Research Paper

DISTRIBUTION OF SUGAR BASED ON TRANSPORTATION PROBLEM ALGORITHM

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Abstract

Transportation problem (TP) is a special case for the general Linear Programming (LP). LP is a mathematical technique that has been developed to help managers make decision. TP will be applied in this study in order to find the best decision for the distribution of sugar from suppliers to hypermarket in Kelantan, Malaysia. This study will help the sugar distributors to minimize the shipping cost and make sure the sugar will be distribute in efficient way. By using excel solver, the efficiency and effectiveness of TP algorithm will be established. The excel solver will inform the suppliers which one is the right decision should be made in distributing their products. The result found that the shipping cost is lower when TP algorithm is applied. It will save up to RM34,827.90. At the end of the study, the suppliers were able to gain more profit rather than previous method (trial and error method)

Key Terms: Transportation Problem Algorithm, Linear programming, Minimize shipping cost

1. Introduction

Linear Programming (LP) is a mathematical technique that has been developed to help managers make decision (Anderson, Sweeney, and William, 1976). The technique is used in a wide range of application including production scheduling, capital budgeting, plan location, transportation problem, media selection, and health system. It can boost efficient and computational algorithm for problem with thousands of constraints and variables. Based on Taha (2003), LP form the backbones of the solution algorithm for other operational research (OR) problem including integer, stochastic and non-linear programming.

The transportation model is a special class of LP that deals with shipping a commodity from sources to destinations. By having a transportation model, it will determine the shipping schedule that minimizes the total shipping cost while satisfying supply and demand limits (Taha, 2003). As stated by Cheng (1985), it was first introduced by Kantorovich. It is one of the most important and successful application of quantitative analysis to solve business problem that deal with physical distribution of products.
On 2010, the phenomenon of lack of sugar is often heard in Malaysia. One of them is in Kelantan state. During that time, the quantity of sugar allowed to be purchased were limited to 1kg – 2kg per person. The number of suppliers and Hypermarket got the sugar supply also decreased. In fact, there are 8 sugar suppliers and 30 hypermarkets involved with sugar business. But, due to the sugar shortage, the number of suppliers and Hypermarket were decreased to 4 and 17 respectively.

Other than suppliers and retailer, people or end users also need to face this kind of problem. Sometimes, the ‘shortage of sugar supply’ was happen up to a week. Unfortunately, there were some greedy resellers exorbitantly increased the sugar price up to more than RM1.90. It is too much because the standard price of sugar is only RM1.60. They were increased the price because they claimed that they can’t gain the profit. Even though the sugar price is increased, people were willing to buy it since almost household need the sugars.

No matter what, this situation should not be happen. The retailer cannot simply increase the sugar price. It is because it will affect the end users who come from different levels.

Based on observation, it noticed that the suppliers have distributed the sugars to the Hypermarket in inefficient way. It is detected that there are problem in the way the suppliers ship the sugar. It is detected that the sugars has been distributed with ignoring the distance travelled. It is well known that the transportation cost will increased if the distance between the suppliers and hypermarket increased. At the end, it will decreased the profit. Due to these situation also sometimes the retailer mark up the sugar price in order to cover the high transportation cost. End up, the end users will suffer due to this problem.

Based on TP algorithm, distance travelled is important in order to transport the product from sources to destinations. Therefore, this study will be conducted in order to determine the shipping schedule and definitely it will minimizing the shipping cost. At the end of the study, this study will help the suppliers and hypermarket obtain high profit without affecting the end users.

2. Literature Review

Over the last decades, TP has been evolved from necessity to an important part of business that can enable companies to attain a competitive edge over their competitors. To cut down the transportation cost, shippers often outsource their transportation activities to a logistic service provider of their choice.

Transportation plays a vital role in the life of a region. It is an aspect of economic activities which provides for the carriage of goods and persons from one place to another places. An inefficient transportation system was one of the factors contributing to the failure in business orientation.

Based on Anderson (1976), LP for TP algorithm can be formulated as:

\[ \text{Min } z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \]  

Subject to: 
\[ \sum_{j=1}^{n} x_{ij} \leq a_i \]  
\[ i = 1,2, ..., m \text{ (supply)} \]
\[ \sum_{j=1}^{m} x_{ij} = b_j \quad j = 1, 2, \ldots, n \quad (\text{demand}) \]
\[ x_{ij} \geq 0 \quad \text{for all } i \text{ and } j \]

This formulation shows that the supply constraints are in the form of inequalities. As long as total supply is at least as great as total demand, a feasible solution can be found and all demand will be met. If we encounter a TP where total supply is less than total demand, there will be no feasible solution to the problem, which we know in advance the demand cannot be satisfied unless
\[ \sum_{i=1}^{m} s_i \geq \sum_{j=1}^{n} d_j \tag{2} \]

TP has four special situations which are total supply not equal to total demand, maximization objective, unacceptable transportation route and transportation tableau with less than \( m(\text{row})+n(\text{column})-1 \) occupied cell. In this study, we only focus on maximization of an objective. The problems and solution procedure present in TP are concerned with the transportation or physical distribution of goods and service from several supply location to several customer location (Anderson, 1976). The only modification in solution procedure necessary for the problem is in the selection of an occupied cell to allocate units to. The cell will be picked based on the cell which will cause the largest per unit increase in the objective function. An increased objective function means all destination demands are satisfied and the total transportation costs are minimized.

According to Anderson (1976), the solution algorithm of TP involves finding an initial feasible solution, checking for optimality and does improvement routine. The solution will be not optimal and necessary to do improvement if estimation cost is higher than real cost while the solution will be optimal if estimation cost are equal or smaller than real cost.

An advantage of Transportation method is the solution process involves only the main variables. It looks different from the simplex method which is this method should involve artificial variables. In fact, after applying northwest corner rule, the problem is as far along as it would be using simplex method after eliminating artificial variables (Jeeb and Leavengood, 2002). However, they were stated that the computation will get in more convenient form by using the special structure of the transportation model. It proved that special structure of the TP algorithm method is better than the simplex method.

TP algorithm has been applied by many previous researchers (McDaniel, 1975; Nielsen et al., 2008; Milan, Fernandez and Aragones (2008); Sen, Sinha and Som, 2010). McDaniel (1975) have use TP algorithm to find the total number of school by district in order to fulfill the demand. Nielsen et. al. (2008) used TP algorithm in planning of ICT Access Networks. Milan, Fernandez and Aragones (2008) focused on sugarcane transportation in Cuba. While, Sen, Sinha and Som (2010) determined the object oriented programming of southern part of north eastern region of India by formulating OR model.

### 3. Research Design and Methodology
The distribution of sugar from the suppliers to the hypermarket will be studied. The TP algorithm was applied in order to find which hypermarket suppliers should deliver in order to minimize the shipping cost. The weight of sugar and the distance between suppliers and hypermarket will be considered in this study. At the end of the study, it will showed that TP algorithm able to offer the best decision in order to maximize the profit.

The data regarding to the total weight of sugar distributed by suppliers to the hypermarket, the location of suppliers and hypermarket and the actual distance between suppliers and hypermarket are needed. The total weight and the location are collected from Pejabat Perdagangan Dalam Negeri Koperasi dan Kepenggunaan (KPDNKK) Kota Bharu, Kelantan. There are 4 suppliers and 17 hypermarket & supermarket involved in this study. While, the data about the distance is gathered through google map.

Based on the data collected from KPDNKK, it is noticed that a data mining is needed. It is because the original data were not telling enough to complete this study well. The data collected were summarized as weekly data and set the quantity of sugar in a unit form. 50 kilogram (kg) of sugar was equal to 1 unit of sugar. Then, all of the summarized data was being transformed in a tableau form. The tableau form is very important in order to formulate the model in LP formulation. The LP formulation can be written as follows:

\[ i = A, B, C \text{ and } D = \text{number of suppliers} : \]
\[ A = \text{Hock Chuan Hin Sdn Bhd} \]
\[ B = \text{Link Holder Sdn Bhd} \]
\[ C = \text{Ang Kim Lin Sdn Bhd} \]
\[ D = \text{Guan Leong Sdn Bhd} \]

\[ j = 1, 2, \ldots, 17 = \text{number of hypermarket;} \]
\[ 1 = \text{Pacific Hypermarket Kota Bharu} \]
\[ 2 = \text{Pantai Timur Hypermarket, Pengkalan Chepa} \]
\[ 3 = \text{Pasaraya MYDIN} \]
\[ 4 = \text{Pantai Timur Hypermarket, Tanah Merah} \]
\[ 5 = \text{Pantai Timur Hypermarket, Rantau Panjang} \]
\[ 6 = \text{Pantai Timur Hypermarket, Pintu Pong} \]
\[ 7 = \text{Pantai Timur Hypermarket, Pasir Mas} \]
\[ 8 = \text{pasaraya BILAL} \]
\[ 9 = \text{Billion Kota Bharu} \]
\[ 10 = \text{the store Kota Bharu} \]
\[ 11 = \text{PKT Pasir Tumbuh} \]
\[ 12 = \text{PKT Wakaf Bharu} \]
\[ 13 = \text{PKT Kedai Mulong} \]
\[ 14 = \text{Pasaraya SALAMKU, Pasir Pekan} \]
\[ 15 = \text{Pasaraya ECONJAYA, Kok Lasnas} \]
\[ 16 = \text{Pasaraya SALAMKU, Pasir Mas} \]
\[ 17 = \text{Nirwana Maju} \]

Objective Function:
Min \( z = 3.27x_{A1} + 7.45x_{A2} + 2.05x_{A3} + 24x_{A4} + 19.45x_{A5} + 2.1x_{A6} + 10.25x_{A7} + 1.45x_{A8} + 0.61x_{A5} + 2.05x_{A10} + 6.9x_{A11} + 5.5x_{A12} + 3.05x_{A13} + 12.9x_{A14} + 6.75x_{A15} + 1.45x_{A16} + 5.1x_{A17} + 2.46x_{B1} + 4.47x_{B2} + 12.95x_{B3} + 23.37x_{B4} + 4.52x_{B5} + 15.25x_{B6} + 4.82x_{B7} + 4.84x_{B8} + 4.29x_{B9} + 4.06x_{B10} + 7.35x_{B11} + 9.47x_{B12} + 6.8x_{B13} + 16.8x_{B14} + 8.6x_{B15} + 3.76x_{B16} + 24x_{B17} + 28.17x_{C1} + 24.95x_{C2} + 1.05x_{C3} + 17.3x_{C4} + 24.3x_{C5} + 23.8x_{C6} + 29x_{C7} + 21.7x_{C8} + 22.62x_{C9} + 15.7x_{C10} + 14.8x_{C11} + 23.31x_{C12} + 15.6x_{C13} + 24.3x_{C14} + 16.9x_{C15} + 15.9x_{C16} + 8.9x_{C17} + 6.9x_{D1} + 18.9x_{D2} + 13.27x_{D3} + 10.37x_{D4} + 16x_{D5} + 19.89x_{D7} + 24x_{D78} + 26x_{D9} + 20.9x_{D10} + 18.9x_{D11} + 21.35x_{D12} + 28.3x_{D13} + 22.9x_{D14} + 13.9x_{D15} + 26.35x_{D16} + 21.3x_{D17} \)

Subject to

Supply constraint
\[ x_{A1} + x_{A2} + x_{A9} \leq 1172 \]  
Supply A
\[ x_{B2} + x_{B3} + x_{B5} + x_{B6} + x_{B7} + x_{B8} + x_{B9} + x_{B10} + x_{B11} + x_{B12} + x_{B13} + x_{B15} + x_{B17} \leq 3874 \]  
Supply B
\[ x_{C2} + x_{C5} + x_{C14} + x_{C16} + x_{C17} \leq 1473 \]  
Supply C
\[ x_{D4} \leq 2237 \]  
Supply D

and

Demand constraint
\[ x_{A1} = 248 \]  
Hypermarket 1
\[ x_{A2} + x_{B2} + x_{C2} = 1180 \]  
Hypermarket 2
\[ x_{B3} = 460 \]  
Hypermarket 3
\[ x_{B4} = 2237 \]  
Hypermarket 4
\[ x_{B5} = 684 \]  
Hypermarket 5
\[ x_{B6} + x_{C5} = 536 \]  
Hypermarket 6
\[ x_{B7} = 402 \]  
Hypermarket 7
\[ x_{B8} = 308 \]  
Hypermarket 8
\[ x_{B9} + x_{A9} = 304 \]  
Hypermarket 9
\[ x_{B10} = 120 \]  
Hypermarket 10
\[ x_{B11} = 124 \]  
Hypermarket 11
\[ x_{B12} = 52 \]  
Hypermarket 12
\[ x_{B13} = 184 \]  
Hypermarket 13
\[ x_{C14} = 427 \]  
Hypermarket 14
\[ x_{B15} = 260 \]  
Hypermarket 15
\[ x_{C16} = 422 \]  
Hypermarket 16
\[ x_{C17} + x_{C17} = 808 \]  
Hypermarket 17

where
\[ Z = \text{total cost} \]
\[ x_{A1} = \text{supply A deliver the sugar to the hypermarket 1} \]
\[ x_{D17} = \text{supply D deliver the sugar to the hypermarket 17} \]
The coefficients of objective function were formulated by 'shipping cost per km x the distance between the suppliers and hypermarket (km)'. The shipping cost was stimulated based on assumptions. The assumption can be derived as follow:

\[
RM0.50 = 1km = 50kg = 1 \text{ unit} \tag{4}
\]

Given that,
\[
x = 1kg
\]
\[
x = \frac{RM0.50 \times 1kg}{50kg}
\]
\[
\therefore x = RM0.01
\]

Here, it showed the cost that will be charge for 1kg of sugar is RM0.01. Then, the shipping cost of sugar from a Hock Chuan Hin Sdn. Bhd (supply A) to a pacific Hypermarket KB Mall (demand 1) was as follow:

The distance between supplier A and Hypermarket 1, \(x_{A1}\) was 6.540km and the shipping cost for 1 km and 1 unit was RM0.50. Hence,
\[
X_{A1} = \frac{RM0.50}{km} \times 6.54 \text{ km} = RM3.27 \tag{5}
\]

The excel solver will be applied in order to solve the LP formulation. It will give the fastest result compared to calculate manually. The answer will be obtained when the solution is optimal solution.

4. Results and Discussion

Table 1 presents an adjustable cells. An adjustable cell provides some important information as such the original value and final value. The original value obtain in adjustable cell is the value we can obtain from the original shipment. The final value can be defines as the value of the variable in the optimal solution. Having said that, it showed the best value need to deliver by the suppliers in order to minimize the cost.

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<th>Variable (x)</th>
<th>Original Value</th>
<th>Final Value</th>
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Table 1 revealed that the Link Holder Sdn Bhd should play an important role because it has the most basic feasible solution with 10 hypermarkets. The results also showed that half of the hypermarkets got the sugar supply from Link Holder Sdn Bhd.

Specifically, Link Holder Sdn Bhd need to deliver 248 units sugar to Hypermarket 1, 1180 units to Hypermarket 2, 460 units to Hypermarket 3, 536 units to Hypermarket 6, 51 units to Hypermarket 8, 124 units to Hypermarket 10, 120 units to Hypermarket 11, 52 units to Hypermarket 12, 295 units to Hypermarket 16 and 808 units to Hypermarket 17. While, Hock Chuan Hin Sdn Bhd and Ang Kim Lim play a same role because it has same number of basic feasible solution with 4 hypermarkets. It shows that about 23.53% of hypermarkets depend the sugar supply from them. Hock Chuan Hin Sdn Bhd should deliver 257 units sugar to Hypermarket 8, 304 units to Hypermarket 9, 184 units to Hypermarket 13, and 427 units to Hypermarket 14. While, Ang Kim Lim Sdn Bhd should deliver 260 units to Hypermarket 4, 684 units to Hypermarket 5, 402 units to Hypermarket 7 and 127 units to Hypermarket 16. The last but not least is Guan Leong Sdn Bhd which has the lowest number of feasible solution. It just need to deliver the sugar to the 2 hypermarkets. It shows that only 11.76% of hypermarket depend the sugar supply from them which are 1977 units to hypermarket 4 and 260 units to hypermarket 15.

Before run the model by using TPA, the minimum cost is RM79,227.54. But, after using TP algorithm, the shipping cost can be reduced to RM44,399.64. Hence, the suppliers can obtain the profit by RM34,827.90.

5. Conclusion

TP algorithm is very important for a businessman. An efficient decision can be made if they applied this method in running their business especially the business involved with transportation. With the help of Microsoft excel solver, the result found that the minimum shipping cost for distribution of sugar without TP algorithm and with TP algorithm method were RM79,227.54 and RM44,399.64 respectively. Clearly, it showed that TP algorithm method can generate more profit.
Reference


