Modelling Logistic Decision-Making Optimization Techniques: A Longitudinal Study of the Seaport of Aqaba

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***Abstract*—Through a correlative comparative analysis, the purpose of this study is to utilize LP and the data accumulated between (2009 - 2017) to investigate the optimality of the current transportation strategy of actual costs to transport major Jordanian exports and imports. Study findings reveal that current exporting and importing strategies are ineffective. Results assert that decision-makers have not developed nor have taken the required action needed to resolve excessive expenditures. The current study poses some implications and recommendations as a strategic technique within decision-making paradigms to utilize effective decision making to minimize transportation costs.**

Keywords*—linear programming, transportation, optimization, shipping route, logistics, Aqaba seaport, Jordan.*

1. Introduction

Nowadays, the existence of a highly competitive environment has forced organizations and countries alike to re-evaluate their transportation strategies to meet economic pressures and challenges. With the consistent drop in the world economy, countries and organizations alike ought to re-examine and revise their operational strategies to increase their efficiency through shrinking costs and increasing profits [1]. The countries that face the hardest challenge are both developing and undeveloped countries as they own relatively meek resources. Such countries' main resource is the export and import industry. Although these countries possess a noticeable dearth in natural resource, this dearth can be significantly improved if the problem was tackled utilizing proper decision-making methods (i.e. re-examining current transportation strategies.) Hence, the current study is an extended study highlighting the shortage of resources in a developing country (i.e. Jordan).

Jordan is one of the developing countries that experience an ongoing dearth of resources especially natural ones. Nonetheless, the country tries to stay up to date with the requirements of the modern world and the development that comes with it, whether economically, politically, technologically, or even socially. Although the country is known as one of the smallest economies in the Middle East, Jordan includes several organizations that may enhance its economic background and status if proper strategies were applied. Among these organizations is the Aqaba Development Corporation (ADC) which owned Aqaba only seaport of Jordan. The port connects the country to several continents; namely, Asia, Africa and Europe. Despite certain obstacles and the port's narrow capacity, the economy succeeded in achieving certain growth rates. However, these growth rates remain below required ones due to certain structural imbalances that brought sectorial contributions to gross domestic product [2]. The port exports five major products (i.e. Raw Phosphate, Raw Fertilizers, Raw Potash, building materials, and General Cargo) and imports ten different types of product categories (i.e. Consumer Goods, Capital goods, Durable goods, crude oil, general Cargo, Construction materials, Pharmaceutical preparations, Other commodities, Government supplies). These products are shipped to eleven different geographical regions. This study utilizes LP and other transportation algorithms to find the most effective sea transportation routes between the port of Aqaba and global destinations. In other words, the techniques employed here are to find the least cost model of transportation or transshipment.

The significance of the current study lies in the dearth of empirical studies in the field of transportation problems in a developing country;

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namely, Jordan. The research is one of the few researches to utilize LP methods to evaluate the effectiveness of the shipment industry in Jordan. This study; thus, aims at recognizing the efficient and inefficient shipping routes, and the remedial action that would make an inefficient shipping route relatively efficient. The results of this study would be of great knowledge to policy and decision-makers, Aqaba private zone managers, academics, researchers and the public and private economic and shipping sector in general. It is also important to recall the caution made by [1] concerning developing countries economics which reads as “the most vulnerable economies that face acute logistical challenges and high transport costs hindering their market access and driving up their transport costs and import expenditure”. The current study employs linear programming (LP) as a form of analysis to investigate the current logistical transportation network to identify the best optimal transport pathways.

The next section presents a brief literature review. Followed by research methodology. The paper presents the results and discussion. In the last section, the paper provides conclusions, recommendations and implications.

2. Literature Review

Transportation problem (TP) is a special case of LP. It is used to determine how many units of goods to be shipped from each supply origin to different demand destinations to optimize total transportation cost. Ref. [3] originated the transportation problem using LP model. Afterwards, Ref. [4] applied the simplex method to solve the standard LP formulation of TP. Ref. [5] state that "LP is one of the most widely and successfully used optimization methods in real-world problems". Ref. [6] point out that (TP) is a special case of LP that has linear constraints for capacity limitations and demand requirements. They assert that the main goal of the transportation problem is to minimize the transportation cost of transporting commodities from sources to sinks. Thus, potentially shedding expenses and reducing cost. According to [7] up to 90 per cent of the world's trade is held by the international shipping service. Thus, the operation of the shipping industry highly influences the world economy which justifiably spots light on it and attracts extensive research. Shipping is a highly effective goods transportation mean of large quantities to various continents. To meet the market demand, shipping corporations invest huge capital in new ships to stay updated. These vessels are seen as a physical resource to increase the corporations' capabilities. According to [8], an organizational capability is a "firm's capacity to deploy resources for the desired end result." Thus, developing the organization's capability will positively influence corporations increasing their competitive advantage in the economic market.

Yet, with the increase of vessels in the industry, scheduling has become problematic. Thus, the importance of non-physical resources (i.e. optimizing and improving shipping methods) comes in as a major concern to corporations. LP can aid managers to find the best scheduling solution and offer data on the importance of supplementary resources [6]. Ref. [9] investigates the optimality of existing actual costs to transport the major Jordanian exports and imports. He concludes that strategies underpinning exports and imports of major products are ineffectual. Ref. [10] investigate optimal production cost of raw materials to its production output using LP to optimize its monthly production output. Ref. [11] state that physical distribution is one of the key functions in logistics systems. It is a very costly function, especially for the distribution industries. They developed a mixed-integer linear programming model to improve and reduce the cost for the multi-product, multi-depot periodic distribution problem. To maximize profit, Ref. [12] investigate the impact of LP in the entrepreneur decision-making process. They conclude that such firms should focus on the impact of LP in the entrepreneur decision-making process as an optimization technique for maximizing profit with the available resources. Ref. [13] developed several LP models to aid the management of General Electric company to allocate its shipping to over 17 different trucking companies. Ref. [14] indicate that in many companies, costs of inventory, transportation and distribution fill the greatest portion of the total cost. Ref. [15] apply LP model to determine the optimum transportation cost in a Malaysian Trading Company. They indicate that LP is an alternative decision tool available to engineers and managers alike in ensuring their operations are conducted effectively at the lowest cost possible and consequently maximize the company's profit.

Critical review of transportation literature indicates that scholars [16]-[27] & [13]

acknowledged the significant of LP in minimizing total transportation cost of general cargo, scheduling, truck loading, seaport shipment, vehicles routing and raw materials in manufacturing system from origins to destinations.

3. Methodology

Data for this study has been collected from the ministry of transportation [28] and the department of statistics websites [29]. However, shipping costs were retrieved from various shipping companies. The average of nine years (2009-2017) from both exports and imports products has been obtained to estimate supply and demand quantities for each type of product. These averages are used as projections or forecasts for the next period starting from 2018. Excel solver V2018 was utilized to resolve various LP to optimize both the exporting and importing of products from and to Jordan. Ref. [24] indicate that Excel solver is a powerful spreadsheet tool for handling linear and nonlinear optimization problems. To achieve the objective of this study, the author formulated four-LP mathematical models' (i.e. export transportation model, import transportation model, export transshipment model, and import transshipment model) as follows:

3.1 Exports and imports transportation models

The transportation problem suggests that there is a direct route between origin i to destination j. In this problem from Aqaba seaport as an origin to eleven destinations. As stated earlier, there are five major products (i.e. Raw Phosphate, Raw Fertilizers, Raw Potash, building materials, and General Cargo) transported to destinations (i.e. Eastern world, Southwest Asia, Oceania, Gulf countries, East-African, Northwest Africa, Western Europe, Eastern Europe, Eastern Mediterranean, USA & Canada, and American countries). Therefore, the general LP model for export from Aqaba seaport to the eleventh destinations is:

$$Min\ TCE = \sum_{i=1}^{5} \sum_{j=1}^{11} c_{ij} x_{ij} \qquad (1)$$

S.T:

$$\begin{cases} \sum_{j=1}^{11} x_{ij} \leq \bar{x}_{ij} \\ 1 \leq i \leq 5 \\ x_{ij} \geq 0 \end{cases} \qquad (2)$$

Where:

- x_{ij} = the amount (tons) of commodity i shipped to destination j
- c_{ij} = the cost of transportation of product i to destination j
- $\bar{x}_{ij}$ = the average quantity shipped during the years 2009-2017 for the product i to destination j

As such the port receives ten different types of product categories (i.e. Consumer Goods, Capital goods, Durable goods, crude oil, general Cargo, Construction materials, Pharmaceutical preparations, Other commodities, Government supplies). These products are shipped to Aqaba seaport from eleven destinations (i.e. Eastern world, Southwest Asia, Oceania, Gulf countries, East-African, Northwest Africa, Western Europe, Eastern Europe, Eastern Mediterranean, USA & Canada, and American countries). Subsequently, the general LP model for imports transportation to Aqaba seaport from the eleventh destinations is:

$$Min\ TCE = \sum_{i=1}^{5} \sum_{j=1}^{11} c_{ij} x_{ij} \qquad (3)$$

S.T:

$$\begin{cases} \sum_{i=1}^{10} x_{ij} \leq S_j \\ 1 \leq j \leq 11 \\ \sum_{j=1}^{11} x_{ij} \geq D_i \\ 1 \leq i \leq 10 \\ x_{ij} \geq 0 \end{cases} \qquad (4)$$

Where:

- x_{ij} = the amount (tons) of product i shipped from destination j to Aqaba port
- c_{ij} = the cost of transporting one ton of imported product i from the destination j to Aqaba seaport
- S_j = the supply limit transported from the destination j
- D_i = the demand limit for the product i

3.2 Exports and imports Transshipment Models

A transportation model deals with the commodities shipping from several supply points (origins) to several demand points (destinations). Ref. [30] states that "A transshipment problem allows shipment between supply points and between demand points, and it may also contain transshipment points through which goods may be shipped on their way from a supply point to a demand point". Indeed, transshipment model was first introduced by [31] as a unique development to

transportation model to allow transshipment point. In this research, a supply point is a point that send goods to another point, and a demand point is a point that can receive goods from other points only, a transshipment on the other hand, is a point that can both receive goods from other points and send goods to others [32], [9]. To find the optimal solution to a transshipment problem, the author defined some transshipment midpoints to provide imports and exports from and to Aqaba seaport. These transshipment midpoints are as follows: First, Mumbai port in India is chosen as a first demand point to receive Jordanian exports and send them to the Eastern world, Southwest Asia, Oceania. Second, Yanbu' Al Bahr port Saudi Arabia is chosen as a second demand point which, inter alia, can send goods from Jordan to the Eastern world, Southwest Asia, Oceania, Gulf countries, East-African. The Port of Alexandria, Egypt as a third demand point to receive export goods from Aqaba seaport and send them to East-African, Northwest Africa, Western Europe, Eastern Europe, Eastern Mediterranean. Port of Rotterdam as a fourth demand point to receive export goods from Aqaba seaport and send them to Western Europe, Eastern Europe, USA & Canada, and American countries. Port of New York as a fifth demand point to receive export goods from Aqaba seaport and send them to the USA and the Rest of American countries.

consequently, the general LP model of a transshipment problem exports from Aqaba seaport is:

$$Min\ TCE = \sum_{j=1}^{5}\sum_{i=1}^{5} c_{ij}x_{ijk} + \sum_{i=1}^{5} c_{ijk}x_{ijk} + \sum_{j=1}^{5} c_{ijk}x_{ijk} + \sum_{k=1}^{11} c_{ijk}x_{ijk} \quad (5)$$

S.T:

$$\begin{cases} \sum_{i=1}^{5} x_{ijk} = MD_j \ for\ 1 \le j \le 5 \\ \sum_{j=1}^{5} x_{ijk} = FD_k \ for\ 1 \le k \le 11 \\ \sum_{i=1}^{5} x_{ijk} - \sum_{k=1}^{11} x_{ijk} \ for\ 1 \le j \le 5 \\ x_{ijk} \ge 0 \end{cases} \quad (6)$$

Where:

- x_{ijk} = the amount of the commodity i shipped from Aqaba seaport through the demand point j to destination k
- c_{ij} = the cost of transportation of commodity i to midpoint j
- c_{ijk} = the cost of shipping the commodity i from midpoint j to destination k
- MD_j = the demand at the midpoint j
- FD_k = the demand at the destination k

Subsequently, the general LP model of a transshipment problem imports from the five midpoints to Aqaba seaport is:

$$Min\ TCE = \sum_{i=1}^{10}\sum_{j=1}^{5}\sum_{k=1}^{11} c_{kij}x_{ijk} + \sum_{i=1}^{10}\sum_{j=1}^{5} c_{ijk}x_{ijk} \quad (7)$$

S.T:

$$\begin{cases} \sum_{k=1}^{11} x_{ijk} \ge MD_{ij} \ for\ i \in \{1,\dots,10\}\ and\ j \in \{1,\dots,5\} \\ \sum_{k=1}^{11} x_{ijk} \ge FD_i \ for\ i \in \{1,\dots,10\} \\ \sum_{k=1}^{11} x_{ijk} - \sum_{j=1}^{5} x_{ijk} \ for\ 1 \le i \le 10 \\ x_{ijk} \ge 0 \end{cases} \quad (8)$$

Where:

- x_{ijk} = the amount of the commodity i shipped from starting point k through the midpoint j to Aqaba seaport
- c_{ij} = the cost of transportation of commodity i from starting point k to midpoint j
- c_{ijk} = the cost of shipping the commodity i from starting point k through midpoint j to Aqaba seaport
- MD_j = the midpoint j demand for the commodity i
- FD_k = the final destination's demand for the commodity i

4. Data Analysis

As stated earlier, Excel solver was utilized to find the optimal solution results for the four-models developed earlier. First, the calculation of export transportation has resulted in a total transportation cost of (247485214.9). Results further revealed that the total exported cargo of Raw Phosphate (3789356), Raw Fertilizers (1314695), Raw Potash (1669219), building materials (855868.7) and General Cargo (681398.9). Second, the results of the export transshipment model were crucial and impractical. While the author intended to minimize total exportation cost (as suggested in transshipment models formulation) by building stocks of products in five sites revealed that every location should have a combination of exported products. The solution suggests that we should build individual stocks in

different locations. This sort of planning is impractical, especially if we know that such a solution will not help supply the regions with commodities [32]. The optimal result of export transshipment costs is higher than both the optimal obtained by the transportation model and the actual total transportation cost of the Jordanian exports to the different regions. Third, the optimal imports transportation solution resulted in a total cost of (499992674.5). Results revealed that the total imported shipments of Consumer goods (1745795), Capital goods (288419.7), Durable goods (168792.8), crude oil (7359542), Construction materials (1136938), Pharmaceutical preparations (12498.8), Other commodities (2380986.72), Government supplies (11216925), Fertilizers (76205.13), General cargo (2712824). Fourth, data analysis of the import transshipment model also revealed critical and infeasible results. While the author also planned to minimize the total importation cost by building individual stocks in different locations. The optimal solution indicated that those locations should receive goods from selected countries, which in turn should be sent in bulk to Aqaba seaport, at a total cost of (527720144) which is higher than the optimal solution of the import transportation model. This form of strategy is impractical as it can undermine the overall policy [9].

5. Discussion

Jordan is a developing country surrounded by turbulent dynamic environments. This environment has forced Jordan to involuntary host millions of people fleeing from hostile environments. Consequently, the demand for products and services has increased. In fact, such an environment has affected economic growth, trade, exports, tourism and investment, in turn leading to an increase in the budget deficit and public debt [33].

This paper aims to minimize the total transportation costs of both major export and import products to and from Aqaba seaport of Jordan. Specifically, it investigates whether the current transportation strategy is optimal. To achieve this goal, the author uses LP and formulated four models (i.e. export transportation model, import transportation model, export transshipment model, and import transshipment model). Study results are discussed as follows:

First, export results reveal that the current transportation strategy is unavailing; it resulted in a total cost of (247485214.9). Results also reveal that the shipments of Phosphate to the regions (i.e. Eastern world, Gulf countries, East-African, Eastern Europe, Eastern Mediterranean) result in a significant increase of costs which in return may harm the general policy of transportation. Shipments of Fertilizers to regions (i.e. East African, Western Europe, Eastern Mediterranean) should be cut to avoid affecting the government policies and increasing transportation costs. In regard to Potash it is viewed that in order to reduce transportation costs, it can be only shipped to certain regions (i.e. North west Africa, American countries). To be more efficient and reduce transportation costs, building materials should be only shipped to Oceania and Eastern Europe. Finally, general Cargo should only be shipped to Southwest Asia to cut transportation total cost. The sensitivity analysis shows that the quantities of five exporting products can be reduced by (173041.3991) tons without affecting the optimal policy of Aqaba seaport. Meanwhile, the same quantity can be increased for each shipment point to keep the same optimal policy.

Second, import results also reveal that the current transportation strategy is ineffective and results in a total cost of (499992674.5). In fact, to reduce transportation imports, this optimality shows that consumer goods should only be imported from Southwest Asia and American countries. Capital goods should only be imported from regions (i.e. Western and Eastern Europe). Durable goods should only be imported from regions (i.e. Western Europe). Crude oil should only be imported from regions (i.e. Gulf countries). Construction materials should only be imported from regions (i.e. Eastern Europe). Pharmaceutical preparations should only be imported from regions (i.e. Eastern Europe). Other commodities should only be imported from regions (i.e. Western Europe). Government supplies should only be imported from regions (i.e. Eastern world, Southwest Asia, Oceania, East-African, Northwest Africa, Eastern Europe, Eastern Mediterranean, USA & Canada). Fertilizers should only be imported from USA & Canada. General cargo should only be imported from regions (i.e. Gulf countries). This optimal solution for transporting the Jordanian imports is not practical in the sense that it suggests importing only from the nearest regions. Instead of that, it is recommended that Jordan ought to develop its own shipping fleet

to cut drastically the cost of importation through means of economics of scale and bulk shipping. Sensitivity analysis results show that the quantities of the ten main importing categories can be reduced accordingly. These quantities are small according to the quantities shipped. For example, consumer goods can be reduced by 13 tons without affecting the optimal cost. Moreover, the same quantities can be increased for each shipment point to keep the same optimal policy.

Third, results emerging from both export and import transshipment models further reveal that building individual stocks at different locations is impractical as such building resulted in a cost higher than both exports and imports transportation costs. These results suggest that decision makers should focus on developing a LP strategy that will lead to minimizing total transportation costs. Although decision makers have exerted their efforts to reform the economy by developing different strategies [2], the take-up has been slow and actual implementation and serious decisions have not been produced.

6. Implications

This study presents theoretical and practical implications. It identifies various contributions to the literature. First, while developed countries' literature has identified the significance of the optimization problem in cost reduction, developing countries' literature is still progressing and encounters a dearth in empirical evidence. Second, Results of the study may be important for future researches as such results can be the foundation for upcoming studies covering optimization problems in developing countries. Third, it bridges the gap in transportation literature in general whilst goods exports and imports trade is carried out between and among both developed and developing countries. Fourth, it emphasizes the shortage of clear transportation strategy [34], [35] in developing countries. Ref. [34] indicate that developing countries, transport policies are often poorly designed and implemented.

Regarding practical and Policy implications of the research, Decision makers ought to recognize that the results of this research are important to minimize transportation costs. Indeed, decision makers have made remarkable strides to develop and devise an overall "strategy" to resolve a number of Jordanian crisis (i.e. economic growth, trade, exports, tourism and investment) simultaneously which produced unsuccessful results. Nowadays, the challenges of decision makers are to adopt a strategy that builds on investments in infrastructure [34], [36]. In fact, the competitive opportunity enabled by infrastructure investment is probably important. Infrastructure investment may provide the umbrella of new form of differentiation which, when managed effectively provide a solution to all Jordanian crisis. undoubtedly, the basic need for infrastructure investment is the participation of the private sector either locally or externally. Private sector involvement may promote two challenges. First, decision-maker commitment to ensure continuous and active coordination. Second, the political economy [34], [37] that underpins infrastructure investment choices may result in the inefficiency to invest in such an environment.

7. Limitations and Future work

The data of this study has been collected from the Ministry of transportation and the department of statistics websites during the period of (2009-2017). Throughout this period, oil prices were varied and dramatically changed, in several instances, bloated as economic (i.e. financial crisis) and political (i.e. international conflict) crisis endured; therefore, affecting the total optimal cost. Further research may highlight the impact of Aqaba seaport transportation policies on congestion or may investigate the impact of current infrastructure on present transportation policies.

8. Conclusions and Recommendations

This study uses LP and formulates transportation and transshipment models in order to determine whether the current shipping strategy of actual costs to transport major exports and imports is optimal. The main findings of this study show evidence highlighting the ineffectiveness of the current transportation and transshipment policies which stipulates a change towards optimal values to target minimal overall costs of transportation and transshipment. Upon analysis, for time being, the author recommends that Jordanian decision makers ought to first, develop a Jordanian shipping fleet to cut drastically the cost of importation through means of economics of scale and bulk shipping. Second, to reduce the quantities of decision variables (i.e., quantity of products transported or transshipped

from various outlined ports) to the optimal quantities shown in (table one). Finally, Jordan must define a long-term strategy for its various types of products. Along with this strategy, it is strongly suggested that the government ought to avoid some product cases such as Phosphate, fertilizers, potash where the country is exporting them as raw materials and importing them in turn as finished goods which increases the costs of transportation. For example, rather than exporting phosphate, potash, fertilizers in enormous amounts, decision makers ought to find investors to construct factories in Jordan. In addition to minimizing the total transportation cost, these factories will also assist in solving the issue of unemployment as the greatest economic challenge to decision makers.

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