REDESIGN A TIME RESPONSIVE DISTRIBUTION NETWORK USING SIMULATION

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ABSTRACT
This paper aims to redesign a more effective distribution network for a fast-moving consumer goods (FMCG) company in Singapore so as to ensure a higher service level with minimized cost structure. Both strategic and operational approaches are applied in this study. At the strategic level, well-known distribution network models are introduced and five most important factors required for selecting the design of the distribution network for the company (response time, product availability, inventory, transportation, and facility & handling) were identified. After analysing the delivery data of the company, two demand and delivery patterns were identified for the five current delivery channels. For the second part of the study, at operational level, an agent-based simulation model is developed to investigate the trade-off analysis of service level versus cost. Clustering method is implemented to aggregate demand points according to their geographical locations. At strategic level, two different distribution network designs are recommended for identified demand and delivery patterns. For the first demand pattern, manufacturer storage with direct shipping is suggested while distributor storage with last mile delivery is recommended for the second demand pattern. At the operational level, a simulation model assists the company to analyse the effects of different scenarios such as opening a new DC, modifying fleet size, changing replenishment policy, closing/opening channel(s), etc. For instance, the results revealed that adding a new distribution centre reduces the operating costs by 30%. This cost saving covers new DC's expenses such as rental, manpower, etc.

Keywords: Distribution network, Simulation model, Service level, Operational costs, Consolidated deliveries.

Introduction

Singapore is ranked number one among more than 170 countries in the World Bank's 'Ease of Doing Business' rankings. Company based in Singapore enjoy greater ease of trading across border and policy maker is also interested in trade facilitation to reduce non-tariff barriers. The beverage industries have significant impact in Singapore economy and development. According to Tonby (2016), beverage and food industry contributed to 38% of manufacturing related Foreign Direct Investment in Singapore. The objective of this paper is to explore distribution network design that enables a beverage company to win in Singapore market. The desired distribution network has the following features: 1) meet customer demand with better agility and responsiveness. 2) competitive and sustainable cost structure. At strategic level, two distribution models are selected based on industry and market characteristics. At operational level, an agent-based simulation model is developed to evaluate different scenarios before implementation phase.

A few innovations in supply chain industry are considered to improve the base distribution model on both service level and cost structure. For beverage industry, products are generally fast moving and consumer demand could be easily fulfilled by competitors. Therefore demand coverage and distribution responsiveness are most important performance measurement for the new network. The custom clearance at Singapore and Malaysia border and road congestion during peak hours are identified as key bottleneck. If custom clearance and urban logistics can be handled with better efficiency, the beverage company can achieve higher service level with lower distribution cost.
In next section, a thorough literature review on distribution network design and recent innovations on urban transportation is provided. Section 3 is the analysis of specific models relevant to the company's situation and discussions relating to the conceptual network design. In section 4, we study the distribution network in an operational level and develop a simulation model. Our findings are summarized in Section 5.

Literature Review

In logistics sector, Singapore in ranked number one in Asia Pacific region based on Logistics Performance Index published by World Bank in 2015. Singapore outperforms most of countries regionally on custom clearance efficiency and complexity, infrastructure quality, shipment timeliness, competence of local logistics industry and so on ("Ranking of economies - Doing Business - World Bank Group." 2010). According to Layton (2007), these advantages make Singapore the top choice to international companies to start and develop business. On the other hand, Singapore is one of the most densely populated cities with more than 5.5 million residents. Company based in Singapore has to face challenges in resource scarcity in land, transportation and labour. To deal with the limitations, De Souza et al. (2014), discussed consolidation warehouse and synchronized last mile as solution to urban logistics constraints.

According to Chopra, (2003), distribution network can be classified into six distinct designs: 1) Manufacturer storage with direct shipping. 2) Manufacturer storage with direct shipping and in-transit merge. 3) Distributor storage with package carrier delivery. 4) Distributor storage with last mile delivery. 5) Manufacturer/distributor storage with customer pickup. 6) Retail storage with customer pickup. Each design has its own strength and weakness and the six models can be adopted in hybridly to achieve better performance. In both Chopra, (2003) and Xia, (2009), work, service level and distribution cost are identified as key measures to evaluate distribution network performance. Service level considered various elements impacting network structure: responsive time, stock availability, product variety, customer experience, order visibility and returnability. Distribution cost can also be categorized into transportation cost, facility and handling cost, inventory cost and information cost.

De Souza et al. (2014) proposed the concept of consolidation centre to enhance multi-party coordination in urban logistics. The consolidation centre is a facility in which goods are consolidated to bundle inner-city transportation. Use of consolidation centre can increase load factor, decrease commercial vehicular traffic, reduce emission and increase overall service level. However, to rely less on governing authority and make the operation financially viable, a flexible and dynamic model is needed to attract and retain different parties and stakeholders. Use of logistics service provider is one of the ways to join the collaborative network. Vasiliauskas et al. (2007), examined advantages and disadvantages in 3PL application. Outsourcing the warehouse to 3PL can benefit company in a few aspects. Firstly, company

will be able to better utilize resource to focus on their own competency and core business. Secondly, utilizing a 3PL distribution provider allows flexibility to set up and scale distribution model as demands shift. Furthermore, company save significant capital expenditures in warehouse set up and obtain economies of scale by outsourcing. Lastly, company can leverage 3PL expertise in process and industry to improve service level. However, there is risk in selecting and maintaining a 3PL as strategic partner. Distribution network design has been a very active research area. Macharis et al. (2011), presented a Multi-actor multi-criteria analysis on night-time delivery for urban distribution. Various stakeholders' perspective are incorporated into the case study. It is promising to implement night-time deliveries but only in selective time and type of business. As there will be conflict of interest among stakeholders, their concerns must be addressed appropriately to win general support on implementation.

After the single window concept is widely embraced by ASEAN, the regional community has set further plans to integrate the existing system for better trade facilitation. The ASEAN Framework Agreement Facilitation of Goods in Transit (AFAFGIT) set the legal framework for ASEAN Customs Transit System (ACTS) ("Brochure ACTS - Arise - Asean." 2014). It is on track to complete pilot implementation in Singapore, Malaysia and Thailand by 2016. The ACTS offers direct access to all traders through a secure and efficient computerised Customs transit management system. By increasing the efficiency for legitimate trade, this facilitation allows traders to shorten transportation lead time with cost reduction.

Allan et al. (2005), discussed numerous Urban Consolidation Centre (UCC) scheme in literature and existing set-ups and constructed a framework for urban consolidation centre. The report also summarized advantages and disadvantages of urban consolidation centre. Key elements in UCC scheme evaluation are identified as number of vehicle trips, travel distance, travel time, number of vehicles, goods delivered per delivery point, vehicle load factor, loading/unloading time and frequency, total fuel consumption, vehicle emission and operational cost. UCC also has impact on other supply chain activities such as transport operation, inventory control, delivery location and product flow. Essentially, UCC help to maximize utilization of available capacity by reducing the time and distance travelled and number of vehicles needed in final delivery stage. However, the benefits need to be considered together with the capital and operating cost, added supply chain complexity and also the security and liability issues.

Strategic Level Analysis

Different Distribution Networks Design

Distribution network of a company mostly handle and store the goods of the company and maintain the flow of the goods from suppliers to final customers. It is very important to select the appropriate distribution network, as it is directly related to the cost and service level of the company. Distribution network for different companies are different depending on the specific objective of the particular company. The ultimate goal of the distribution network is not to achieve highest performance in every area of the supply chain, rather to fulfil the requirement of the customer while maximizing the profitability of the company. In case of the companies, which customers can endure long response time, can have fewer location with higher storage capacity. On the other hand, the companies with customers who expect lower response time need to have many facilities with low capacity and closer to the end customers. According to literature, the performance of any distribution network should be evaluated along two dimensions:

1. Customer needs that are met, which influences the company's revenue
2. Cost of meeting customer needs, which influences the profitability of the delivery network

The different Designs of distribution networks are specified based on two decisions:

1. Whether the products will be delivered to customer's location or the customers will pick up the products from a predetermined location
2. Whether the product will flow through an intermediary

Based on the above-mentioned decisions, six different designs are defined:

A. Manufacturer storage with direct Shipping
B. Manufacturer storage with direct shipping and in transit merge
C. Distributor storage with package carrier delivery
D. Distributor storage with last mile delivery
E. Manufacture/distributor storage with customer pickup
F. Retail Storage with customer pickup.

Choosing distribution network for the beverage company

While choosing distribution network for any company, it is very important to consider the product characteristics as well as the service and cost factors, which are more important for that particular company. As discussed before, different networks have different merits and demerits. It is very important to first define the product characteristics and the network requirement for the company before choosing the appropriate distribution network. Characteristics of a bevarage company are listed below:

- The products are fast moving consumer goods.
- Profit margin of product is quite low.
- It has several big competitors, so the pressure for the competitors is quite high.
- Weights of All the products are mostly heavy.

Network Requirements

There are six factors in customer service, which influence the distribution network. Those factors are response time, product variety, product availability, customer experience, order visibility and returnability. On the other hand different distribution network design affect some supply chain costs, which are inventories, transportation, facilities and handling and information. Chopra, (2003) has created a table where he ranked different strength and weakness of the six-network design relative to each other's. According to the table, one particular distribution model cannot be selected, which will fulfil all the factors important for a beverage company. For example: response time and transportation is showing high performance for retail storage with customer pick up but in case of product availability and facility and handling, the table is showing low performance. In order to find the most appropriate distribution network for the company, the data related to the customers and delivery need to be analysed.

Data Analysis

Total drop size for all the channels per week is 500,000, which is quite large. Table 1 shows the total drop size for all the channels per week and their percentage.

Channels	Total drop size/week	Percentage
A	100,000	20%
B	120,000	24%
C	150,000	30%
D	80,000	16%
E	50,000	10%

Table 1: Drop Size per Week

According to the graph, the drop size for channel A is 20%, channel B is 24%, channel C is 30%, channel D is 16% and channel E is 10%. According to the data the drop sizes for channel A are quite large comparing to other channels but the relative drop size for the channel is not highest compares to other channels. The main reason behind this difference is the number of drop point for each channel. For channel A drop points are only 5 whereas the drop point for other channels are 21,030. So it is clear that it would be feasible for the company does use different distribution networks for the different channels. Table 2 shows trips per week per channel and the drop size per week per delivery points.

Channels	Trips per week	Drop size/delivery point
A	30	3,500
B	6,000	20
C	7,000	25
D	5,000	10
E	3,000	5

Table 2: Trips per week and drop size per delivery point

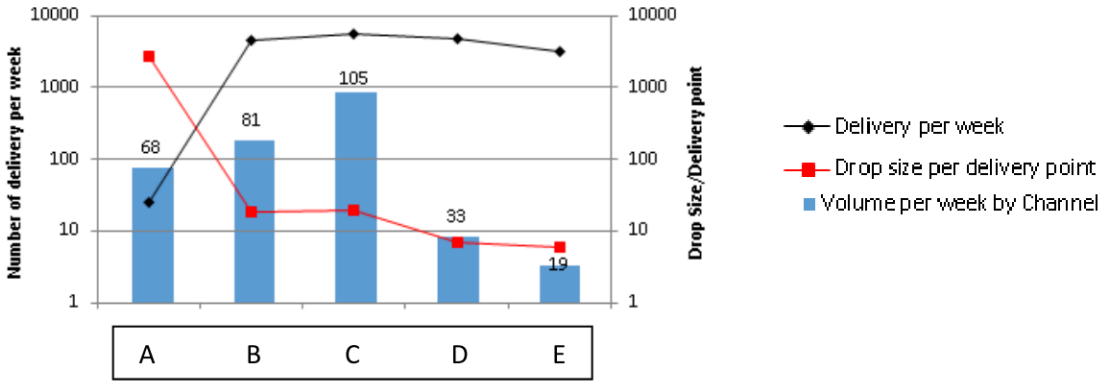

Figure 1: Comparison between Delivery Size and Frequency by Channel

Figure 1 shows, given the volume of the channels per week, as the delivery frequency decreases drop size per delivery point increases. It can be said that there are two demand and delivery patterns for the given five channels of retailers. For first pattern, which is for channel A, the drop size per point is quite large but the frequency of delivery per week and the total numbers of delivery points are quite low. The second pattern, which is for the rest of the channels or retailers, drop size per point is quite low but the frequency of delivery per week and the total numbers of delivery points are quite high. The company has different types of customer with different demand pattern. So it is not feasible for the company to deliver the products to different channels by using the same distribution network. After analysing the data, it can be said although the company has five different channels or parties where the company need to deliver the products, there are mainly two different type of delivery pattern. One pattern is for channel A and another one is for the rest of the channels. So the distribution networks suitable for these two patterns are as follows: In case of channel A, the drop size per point is quite large but the frequency of delivery per week and the total numbers of delivery points are quite low. In this this scenario, most suitable distribution network is the manufacturer storage with direct shipping. In case of rest of the channels, drop size per point is quite small but the frequency of delivery per week and the total numbers of delivery points are quite high. The company actually delivers their product to every outlet under this category. So for this demand pattern the most suitable distribution network is distributor storage with last mile delivery.

Operational Level Analysis

Supply Chain map

Supply Chain map of the company in Singapore is demonstrated in Figure 2. The network consists of 2 plants, 1 distribution centre, 5 warehouses and 6 distribution channels.

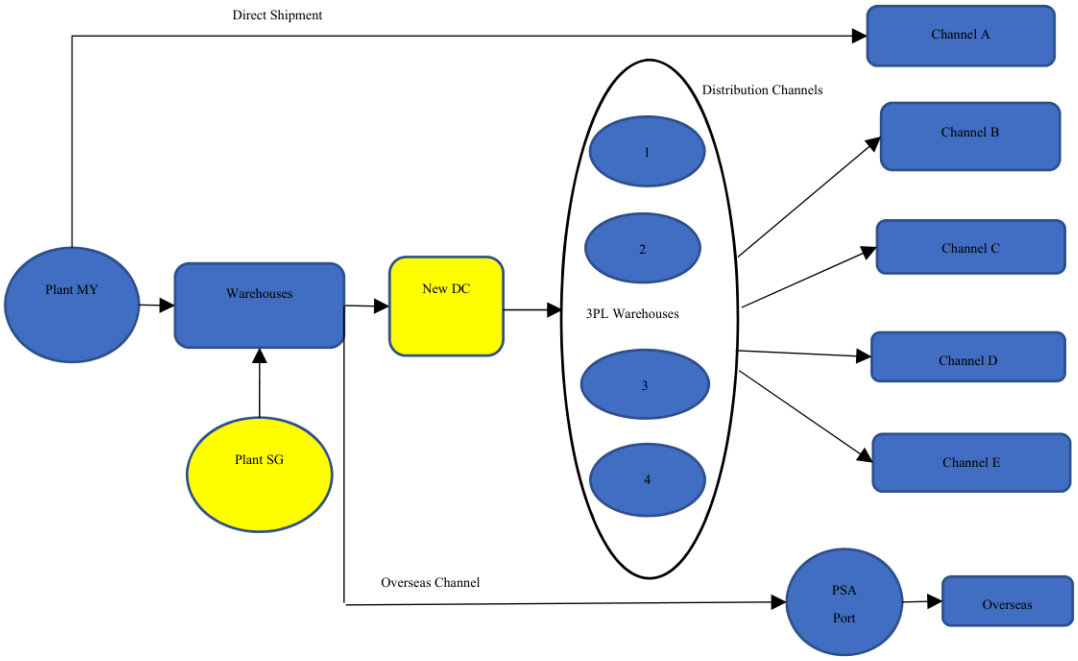

Figure 2. Supply Chain Map

Considering high manufacturing costs of SG plant and low transportation costs between Malaysia and Singapore, the company decided to shut down SG manufacturing and fulfill Singapore market's demand from Malaysia plant.

Creating Master File
Starting the data collection phase, we realized that there is no integrated data base to be used as simulation model input. Therefore, we created a master file using excel VBA which combines all available single files and exports required data to an integrated file based on some key and unique indexes. We collected historical demand data and used "EasyFit" software to fit an appropriate distribution function.

Simulation Model
We developed a simulation model using Anylogic as a multimethod simulation modeling tool. An agent-based simulation methodology is applied that combines elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming. The model contains three main mudules which are listed below:

Clustering: To define four clusters (West, North, East and Central) according to customers locations.

Order Consolidation: To consolidate all received orders based on zone definition and cut off time.

Truck Assignment: To assign trucks to deliver to retailers located in each zone based on truck type and order amount.

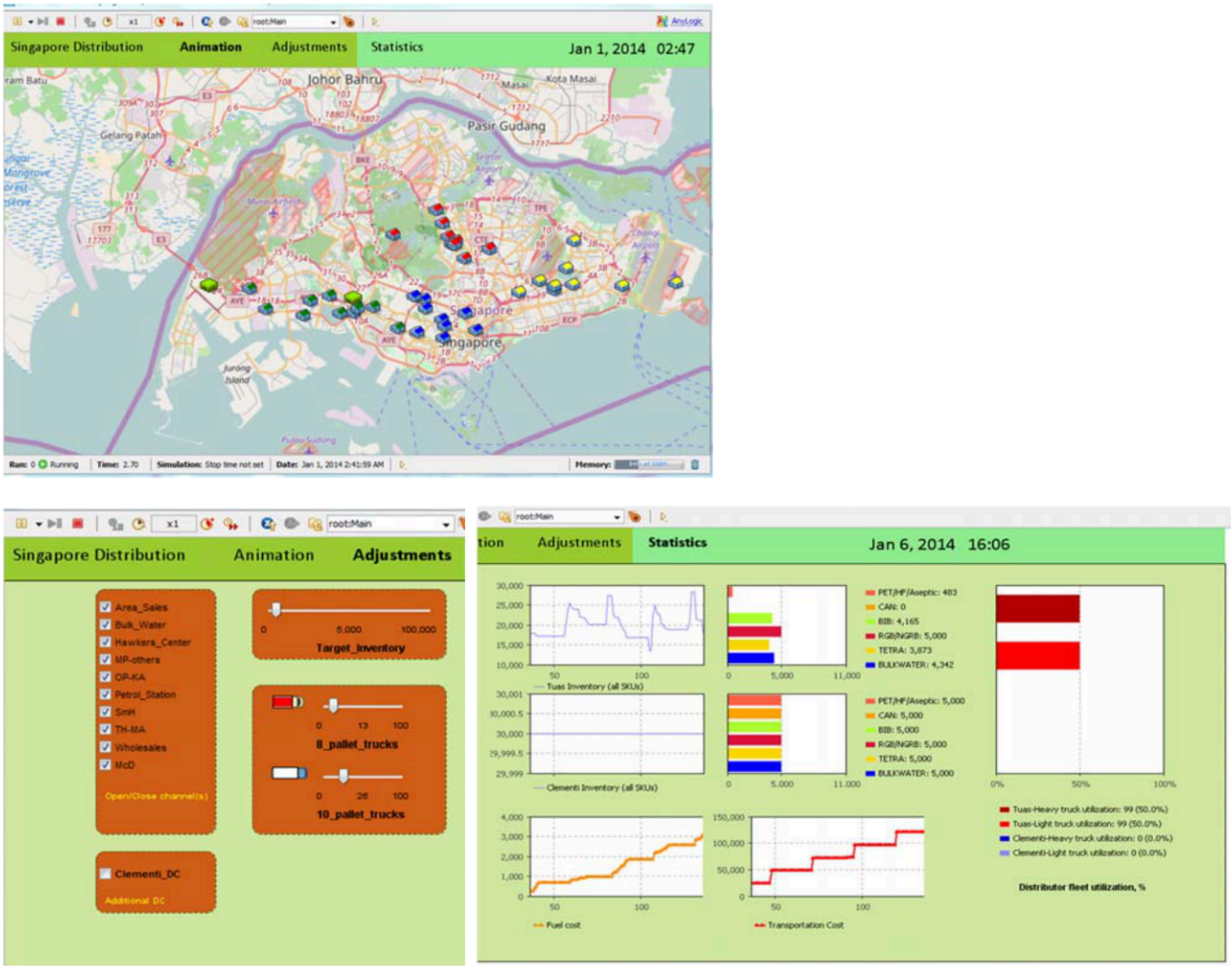

Figure 3. Simulation Dashboards (Animation, Adjustment and Statistics)

We use Master file as input of simulation model and output is a trade-off analysis of service level versus cost (Figure 3). This helps the company to compare different scenarios of the number and quality of distribution features and make the best decision based on desired service level and its associated costs.

Conclusion

This paper seeks to undertake the study of different distribution network models and innovative distribution strategies to build an appropriate distribution network for a beverage company in Singapore. The company has decided to shut down the manufacturing plant in Singapore and use the plant in Malaysia to fulfil Singapore market demand. The main goal is to establish an innovative distribution network for the company in Singapore to ensure higher service level with minimized cost structure. We applied both strategic and operational approaches in this study to figure out what is an appropriate distribution network design for the company in Singapore. At the strategic level, well-known distribution network models are introduced and five most important factors required for selecting the design of the distribution network for the company, which are response time, product availability, inventory, transportation, and facility &handling, were identified. After analysing the delivery data of the company, two demand and delivery pattern was recognized for the five currents delivery channels. Two different distribution network design are recommended for identified demand and delivery patterns. For the first pattern, which includes channel A, manufacturer storage with direct shipping was chosen and for the

second pattern, which includes other channels, distributor storage with last mile delivery was chosen. For the second part of the project, at operational level, we developed a simulation model using agent-based methodology. A master file has been created to integrate all required data for simulation model. The simulation model uses the master file as an input and the output of the model will be a trade-off analysis of service level versus cost. The transportation costs considers in the model as integral portion of distribution network costs and Delivery in Full on Time (DIFOT) performance is defined as service level indicator. For validation propose, the developed model has been run using two months provided data and the results support accuracy of the model. This simulation model can support the company to evaluate the outcome performance of new scenarios before implementation phase. We ran the model for the scenario of shutting down SG plant and opening a distribution centre at Celementi area. The result revealed that this decision leads to 30% reduction in operating costs.

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