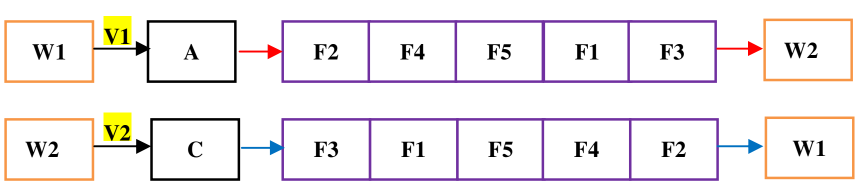

Figure 3, Accessing and distributing Gasoline and LPG

Case 2

Considers OMC's ordering petroleum products (gasoline, gasoil, LPG and kerosene) in e-commerce environment to be delivered to 20 filling stations.

Strategy: In order to fulfill OMC's demand, ORC can allocate two vehicles each from its warehouses, one for each petroleum product (gasoline, gasoil, LPG and kerosene) to access and distribute the petroleum products to the 20 filling stations. The total cost for accessing and distributing the petroleum products is **$7597.40** and the planning route for each petroleum product is shown in figure 4.

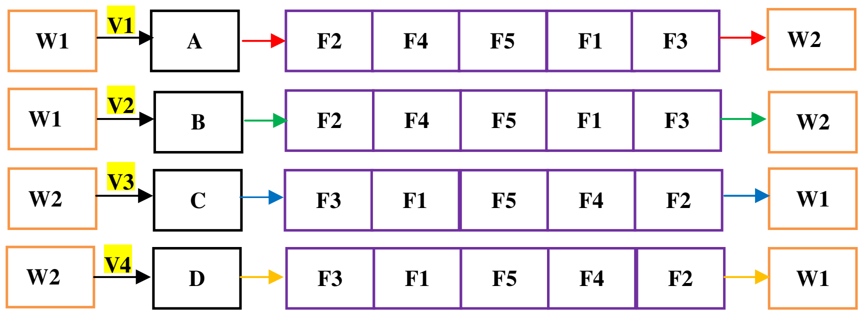

Figure 4, Accessing and Distributing Gasoline, Gasoil, LPG and Kerosene to 20 Filling Stations

Case 3

Considers OMC's ordering petroleum products (gasoline, gasoil, LPG and kerosene) in e-commerce environment to be delivered to 48 filling stations.

Strategy: ORC can satisfy OMC's petroleum product demand by allocating 8 vehicles, four from each warehouse, and two vehicles for each petroleum product (gasoline, gasoil, LPG and kerosene) to access and distribute petroleum product to the 48 filling station. The total cost of accessing and distributing the petroleum products is **$69304.96** and the planning route is shown in figure 5. From figure 5, it can be seen that vehicle **2**, **3**, **6** and **7** finishes their mission by visiting vehicles **1**, **4**, **5** and **8** last filling stations respectively: this is due to insufficient petroleum product delivered by vehicles 1, 4, 5 and 8.

From the three cases analyzed it can be deduced that total cost of accessing and distributing petroleum products increases with increase in OMC's demand. Increasing OMC's petroleum products demand increases the number of filling stations to serve with petroleum products, increases the number of vehicles used by ORC and increases total cost this shows the robustness of the 0-1 MILP model (refer to figure 6). The main cost element that contribute to total cost increment is distance cost between petroleum product storage site and filling stations: nearer distance to filling stations reduces total cost, farer distance to filling station increase total cost and a mixture of nearer and farer distance to filling stations average total cost. That notwithstanding, short distance between petroleum product storage site and filling stations breed extensive development of a particular petroleum product in a specific locality discouraging the development of the same product in other locality.

Besides, the number of filling station to be supplied with petroleum products impact ORC vehicles strategy to minimize the total cost of accessing and distributing petroleum products. In a case where petroleum products demand by OMC is clustered around a storage site, vehicles would be dispatched from a warehouse closer to the storage site to access and distribute the product in order to minimizing total cost. Finally, the advantages amassed by ORC using the internet to sell their product may face a major setback if strategies used to access and distribute petroleum products are not well integrated into it. ORC can integrate their accessing and distributing petroleum product into the internet pace of running business by considering: (i) researching into shorter distance routes from storage sites to filling stations and (ii) ORC and OMC's investing into accessing and distribution automation system using pipelines. Such project are capital intensive in its initial stages but less costive in long run.

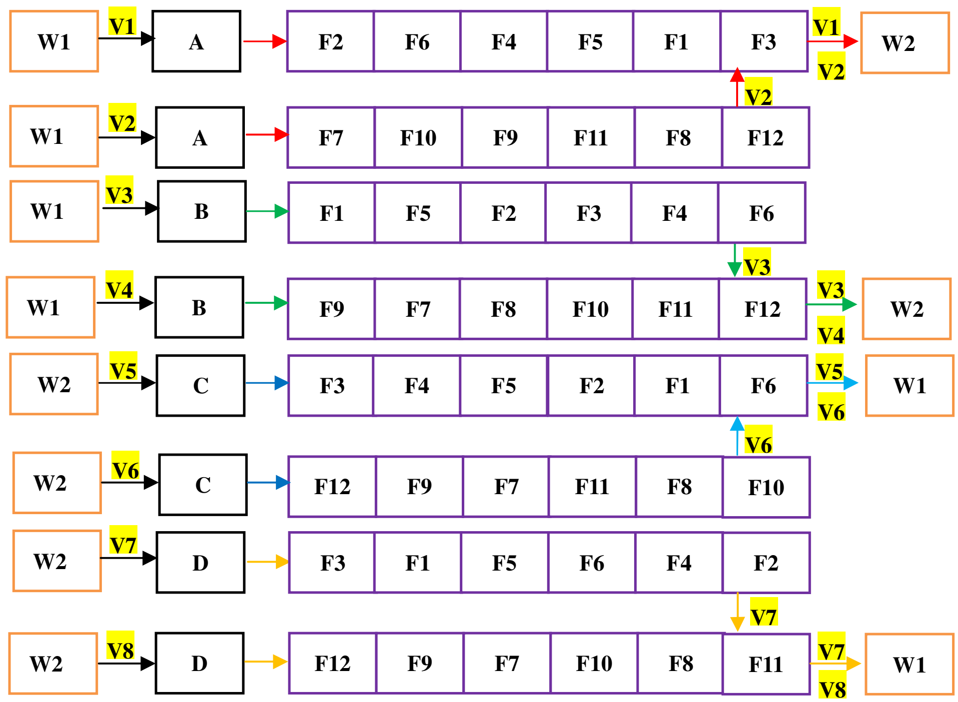

Figure 5, Accessing and Distributing Gasoline, Gasoil, LPG and Kerosene to 48 Filling Stations

4 CONCLUSIONS

Inefficient transportation scheduling can dent the advantages of shopping for a product online. Several studies have suggested ways of optimizing vehicles distribution scheduling in e-commerce environment but this paper seeks ways to minimize the cost of accessing and distributing petroleum products in e-commerce environment. The statement of problem was solved using 0-1 mixed integer linear programming model (Uzar & Catay [7], Onut et al. [8], Avella et al. [9], Dondo et al. [10]) by taken certain assumptions into consideration. GAMS was used to analyze three different scenarios to ascertain the robustness of the 0-1 MILP model. In solving the three scenarios, three different strategies were applied to minimize the cost of accessing and distributing petroleum product in e-commerce environment. OMC's demand increment, increases vehicles used to access and distribute product whereas distance between storage site and filling stations impact implicitly on total cost. In order to improve customers' satisfaction ORC needs to vigorously integrate vehicles accessing and distribution scheduling plan with e-commerce pace. The limitation of this paper may be traced to the 0-1 MILP model assumption taken and vehicle and distance parameters assumed variables. Because any change in the assumption and the assumed parameters variable may alter the total cost value and tilt the explanation. In term of future research, research can be conducted by expanding the 0-1 MILP assumptions (for example including cost of delay penalty, vehicle breakdown cost, limitation of product availability due to product shortages, etc.) to verify its robustness.

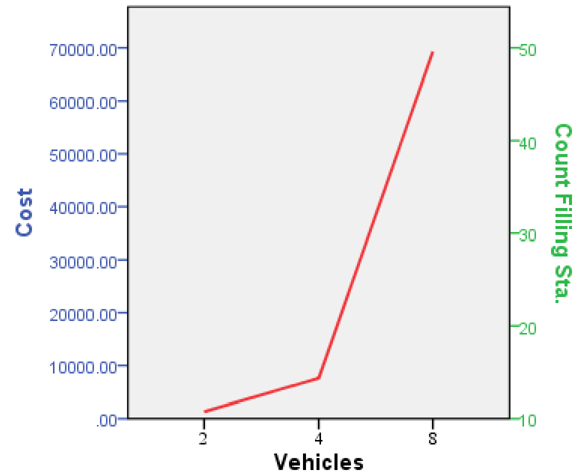

Figure 6, Increasing OMC's Petroleum Products Demand

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Appendix 1

Nomenclature

Subscripts

$z, z^{'}$	nodes
$p, p^{'}$	products
$v, v^{'}$	vehicles
s	petroleum product storage site
w	warehouse

Sets

P	sets of petroleum products
V	sets of vehicles
W	sets of warehouses
Z	sets of filling stations
S	sets of storage sites

Parameters

VC_V	vehicle ***v*** volume capacity
WC_V	vehicle ***v*** weight capacity
$D_{ZZ^{'}}$	distance between filling station ***z*** and ***z'*** in kilometers
DEM_{PZ}	demand of petroleum products ***p*** at various filling stations ***z***
DC_{PV}	unit distance cost for delivery petroleum products ***p*** using vehicle ***v***
TL_{PVS}	total amount of petroleum product ***p*** loaded on vehicle ***v*** at storage site ***s***
TUL_{PZV}	total amount of petroleum product ***p*** unloaded at filling station ***z*** from vehicle ***v***
UV_P	unit volume of petroleum product ***p***
UW_P	unit weight of petroleum product ***p***
Q	upper boundary of constraint

Binary Variable

W_V	set of vehicles v housed at oil refiner company warehouse
DV_{VP}	variable denotes vehicle ***v*** is used for delivering petroleum products ***p***
$LFSV_{Z^{'}V}$	variable determines that filling station ***z'*** is the last filling station vehicle ***v*** visited
$FFSV_{ZV}$	variable determines that filling station ***z*** is the first filling station vehicle ***v*** visited
$F_{VZ^{'}Z}$	variable denotes vehicle ***v*** visited filling station $z^{'}$ after visiting filling station ***z***
NV_{ZV}	variable determines that first filling station ***z*** is visited by vehicle ***v***
$NV_{Z^{'}V}$	variable determines that last filling station ***z'*** is visited by vehicle v
WW_{V12}	variable denotes vehicle ***v*** was dispatched from warehouse ***1*** and parked at warehouse ***2*** after completing its delivery cycle
WW_{V21}	variable denotes vehicle ***v*** was dispatched from warehouse ***2*** and parked at warehouse ***1*** after completing its delivery cycle
XX_{VP}	variable denotes vehicle ***v*** can be used to deliver any petroleum product ***p***