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Enhancing Supply Chain Upstream Management Efficiency and Cost Reduction for a Saudi Electronics Company

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***Abstract*— This paper presents an appropriate linear model for the examination and for the scheduling of electronic appliances transportation through Inland and Seaport networks. The primal goal of this paper is to present a linear operations research model for Saudi Electronics Appliances distributor to minimize shipping costs. Actual costs are given from freight forwarders and Inland transporters in Saudi Arabia. Freight forwarders are cost-sensitive. So, freight forwarders are more conservative in their port choice decisions and how attractive is the port in terms of costs. The schedule that meets Supply and Demand of Home Appliances (Specific Television Brand) is targeted. The problem has been formulated as a linear model; Tora for windows software version 2.0, 2006 is used as a solving tool. The obtained solution are tested and validated. The presented methodology has been found practical and expected to improve transport economics.**

Keywords—Inland Transportation; Forewarder Cost; Warehouse; Seaport; Stage point; Distribution.

I. INTRODUCTION

Haralambides (2019) stated that shipping accounts for some 90% of world trade and that freight rates is based on geographical distance and port costs [1].

According to United Nations Conference on Trade and Development (2019), Container ships are measured in twenty-foot equivalent units (TEUs) and recent vessels introductions range between 20,000 to nearly 24,000 TEUs, up to 4000 meters long [2]. According to the source, the international container port traffic in 2018 accounted for a volume of 11 billion tons. 64% of Container traffic was for Asia, 16% for Europe, 8% for North America, 7% for Latin America and the Caribbean, 4% for Africa and 2% for Oceana. Liner ships comprise container and roll on roll off vessels, carrying about 60 % of freight by value globally each year.

According to Saudi Port Authority (2024), in its geopolitical region, Saudi Arabia has the largest port network with 10 commercial seaports, 291 berth, yearly capacity of 15K ships, loading 1.1 Billion Tons, and a throughput of 13 Million TEU containers [3].

Jeddah Islamic Port is the largest with a 65 % of the Kingdom's freight capacity. Jeddah is a hub port for 9 scheduled routes connecting Far East, Mediterranean, the Gulf/Eastern Mediterranean, Indian Subcontinent, and North American ports. Also, Dammam Seaport plays a significant role in the container shipping industry and is considered the largest seaport for Containers capacity in Saudi Arabia after Jeddah Islamic Port. Dammam Seaport has a direct railway connection with the Dry Port in the capital Riyadh.

Highlighted by Talley and Ng (2013), shippers generate the cargo routes that starts the trade and transport flow, freight forwarders are intermediary agents contracted by the former to manage their shipments [4]. As per Rezaei et al. (2019), Freight forwarders decision regarding the route used are based on; Total cost, Inland transit time, Maritime Transit Time, and frequency of inland lines [5].

In this paper, the case company is responsible for managing and distributing home appliances brands such as TCL, Hoover, Galanz, Dreame, Panasonic and Vestel in the Saudi market. As per BlueWeave Consulting website (2024), Saudi Arabia Home Appliances Market size was estimated to be worth USD 2.84 billion in 2023. Any disruptions or inconsistencies in the early sourcing of such products potentially cause delays, increase costs, or impact quality as distribution moves downstream. This study focuses on the initial stages of the company supply chain, starting from the planning, logistic operations, clearance and warehouse receiving.

A. Forwarder Performance

Freight forwarders act as a key link to facilitate seamless international transport for the supply chain at optimal costs. Freight forwarders arrange all modes of transport like ocean freight, air cargo, and road/rail to move goods internationally. This ensures seamless cargo movement. Forwarders prepare all customs and trade compliance documents like commercial invoices, packing lists, certificates of origin and other services on behalf of shippers. Freight Forwarders help in analyzing and managing the cost of transporting goods to different markets. In addition, Freight forwarders helps in optimizing freight costs and finding ways to reduce transportation expenses while maintaining service levels. Moreover, Freight forwarders helps to navigate trade regulations, tariffs, and necessary clearances for smooth customs clearance of goods.

B. Shipping and Freight Rates

There are several factors that influence shipping and freight rates, such as the distance, weight, size, mode of transportation, and any additional services required. By paying close attention to shipping and freight rates, supply chain managers can make informed decisions to optimize costs, improve delivery times, and enhance overall operational efficiency.

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One of the key roles in the supply chain is the transportation Cost Reduction; by optimizing shipping routes, consolidating shipments, and negotiating favorable freight rates, businesses can achieve substantial savings in transportation costs.

By incorporating multiple ports into their supply chain strategy, businesses can enhance flexibility, reduce risks, optimize costs, and ensure a smooth flow of goods, ultimately boosting their overall competitiveness in the market. The case company is using Dammam and Jeddah ports as the receiving seaports in Saudi Arabia.

II. MODEL FORMULATION

The Case Home Appliances Distribution Company is facing the challenge of high shipping and transportation costs, which impact on the budget and result in unnecessary expenses. The current shipping costs are affecting the overall financial performance of the company.

The problem revolves around the need to address the issue of the avoidable shipping and transportation costs. These costs can be avoided or reduced by implementing strategies to optimize the shipping process and identify more cost-effective solutions that still meet the company's delivery requirements.

This paper goal is to find a solution to reduce these shipping costs and optimize the company's budget. By identifying strategies and implementing linear programming to minimize expenses without compromising the quality of logistics process and delivery timelines. The objective of this paper is to find ways to reduce these expenses and optimize the case company's finances for better overall performance.

This paper considers techniques to determine the best scenario for distributing the 40" feet containers between Jeddah and Riyadh warehouses, specifically for TCL Televisions. A linear operations research model that minimizes total shipping cost subjected to demand and supply constraints is expected to be formulated. See Fig. 1 below.

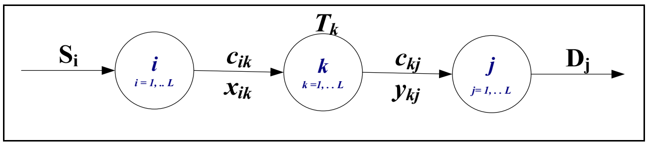

Fig. 1. *Case Company transportation network composed of (L) Origins/Destinations*

Based on AL-Tahat et al. contributions to operations research, The following notations are used when formulating the model [7],[8]:

L Total Number of origins/destinations in the network

I Origin shipment seaport index, i= {1, 2, . . . L}

K Receiving seaport city index, k= {1, 2, . . . L}

J Destination city warehouse index, j= {1, 2, . . . L}

c_{ik} Forwarder Shipping cost in USD per 40 feet container (FEU), traveling from origin city seaport (i) to Receiving city seaport (k).

c_{kj} Inland Transportation cost in USD per 40 feet container (FEU), travelling from Receiving city seaport (k) to destination warehouse (j)

x_{ik} Number of containers (FEU) traveling from origin city seaport (i) to receiving city seaport (k)

y_{kj} Number of containers (FEU) traveling from receiving city seaport (k) to destination city warehouse (j)

S_i Supply at each pure supply node (i),

T_k Received quantity at each Receiving seaport (k)

D_j Demand at each warehouse demand node (j)

Accordingly, the objective function (z) and the model constraints are represented as follow:

$$\text{Min } Z = \sum_{i=1}^{L}\sum_{k=1}^{L} c_{ik}x_{ik} + \sum_{k=1}^{L}\sum_{j=1}^{L} c_{kj}y_{kj} \quad (1)$$

$$\sum_{k=1}^{L} x_{ik} = S_i \quad \forall\, i = 1,2,3,\ldots.L \quad \text{(Supply Constraint at Origin)} \quad (2)$$

$$\sum_{i=1}^{L} x_{ik} = T_k \quad \forall\, k = 1,2,3,\ldots.L \quad \text{(Receiving seaport Constraint)} \quad (3)$$

$$\sum_{k=1}^{L} y_{kj} = D_j \quad \forall\, j = 1,2,3,\ldots.L \quad \text{(Receiving Warehouse Constraint at destination)}(4)$$

$$\sum_{i=1}^{L} x_{ik} - \sum_{j=1}^{J} y_{kj} = 0 \quad \forall\, k = 1,2,3,\ldots.L \quad \text{(Network Balancing)}(5)$$

Where;

$$x_{ik}, y_{kj} \geq 0 \quad \forall\, i,k,j$$

III. TCL TELEVISION CASE STUDY

The case distribution company is the sole distributor of TCL Televisions. The first attempt is to gather the forecasted sales from the planning department. These inputs will be used in the later stages of the linear programming analysis. 50% of the sales are fulfilled via Riyadh and 50% is fulfilled by Jeddah warehouse. The Forecasted demand for a year is 100 40" feet Containers.

Table I shows all different feasible scenarios for the shipping of the containers to Jeddah warehouse or to Riyadh warehouse. Four scenarios are feasible for the shipment going to Jeddah warehouse. In scenario 1, the shipment goes directly to Jeddah. In scenario 2, the shipment goes to Riyadh and then to Jeddah. In scenario 3, the shipment goes to Dammam and then to Jeddah. Lastly, in scenario 4, the shipment goes to Dammam, then Riyadh, and finally to Jeddah. Similarly, the possible scenarios for shipping to Riyadh warehouse are; Scenario 5 is direct shipping to Riyadh, scenario 6 is shipping to Jeddah and then to Riyadh, and scenario 7 is shipping to Dammam and then to Riyadh. See Fig. 2 for the possible transportation scenarios.

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TABLE I. ALL POSSIBLE SCENARIOS FOR SHIPPING FROM CHINA TO SAUDI ARABIA STAGE POINTS WAREHOUSES IN JEDDAH AND RIYADH

All Possible Scenarios - DOE					
Scenarios (JEDDAH)			Scenarios (RIYADH)		
SC#1	-	JED	SC#5	-	RIY
SC#2	RIY	JED	SC#6	JED	RIY
SC#3	DAM	JED	SC#7	DAM	RIY
SC#4	DAM – RYD	JED			

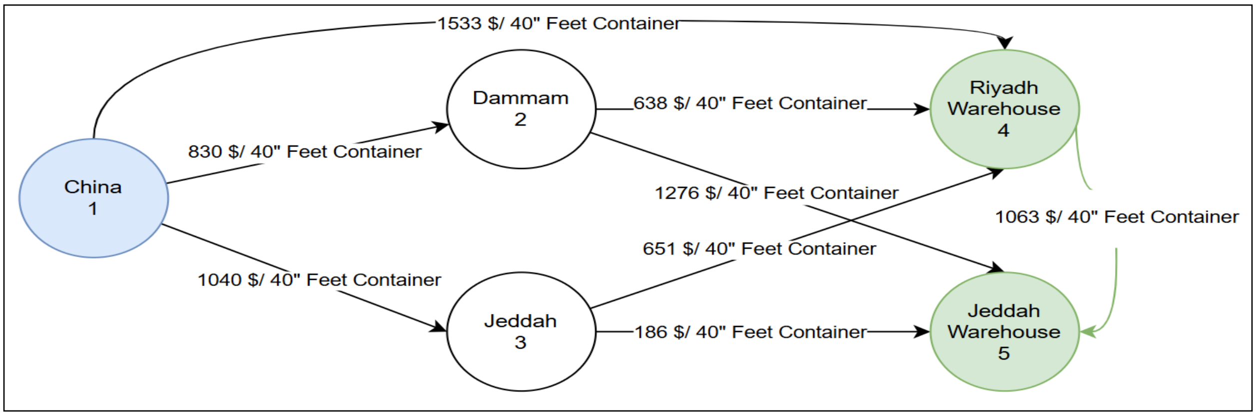

Fig. 2. *Saudi Home Appliances Transportations Network*

The Forwarder shipping cost (c_{ik}) will vary based on which option is chosen. Shipping one container from China to Jeddah costs $1040, while shipping to Riyadh, including transportation, costs $1320, and shipping to Dammam costs $830. See Table II below.

TABLE II. ALL POSSIBLE FORWARDER SHIPPING OPTIONS TO SHIP TO JEDDAH, RIYADH AND DAMMAM SEAPORTS

FREIGHT - Shipping line (c_{ik})	
CHINA TO JED (1-3)	**$ 1,040.00**
CHINA TO RIY (INCLUDING TRAINS) (1-2-4)	**$ 1,533.00**
CHINA TO DAM (1-2)	**$ 830.00**

Farha Transportation is the local transportation company that ships the shipments from Jeddah, Riyadh, and Dammam. The Inland transportation cost (c_{kj}) for each transportation option differ, as shown in table 4. The cost of transporting one container from Jeddah port to Jeddah warehouse is $186, while the cost of transporting one container from Jeddah to Riyadh is $651. The cost of transporting one container from Dammam port to Riyadh is $638. See Table III below. Table IV shows the decision variables (represented as x_1, x_2, x_3, …,x_7) for each scenario. The goal is to identify the most optimal option for the company's shipping process, ensuring efficient and cost-effective operations.

TABLE III. ALL POSSIBLE INLAND TRANSPORTATION OPTIONS TO SHIP TO JEDDAH AND RIYADH STAGE POINTS

INLAND TRANSPORTATION COST– FARHA (c_{kj})		
FROM / TO	JED WAREHOUSE (5)	RIY WAREHOUSE (4)
JED (3)	$ 186.00	$ 651.00
RIY WAREHOUSE (4)	$ 1,063.00	NA
DAM (2)	$ 1,276.00	$638.00

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TABLE IV. ALL POSSIBLE SCENARIOS FOR INLAND AND FORWARDER SERVICES

Decision Variables			
Number of containers in Scenario #1	x_1	$c_{13}x_{13} + c_{35}y_{35} = 1040x_{13} + 186y_{35}$	$1,226\ x_1$
Number of containers in Scenario #2	x_2	$c_{14}x_{14} + c_{45}y_{45} = 1320\ x_{14} + 1063y_{45}$	$2,383\ x_2$
Number of containers in Scenario #3	x_3	$c_{12}x_{12} + c_{25}y_{25} = 830x_{12} + 1276y_{25}$	$2,106\ x_3$
Number of containers in Scenario #4	x_4	$c_{12}x_{12} + c_{24}y_{24} + c_{45}y_{45} = 830x_{12} + 638y_{24} + 1063y_{45}$	$2,531\ x_4$
Number of containers in Scenario #5	x_5	$c_{14}x_{14} = 1533x_{14}$	$1533x_5$
Number of containers in Scenario #6	x_6	$c_{13}x_{13} + c_{34}y_{34} = 1040x_{12} + 651y_{25}$	$1691x_6$
Number of containers in Scenario #7	x_7	$c_{12}x_{12} + c_{24}y_{24} = 830x_{12} + 638y_{25}$	$1468x_7$

Table V shows the capacity constraints. In the first constraint, the total units shipped in all scenarios equals to the total supply. For the second constraint, LHS of the variables X_1, X_2, X_3, and X_4 amount equals to the demand of Jeddah warehouse.

Similarly, the third constraint was for Riyadh which have X_5, X_6, and X_7. Moreover, the rest of the constraints are the non-negativity.

TABLE V. ALL CONSTRAINTS OF THE OBJECTIVE FUNCTION

Constraints – OR				
# of constraint	**Left hand side**	**Inequality**	**Right hand side**	**Description**
#1 (TOTAL DEMAND)	**100**	=	**100**	**$X_1+X_2+X_3+X_4+X_5+X_6+X_7$ = TOTAL DEMAND**
#2 (JED)	**50**	=	**50**	**$X_1+X_2+X_3+X_4$ = (TOTAL JED DEMAND)**
#3 (RIY)	**50**	=	**50**	**$X_5+X_6+X_7$ = (TOTAL RIYADH DEMAND)**
#4 (NON - NEG)	**50**	>=	**0**	**X1 >= 0**
#5 (NON - NEG)	**0**	>=	**0**	**X2 >= 0**
#6 (NON - NEG)	**0**	>=	**0**	**X3 >= 0**
#7 (NON - NEG)	**0**	>=	**0**	**X4 >= 0**
#8 (NON - NEG)	**0**	>=	**0**	**X5 >= 0**
#9 (NON - NEG)	**0**	>=	**0**	**X6 >= 0**
#10 (NON - NEG)	**50**	>=	**0**	**X7 >= 0**

The numerical objective function (z) and the model constraints are represented as follow:

$$\text{Min } Z = 1226x_1 + 2383x_2 + 2106x_3 + 2531x_4 + 1533x_5 + 1691x_6 + 1468x_7 \quad (9)$$

$$x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 = 100$$
$$x_1 + x_2 + x_3 + x_4 = 50$$
$$x_5 + x_6 + x_7 = 50 \quad (10, 11, 12)$$

$$x_{1,2,3,4,..,7} \geq 0 \quad (13)$$

A. Results

Using Tora for Windows, the optimum distribution of containers for each warehouse was determined. After considering the objective function of the minimum cost, the final cost is determined to be $134,700. Both Jeddah and Riyadh warehouses requires 50 containers each, as shown in the decision variable. For Jeddah, the best solution is scenario 1, where the shipping line directly ships the containers to Jeddah port and then Farha Transportation handles the transportation to the warehouse in Jeddah. Similarly, for Riyadh, the optimal solution is scenario 7, where the shipping line transports the shipment to the Dammam port, and then Farha Transportation delivers the shipment to the warehouse in Riyadh.

As per the company, the method of modeling the problem as a Linear Programming problem and solving it via Operations Research optimization techniques has proven to make a significant difference in terms of cost savings and efficient delivery times. This systematic technique has enabled the company to overcome challenges related to high shipping and transportation costs.

IV. Conclousions

The presented methodology succeeding on creating a route matrix between Home Appliances Manufacturer and a Saudi Electronics Distributor with the minimum costs. An operations research model with single objective is developed. Results is found to satisfy customer's needs. Tora for windows version 2 is used to finalize the solutions. Validity of solutions has been upraised when the obtained solutions discussed with the case electronics distributor logistics manager, and when model output compared with historical data under similar input conditions, it has been found that the optimal transportation cost; Subject to supply constraints is satisfied, Similarly, supply and demand of the Manufacturer and the Distributor stage points in Riyadh and Jeddah is checked and found to be satisfied.

A linear operations research model is used for the generation of the solution of the capacitated distribution network routing problem, yielding to the minimum transportation costs. The developed model with an objective to minimize the total transportation costs relying on the number of 40' feet Containers shipped per route as decision variables, the constraint parameters are: the forecasted demand at each stage point, the freight forwarder costs, the Inland Transportation costs, and the supply at the Manufacturer node.

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Conflicts of Interest: The authors declare no conflict of interest.

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