World Academy of Science, Engineering and Technology
International Journal of Industrial and Manufacturing Engineering
Vol:11, No:5, 2017

Design of Distribution Network for Gas Cylinders in Jordan

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***Abstract*—**Performance of a supply chain is directly related to a distribution network that entails the location of storing materials or products and how products are delivered to the end customer through different stages in the supply chain. This study analyses the current distribution network used for delivering gas cylinders to end customer in Jordan. Evaluation of current distribution has been conducted across customer service components. A modification on the current distribution network in terms of central warehousing in each city in the country improves the response time and customer experience.

***Keywords*—**Distribution network, gas cylinder, Jordan, supply chain.

I. Introduction

SUPPLY chain distribution network is related to the steps that are taken to store and move products or services from supplier stage to customer stage. It is related to storing of materials through the supply chain considering different stages. Distribution networks influences the efficiency and responsiveness of a supply chain. While supply chain efficiency is related to the minimization of costs that incur through supply chain stages, responsiveness is related to the capability of a supply chain to respond to a customer's order [1].

Responding to the customer' orders requires high responsiveness through the whole supply chain not only at customer's stages. In order to be able to respond quickly to a customer's order at the customer's stage, all other materials and required services should be available at upstream stages, so a customer will receive the right product or service in the right time. A high responsive supply chain (low efficiency) is known to incur higher costs through stages compared to low responsive supply chain (high efficiency) [2].

Distribution networks can be designed to support a supply chain strategy (efficient or responsive), as designing of these networks influences some customer service components and has direct effect on inventory, transportation, facility, and information cost. Customer service components are known as; response time, product availability, product variety, time-to-market, order visibility, returnability, and customer experience. Some of these components and previous costs drive a supply chain towards efficiency and others drive it towards responsiveness. The optimum design of a distribution network may not consider the highest level of performance of all customer service components [3].

Distribution networks come into six major models. Other models may be a combination of two or more distribution networks to appropriately serve a customer. The distribution networks are: manufacturer storage with direct shipping, manufacturer storage with direct shipping and in-transit merge, distributor storage with package carrier delivery, distributor storage with last-mile delivery, manufacturer/ distributor storage with customer pickup, retail storage with customer pickup. The major difference between the distribution networks is the location of storing products and the way of delivering products to customers [4].

This study aims at proposing a design for a distribution network for a supply chain of liquid petroleum gas (LPG) (cooking-gas) cylinders in Jordan. LPG is considered as the main source of energy used for cooking besides electricity and is one of the main sources of energy used for heating in winter besides electricity, kerosene, and firewood. Jordan is a country in the middle-east that imports oil from different countries and extracts oil products in one oil refinery. LPG is a product that comes from refining oil.

As a review of some previous work related to the management of supply chain for gas cylinders, a study has been conducted for a network design for cylinder gas distribution. The problem was formulated as a mixed integer program followed by a decomposition approach. The results on a numerical example showed that decomposing network design problems into two sub-problems is effective in addressing a solution for large scale problems in cylinder gas distributions [5].

Another study has investigated the relation between distribution cost and the location of facilities in multi-echelon LPG supply chain in Indonesia. The results show that there are trade-offs between facility cost and distribution cost using fixed-charged capacitated facility location model [6].

II. Current Model

Jordan receives oil through tanks sent to the refinery that is located in the middle of the country. LPG as a product is distributed to one cylinder-filling facility in north Jordan in Irbid city to cover the demand of the north region, and to other cylinder-filling facility that is located in the middle of Jordan in the capital Amman to cover the demand in the middle region. There is a third cylinder-filling facility that is located beside the oil refinery to cover the demand of the south region.

LPG is transported to the three cylinder-filling facilities using pipe-lines. Jordan houses use steel cylinders filled with

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12.5 (kg) of LPG. Cylinders are filled on each facility and distributed by trucks to warehouses that are located in different regions of cities. Every warehouse has small trucks that are used to distribute cylinders to houses and restaurants in different suburban areas. The distribution to suburban areas is not according to actual customer orders; trucks make trips to each area once a day or more than one time a day playing loud common music, so as a customer or a resident wants to exchange an empty cylinder with a filled one, he/she has to stop the truck to get a filled-cylinder. This distribution network has been used for decades.

Fig. 1 shows the distribution network of gas cylinders projected on the map of Jordan. The solid arrows show the distribution from the refinery to the cylinder-filling facilities. The dashed-arrows show the transportation of filled cylinders to the cylinder's warehouse, whereas the dotted-arrows show the distribution of cylinders from a warehouse to suburban areas using small trucks.

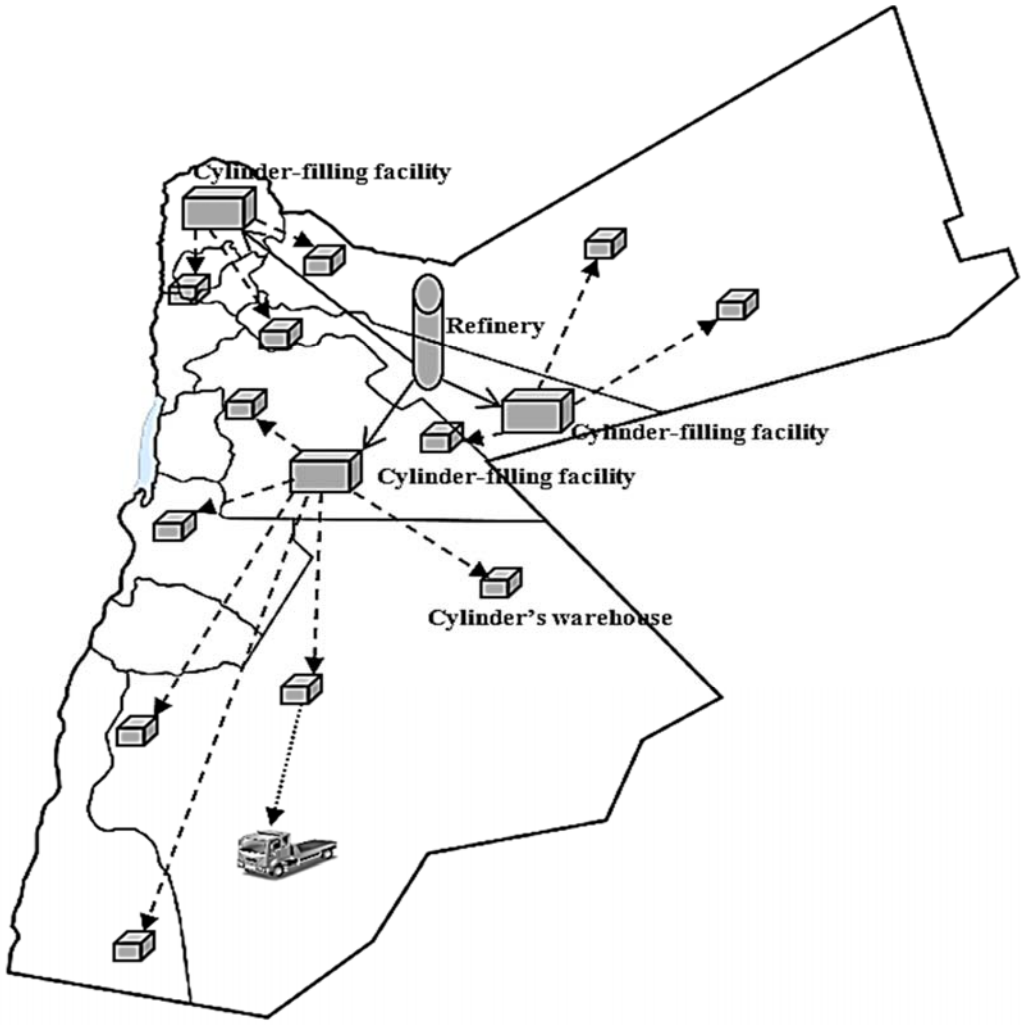

Fig. 1 The distribution network of gas cylinders projected on the map of Jordan

TABLE I
THE EVALUATION OF CUSTOMER SERVICE COMPONENT FOR EACH CURRENT DISTRIBUTION NETWORK BETWEEN DIFFERENT STAGES

Current LPG distribution networks			
Customer service component	R-F	F-W	W-C
Response time	Long	Very long	Short to long
Product variety	N/A	N/A	N/A
Product availability	High	Low	High to low
Time to market	N/A	N/A	N/A
Order visibility	Good	Bad	Bad
Returnability	N/A	High	High
Customer experience	N/A	N/A	Customer may have bad experience in case of delay of delivery

The distribution network between the refinery and the cylinder-filling facilities (notation R-F) is manufacturer storage with direct shipping as the refinery manufacturer LPG and directly ships it to facilities. The second stage of distribution which is from a cylinder-filling facility to a warehouse (notation F-W) is a combination of distributor storage with direct shipping as cylinders are stored at the cylinder-filling facility until being shipped to a warehouse. The lot size of shipping between a cylinder-filling facility and a warehouse comes in truck-load capacity, so milk-run scenario is not appropriate in this stage. The last stage of distribution that is between a warehouse and a suburban area (notation W-C) using small trucks comes of a combination of retail storage as a warehouse in this case is considered as a retail since it is the last stage in the supply chain before the end customer, but the delivery here is accomplished using milk-run as the small truck makes trips in a suburban areas and approaches multiple customers at a time.

Table I illustrates the evaluation of customer service component for each current distribution network between different stages. The cells that contain N/A mean that the component is not applicable on the network, for example the product variety is not applicable on any network as there is only one type of LPG cylinders. The response time of W-C network is supposed to be short according to the network design, but in the current case, customer does not place an order for a filled cylinder; he/she wants until a small truck passes by his location, and this will make the response time longer, so it is assigned as short to long. The response time of F-W network is very long as the warehouses in the south region of the country are being served to the filling facility in Amman that is far from south region, hence this will take long time for distribution between filling facility and warehouses.

III. Proposed Model

Customer service components will be used for evaluation of the proposed distribution network design in different stages. A dramatic improvement can be achieved through changing in the supply chain network design. This will incur high cost as new facilities may be required to be established, and other facilities may be required to shut down. A cheaper and reasonable solution that entails improvement on the supply chain can be achieved by changing on the distribution network only.

The current network has some problems that can be summarized on long leading time or delivery time to end customers as the delivery depends on the trips that the small truck makes in suburban areas. Also, long distances between some filling facilities and warehouses incur high transportation time to deliver filled cylinders. This issue also applies for reverse supply chain when empty cylinders are sent back to filling facilities to be refilled.

A new model is proposing the followings:

- Keep the current distribution network between the refinery and the filling facilities as the transportation between these stages is done using pipelines that require high investment in infrastructure.
- The second distribution network that is between the filling facilities and warehouses will remain the same as no new facilities will be established.
- A change on the warehouses is proposed. Instead of distributing cylinders to individual warehouses, it is proposed to dedicate one of warehouses in each city to be a central warehouse with capacity that covers the demand of that city. Other warehouses in the city will replenish the stock of cylinders from this central warehouse. This means that a new stage of storing cylinders is proposed but without building new facilities. This dedicated facility will keep replenish the stock of cylinders from filling facilities. This scenario ensures that filled cylinders are always available at warehouses as well as at the central warehouse at each city.
- The warehouses at each city that replenish from the central warehouse at the same city will cover a demand of a region in the city, hence the demand of a city is assigned to certain warehouse which makes a warehouse more efficient in demand covering.
- Using this new model will enable a warehouse to build a good relationship with customers in the area that the warehouse is responsible for. The delivery is still made by the same scenario of making trips by a small truck. It is recommended that a customer may place an order of filled cylinder by phone and wait for the truck to deliver the cylinder to customer's location.

The effect of the proposed model on the customer service components is illustrated in Table II. An improvement has been achieved in the response time for W-C network. Also, the product availability will increase for W-C network as the central warehouse will keep filled cylinders available for replenishment by warehouses. A better order visibility on W-C network is achieved as a warehouse in a city focuses on less number of customers and manages their demand better through ordering by phone. Customer experience on W-C network will improve as less delay in delivering cylinders.

IV. Conclusion

Distribution network is essential component in supply chain that is related directly to the efficiency and responsiveness of a supply chain. Distribution network is associated with the place of storing materials and the way of delivering products.

This study proposes a distribution network for gas cylinder in Jordan. The current distribution network suffers from long response to end customer delivery, whereas the new proposed model suggests assigning a warehouse as a central warehouse for each city to cover the demand of the city. Theoretically, the proposed model will reduce the response time and improve customer experience. For future work, it is recommended to implement the proposed model for better improvements or to conduct a discrete event simulation study to test results.

TABLE II
THE EFFECT OF THE PROPOSED MODEL ON THE CUSTOMER SERVICE COMPONENTS

Current LPG distribution networks	
Customer Service Component	W-C
Response time	Short
Product variety	N/A
Product availability	High
Time to market	N/A
Order visibility	Better
Returnability	High
Customer experience	Good customer experience

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