

LOW VOLUME STORE PLANNING FOR WORKLOAD BALANCING AND TRUCKLOAD

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Abstract – In this study, it is aimed to decrease the number of days planned to be shipped in stores with low sales volume, to create a balanced work load and to increase vehicle occupancy capacity. Particularly, Less than Truckload problem is analyzed and model in this study. The techniques used in this study showed that adaptability can be achieved with shipment and store planning as well as green supply chain environment to minimize Less than Truckload (LTL) as well as gas consumption. A mathematical model was created in the direction of multi objective problem and solved in the GAMS environment. Moreover, scenario analyzes were made and the study was tested on five specially identified regions on Turkey.

Keywords – Warehouse Management, Store Planning, Workload Balancing, Truckload

INTRODUCTION

Modernization of supply chain with the internet of things (IoT) has been a crucial part to play in the matter of logistics as management becomes more efficient and able to control and lead more data than it ever was. This technological advancement is meant to make profit easily and turns supply chain more competitive environment as companies can easily invest and earn from this area. Thus, companies have decided to invest their infrastructure to become agiler in the matter of reaching customers' need at right time with right price to charge. Especially, modern customer demands quality and price in any product [1] [2] and price cutting with the best quality becomes a more crucial tool to get ahead of rivals. Therefore, supply chain and logistics are the best possible place to start.

A supply chain covers a raw material and product ordering/production and accommodation as well as product distribution, vehicle occupancy rate, vehicle type and etc. which directly change the price to the customer as well as the profitability of product [3]. However, today supply chain is aimed to reduce waste /loss of resources and this stands for the fact that right product is offered to customers. To achieve such a high goal, not only information technology and management should be capable to provide necessary information but also able to act upon the decision.

One of the best examples of this situation comes from ZARA, the most profitable apparel company as they follow the trends through stores and their suppliers always are ready to complete orders. Such collaboration has been rewarding ZARA with double digit profit since 1990 [4]. This is an important indicator to see supply chain as dependent pieces and the only way to control fluctuations of demands (the bullwhip effect) is to act together. Such a group can only aim to achieve sustainability. Moreover, this collaboration for ZARA provides an environment to less discounted product, less inventory cost and quick response to trend because ZARA keeps tracks of customer's reaction and management acts upon the need of customer instead of what ZARA could desire.

Therefore, this study is to show the benefit of providing right product to customer's need and offer a basic methodology to achieve such a difficult task with mathematical programming as it may act to optimize logistic cost and with better planning, more collaborative environment between third party logistic firms and the company would be developed as it would give ability to quick response to customer's need. Especially, third party logistic firms can lead higher occupancy rate rather than half empty trucks as it becomes more profitable and provide the ability to serve more customers. This also affects overall supply chain and increase productivity through truckload and today LTL means 35\$ billion worth business [5].

There is also another angle which is green logistics as less truck in traffic could lead to less CO₂ and less consumption to fuel for a better environment. According to the United States Environmental Protection Agency (EPA), transportation effect on Green House Gas represented 27% which is second highest level as electricity was seen 29% as highest in 2015. Moreover, the same study pointed out that vehicle that used petroleum represented 90% against all options for fuel. Such waste could be earned back with suggested method [6].

SOURCES OF GREENHOUSE GAS EMISSIONS

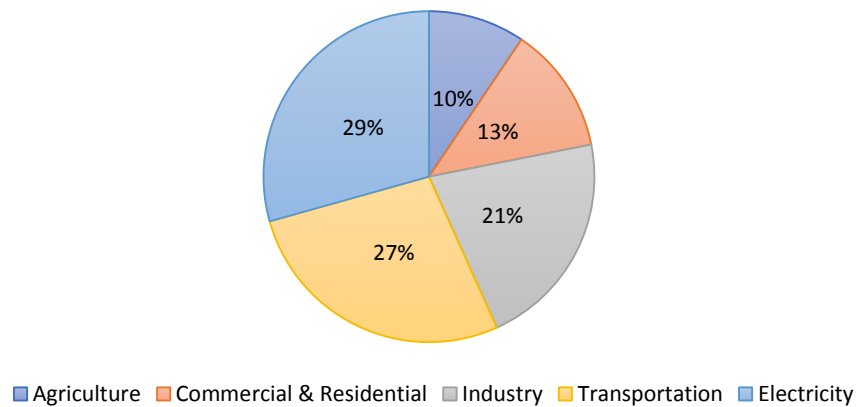


Figure 1. Sources of Greenhouse Gas Emission [6].

The following section introduces problem environment and example solution techniques as literature review, it follows with suggested solution method as mathematical model which follows with scenario analysis to calculate other options and finally this study completes with conclusion which shows importance of this kind of work and benefit of supply chain planning against Less Than Truckload (LTL).

LITERATURE REVIEW

This problem shows similarity to blending problems in operations research because volume distribution throughout the workdays for the best combination of given objective function which contains cost and workload. In the following sections, blending problems features are introduced and show similarity to our problem and how to use it. After that, network features and environment are represented with existing works and it follows with workload feature’s importance and how that means goal programming for the problem.

Thus, blending feature was analyzed first as it plays a crucial part to model as it is the key to the supply chain’s aim and it demands to combine with its network constraints and it increases the difficulty to solve without mathematical model solver. Especially, blending problems could be considered as complex as knapsack problem since both of them are about assignment [7]. There is only one difference between knapsack and blending problems which is blending problems are continuous as they are dealing with amount distribution but knapsack problems are binary such as the decision of “take it or leave it”. This difference makes decision variable continuous.

Although blending problem is more about the combination of chemicals but in this problem, volume carried between two classes (low and high volume distribution points) represents chemicals and distribution of volume to days can be seen as products which result with LTL penalty costs and unbalanced workload. For example, Mendez and friends studied oil refinery to optimize its logistics expenses in order to determine best chemical combination according to their production capabilities [8]. Although this study seems different from our problem but most profitable way to distribute production or volume in our case shows the main logic in this problem.

Another study has shown to model short term balancing importance in refiners according to logistic costs, production capacity and expected the quality of the product. As it results in the final product of blending as well as efficient way to carry under refinery production capacities [9]. This example also supports the importance of logistics and similarity to using blending problem in modeling. However, this also showed a lack of study in blending problem applied in different areas as volume distribution to days does not have a connection with refinery production.

The second part of this study is to analyze the composition of logistic costs and importance of LTL in the supply chain as this study covers balancing the volume among the potential vehicles with the use of fuel efficiency. Therefore, according to one of the recent work of Naoto Katayama and Shigeru Yurimoto, minimizing total line haul cost was aimed and this goal leads them to design efficient design of the logistic network to carry aggregated demand of small points which causes minimizing the number of cross-dock points. However, some cases like covering larger areas might mean inefficient as fuel consumption may rise because of large clusters created [10]. There is also a problem with third party logistics firm as regional deals might prevent to change the larger covers which might contradict. This also shows the importance of partnership strength with third party logistics firms.

Another study of supply chain optimization has searched to optimize transportation network design through simulation as this technique leads to decide warehouse location problem [11]. This aims to decrease their transportation costs including LTL costs and more efficient way with steepest descent algorithm. One of the papers on freight distribution for the daily demand is similar to this study minimizing transportation costs with integral generalized transportation problem on a bipartite graph. In that freight distribution work, rounding and linear programming relaxation techniques are applied and in that problem, user can select their vehicles unlike our problem which basically is solved with GAMS and car selection was based on need rather than user determined selection [12]. This paper shows importance of our work as well as our modeling techniques simplify complicated system to solve the problem. Another study used the goal programming in transportation for different performance measurement techniques. However, this study optimized according to Pareto frontiers and NSGA II method techniques which are heuristic search algorithms [13]. Another goal programming in transportation developed heuristic techniques unlike current transportation model which found the best result for normalized values [14].

There is also another issue to address and it is as important as network features and blending problem. This is load balancing which changes the nature of the problem to goal programming as the problem now has logistic cost minimization as well as workload balancing. As it was a real world problem, this accounts to applicability. This feature is important as it plays balancing the cost of workers as well as it gives the ability to deal with sudden fluctuations of demand which is also another critical point in supply chain and this study. Also, workload balancing can be seen from any areas like distributed computing [15] or assembly line balancing [16]. However, few studies have combined with this feature and cost minimization to solve it as a goal programming which also supports our cases and importance of our work in the example of assembly line balancing with workload balancing and distance [17].

MATHEMATICAL MODEL

The following section is to describe the problem environment and introduce the mathematical model. This model is used for general case which ignores national and religious holiday planning. For holiday cases, this model can be re-run to adjust the distributions days and store planning. In this study, three-week shipments were considered to determine the effectiveness in short term planning (as well as adaptability against demand fluctuations) and comparison. 5 regions were considered in this problem and pre-selected day for low-level stores are assigned to 2 but other numbers were tested in scenario analysis.

Index:

$j = \text{Workdays } (1, \dots, 6).$

$i = \text{Regions } (1, \dots, 5).$

Constants:

CW_{ij} = Volume level in region – i's high sale's class.

AW_i = Volume level in region – i's low sale's class.

$assignDay$ = number of day to distribute.

$Vcap1$ = Vehicle – 1 capacity.

$level1$ = Vehicle – 1 volume LTL level.

$Vcap2$ = Vehicle – 2 capacity.

$level2$ = Vehicle – 2 volume LTL level.

per = Minimum level for ordering.

$M \gg 0$

Decision Variables:

x_{ij} = Assignment of low sale volume for region – i in day – j.

h_{ij} = If LTL is assigned to the vehicle – 2 for region – i in day – j, 1. Otherwise, 0.

u_{ij}^+ = amount over specified level for region – i in day – j.

u_{ij}^- = amount under specified level for region – i in day – j.

z_{ij} = If LTL occurs for region – i in day – j, 1. Otherwise, 0.

m_{ij} = number of vehicle type – 1 for region – i in day – j (integer).

d_j^- = total shipment under balanced demand in day – j.

d_j^+ = total shipment over balanced demand in day – j.

$BCost$ = best cost for LTL only.

tt = objective function.

Model:

$$\text{Min. } tt = \sum_{j=1}^6 \sum_{i=1}^n u_{ij}^- \quad (1)$$

$$Vcap1 * m_{ij} + Vcap2 * h_{ij} * level2 + Vcap1 * level2 * (1 - h_{ij}) + u_{ij}^+ - u_{ij}^- = CW_{ij} + x_{ij} \quad \forall i, j \quad (2)$$

$$Vcap2 * (1 - level2) * h_{ij} + Vcap1 * (1 - level1) * (1 - h_{ij}) \geq u_{ij}^+ \quad \forall i, j \quad (3)$$

$$\sum_{j=1}^6 x_{ij} = AW_i \quad \forall i \quad (4)$$

$$z_{ij} * M \geq x_{ij} \quad \forall i, j \quad (5.a)$$

$$z_{ij} \leq x_{ij} \quad \forall i, j \quad (5.b)$$

$$\sum_{j=1}^6 z_{ij} = assignDay \quad \forall i \quad (6)$$

$$z_{ij} * AW_i * per \leq x_{ij} \quad \forall i, j \quad (7)$$

$$x_{ij}, u_{ij}^+, u_{ij}^- \geq 0 \quad \forall i, j \quad (8)$$

$$h_{ij}, z_{ij} \in \{0,1\} \quad \forall i, j \quad (9)$$

$$m_{ij} \geq 0 \text{ \& integer.} \quad (10)$$

The initial objective function and it minimizes the total amount of LTL is in (1). Decision variables in the objective function is limited with 6 days excluding Sunday and moreover, our initial objective only takes amount under the given limit. Daily LTL amount of assigned volume for regions are determined in (2) and (3). These two equations determine number of vehicle-1 which is used in a full capacity and last vehicle is vehicle-1 or vehicle-2 according to vehicle capacity and assignment to that day. Therefore, the last vehicle decides LTL amount under the given limit which is minimized in our objective. All volumes are forced to be sent with the help of the given equation (4). As this problem is based on finding the days which is determined by users, amount order and order day are need to be connected with constraints (5.a) and (5.b). The low class cannot exceed the number of the given limit for freight days. Therefore, number of freight day is controlled with the constraint in (6) (pre-selected assignment number). In case of low level shipments, a minimum level is determined to prevent unrealistic situation for order shipments which is seen in (7). Decision variables features are presented in (8), (9) and (10).

However, the initial model does not represent goal programming, so in order to use it with workload balancing, the following equations must be replaced with the given objective function with new constraints similar to [13]. The initial objective function is used to find $BCost$ decision variable value which is best cost for minimum LTL amount to normalize the first goal as LTL. Thus, the model balances workload and cost at the same time in (11).

$$\text{Min. } tt = \sum_{j=1}^6 \sum_{i=1}^n u_{ij}^- / \max(BCost, 1) + \sum_{j=1}^6 (d_j^+ + d_j^-) / (\sum_{j=1}^6 \sum_{i=1}^n CW_{ij} + \sum_{i=1}^n AW_i) / 6 \quad (11)$$

The following equation is used as the total fluctuation from balanced workload (12).

$$d_j^+ - d_j^- = (\sum_{j=1}^6 \sum_{i=1}^n CW_{ij} + \sum_{i=1}^n AW_i) / 6 - (\sum_{i=1}^n CW_{ij} + x_{ij}) \quad (12)$$

The following equation is used in scenario analysis to give one day at least between two shipments in (13). This feature can be used as a time for a planner to see fluctuations in demand and prepare for it such as store plays a significant role in the planning phase of ZARA.

$$z_{ij} + z_{i,j+1} \leq 1 \quad \forall i, j \quad (13)$$

SCENARIO ANALYSIS

In this phase, the developed model was tested against the different situation and how it reacts. Especially, some constants are re-evaluated against workload and LTL volumes in order to see expectations can be achieved or applicable. First of all, the model was tested only for LTL volume minimization. In the first test, different numbers of allowed shipment day are used with (13) (at least one day between two shipments). The existing situation is current condition and it means shipment in every day.

In table-1, scenario A and B can be seen. Scenario-A results are based on the model with (13) and Scenario-B results are based on the model with (13). In these scenarios, the objective function is only about LTL volume. Results show there is a significant effect of (13) as one day between two shipments mean important factor on LTL. However, there is a high fluctuation between workloads as Monday and Saturday have the highest difference in most of the cases in scenarios that used (13) (scenarios in A) even existing situation seems more balanced. However, scenarios in B which do not use (13) come more balanced and it has found a result that has not got any LTL amount and balanced workload. This supports our cases as our model can improve LTL costs.

Table 1. LTL minimization results

Scenario-1.A							
Scenario\Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	LTL Volume against Existing LTL Volume
pre-selected day=1	19%	17%	15%	15%	19%	14%	98%
pre-selected day=2	17%	18%	16%	15%	20%	14%	45%
pre-selected day=3	20%	16%	17%	16%	18%	14%	31%
Scenario-1.B							
pre-selected day=5	18%	15%	17%	17%	18%	15%	0%
pre-selected day=2	19%	16%	16%	15%	19%	15%	39%
pre-selected day=3	17%	15%	16%	19%	18%	14%	12%
Existing Situation	18%	15%	17%	17%	18%	15%	Compared

Scenario-2 is about goal programming which minimizing fluctuations of workload and LTL amount for their best values in (11). There is a significant change in scenarios in B which do not use (13). This means there are possible options for workload balancing for the model without one day between two shipments. However, Scenarios in A are not affected as scenarios in B (the only day=1 is affected). This also shows the effectiveness of goal programming in larger options. This means significant options can be found such as scenario-2.B of day=5. Scenario-2 results are seen in Table-2.

Table 2. Goal programming scenario results

Scenario-2.A							
Scenario\Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	LTL Volume against Existing LTL Volume
pre-selected day=1	18%	16%	15%	15%	18%	18%	114%
pre-selected day=2	17%	15%	16%	15%	17%	19%	57%
pre-selected day=3	20%	16%	17%	16%	18%	14%	31%
Scenario-2.B							
pre-selected day=5	17%	15%	17%	16%	18%	17%	0%
pre-selected day=2	18%	15%	16%	15%	17%	18%	47%
pre-selected day=3	17%	15%	17%	15%	18%	18%	17%
Existing Situation	18%	15%	17%	17%	18%	15%	Compared

CONCLUSION

This is a study to understand and exploit supply chain's weaknesses and create a more resilient environment for business. Now, the supply chain is about efficiency and in order to achieve this goal, this study sought an opportunity and decision support technique was offered. This requires known current state of the business which can be the frequency of need in the store, inventory level or production capacities. Thus, it designs need of product flow for LTL and at the same time, there is another issue to balance the workload for demand capacity which can also provide adaptability as one can consider ZARA's example. Results show opportunities and able to outperform the existing situation easily. Moreover, this model shows the importance of planning as unplanned results requires 6 days with highest LTL amount and at the same time, planned approach could have achieved zero LTL and balanced workload. These are the main reasons to have upper hand easily and there is also environment issue as transportation has been seen as the second highest reason for greenhouse gas emissions and LTL transportation is the unnecessary burden of transportation. These are reasons to need this kind of work and also simplicity and realistic calculations can provide better insight into the business and more importantly, it can protect the nature.

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