Transshipment Problem and Its Variants: A Review

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ABSTRACT

The transshipment problem is a unique Linear Programming Problem (LLP) in that it considers the assumption that all sources and sinks can both receive and distribute shipments at the same time (function in both directions). Being an extension of the classical transportation problem, the transshipment problem covers a wide range of scenarios for logistics and/or transportation inputs and products and offers optimum alternatives for same. In this work the review of literatures from the origin and current trends on the transshipment problem were carried out. This was done in view of the unique managerial needs and formulation of models/objective functions. It was revealed that the LLP offers a wide range of decision alternative for the operations manager based on the dynamic and challenging nature of logistics management.

Key words: Transshipment problem, Linear Programming Problems (LPP), model, objective functions, decision alternative.

1. Introduction

The transportation of goods and/or services (from the plants/warehouse to the consumer/final destination) is a major concern for every manufacturer. This concern forms an integral part of the production process. Distribution managers are constantly being faced with this critical transportation need to which they must make the best decisions for the benefit of the consumer at the same time considering the overall profit of the organization. This decision is further complicated with the challenges arising from globalization, increasing market competition, and accelerated technology development. Due to demand variability and market uncertainty, achieving these goals requires flexibility as much as possible, short response time and development of new innovative solutions for reaching the customers (Noham and Tzur, 2014). However, this challenge faced by the decision makers and/or distribution managers is easily surmountable by the decision alternatives provided for by Operations Research.

One of the classic uses of Operations Research and, in particular of Linear Programming is to propose optimum alternatives for the logistics or transport of inputs and products from a group of suppliers to a group of receivers or petitioners (LPW, 2014). Among the Linear Programming Problems (LPP), the transportation problem is a special category which has been widely studied due to its importance in the logistics and operations management where distribution of goods and commodities from sources to destinations is an important issue (Chaudhuri and De, 2013). In considering process with the inclusion of intermediaries between the sources and destinations, this becomes an extension of the basic model of transport which is commonly known as a model of transportation with transshipment (LPW, 2014).

2. History of Transshipment Problem

The Transshipment Problem has a long and rich history, dating back to the medieval times when trading started becoming a mass phenomenon. It was first introduced by Orden (1956) in which he formulated an extension of the original transportation problem to include the possibility of transshipment. This extension of the transportation problem saw a modification in which each origin and destination can act as an intermediate point through which goods can be temporarily received and then transshipped to other points or to the final destination (Gass, 1969: cited by Briš, 2010). From the original work done by Orden, the transshipment technique was and is still used to find the shortest route from one point in a network. Both methods, that is the transportation problem and transshipment problem are widely used for the planning of large scale distribution of goods especially in areas where the distances travelled (via road or otherwise) are very far (NagoorGani et al., 2012).

So many researchers in recent times have extensively studied this LPP and have developed different variants based on the needed objective function.

This study therefore seeks to review literatures on the emergence of the transshipment problem as well as the variants based on objective functions and approach.

3. Literature Review

The transshipment problem is a unique Linear Programming Problem. From the unset of its introduction by A. Orden in 1956, its acceptance and/or use has greatly broadened over the years. The initial problem took into consideration the use of intermediate points through which shipments were to be allowed to pass through to the needed destination. From his work the transshipment problem was and still is the ideal for solving shortest route problems.

Rhody (1963) considered the transshipment problem as a reduced matrix model while King and Logan (1964) went further to formulate an alternative model that allows simultaneously the transportation of main goods through processors to the market as end products as a transshipment problem. Hurt and Tramel (1965) adopted the studies of King and Logan as an alternative formulations of the transshipment problem within the framework of the transportation model but proposed that there was no need for the subtraction of artificial variables.

In 1965 Judge et al. proposed the use of the transshipment problem to cover a multiregional, multiproduct and multi-plant problem. They formulated this transshipment problem in the form of general linear programming model (Judge et al., 1965). The time minimizing transshipment problem was studied by Garg and Prakash in 1985. Their study proposed very clear algorithms as to how the optimal time can be achieved while transshipping goods from different origins to different destinations. Osman and Ellaimony (1984) introduced an algorithm for solving bi-criteria multistage transportation problems. Herer and Tzur (2001) studied the dynamic transshipment problem. Their work was the first time transshipments are examined in a dynamic or deterministic setting. They also considered a system of two locations which receives their stock from a single supply point, and transshipments were possible between these locations.

The introduction of a multi-objective transportation problem (MOTP) with interval cost, source and destination parameters and multi-objective transportation problem (MOTP) under fuzziness were studied by Das et al. (1999) and Abd El-Wahed (2001) respectively. Saraj and Mashkoorzadeh (2010) studied the multi objective transportation problem (MOTP) using interval numbers under fuzziness.

The transshipment problem considers that within a given time period each shipping source has a certain capacity and each destination has certain requirements with a given cost of shipping from source to destination. The Objective Function is to minimize total transportation costs and satisfy destination requirements within source requirements (Gupta and Mohan, 2006).

Notably the main priority in the transshipment problem was first and foremost to obtain the minimum-cost transportational route, however technological development slowly gave place to minimum-durational transportation problems.

Hmiden et al. (2009) studied the transshipment problem that is characterized by the uncertainty relative to customer demands and transfer lead time. They consider a distribution network of one supplier with several locations selling a product. They used expert judgments to evaluate customer demands and the transfer lead time which they represented by fuzzy sets. The purpose of their study was to identify a transshipment policy that takes into account the fuzziness of customer demands and transfer lead times and to determine the approximate replenishment quantities which minimize the total inventory cost. They proposed a new transshipment policy where the transshipment decision is made within the period and the possible transshipment decision moments belong to a fuzzy set to achieve their aim. For the expert judgments they also consider the decision maker behavior types (pessimistic and optimistic) to determine the precise transshipment decision moment and the transshipment quantity.

Hoppe and Tardos (2000) concluded that the transshipment problem is defined by a dynamic network with several sources and sinks and that there were no polynomial-time algorithms known for most of transshipment problems. They gave the first polynomial-time algorithm for the quickest transshipment problem and this algorithm provided an integral optimum flow. Herer and Tzur (2001) investigated the strategy of transshipments in a dynamic deterministic demand environment over a finite planning horizon.

Tadei et al. (2009) noted in their research that in any transshipment problem the transportation process takes place in two stages: from origins to transshipment facilities and from transshipments facilities to final destinations. Economically put, the process could incure three kinds of cost: the fixed cost of locating a transshipment facility, the transportation cost from an origin to a destination through a transshipment facility and the throughput operation cost at each transshipment facility. Their study pointed out the overall cost implication of the transshipment process which may not be incorporated in the transshipment LPP. Kestin and Uster (2007) added that the throughput operations cost are generated by the freight treatment operations, such as loading/unloading, but also to inventories and postponed processing, such as packaging, testing etc. While the fixed cost and the transportation cost are usually well defined, easy to determine and measure, the throughput operation cost is vague, stochastic and cannot be easily measurable, so that their probability distribution remains in general unknown (Tadei et al., 2009). Malakooti (2013) further considered multi-objective transshipment problem (MOTP).

Agarwal and Ergun (2008) considered transshipment in their study but did not consider its cost implication. They explain this highlighting the tremendous increase it will cause to the size of the graph and concluded that "Our results indicate high percentage utilization of ships' capacities and a significant number of transshipment in the final solution". When the transshipment cost is not taken into account the transshipment in the optimal solution will probably be inappropriately large (Ameln and Fuglum, 2015).

Most recent literatures in the study of transshipment covered areas like the Bi-criteria large-scale transshipment problems. Alkhulaifi et al., (2014) presented a formulation of different structures of bi-criteria large-scale transshipment problems and an algorithm for solving a class of them, which they proposed can be solved using the decomposition technique of linear programming by utilizing the special nature of transshipment problems. Al-Rajhi et al., (2013) studied the decomposition algorithm for solving a class of bi-criteria multistage transportation problem. They noted that in transportation problems with one or multistages, single criterion of minimizing the total cost is usually considered however in certain practical situation this may not be the case as two or more objectives may be relevant. For example, the objectives may be minimizations of the total cost, consumption of certain scarce resources such as energy, total deterioration of goods during transportation, etc.

Rajendran and Pandian (2012) introduced the splitting method which they proposed for obtaining an optimal solution to a transshipment problem where all parameters are real intervals. For them, the total transportation cost in the transshipment problem is always lesser than that of the classical total transportation cost. Somani (2015) proposed an innovative method for finding optimal transportation cost which he called the Somani's Approximation Method (SAM). Panda and Das (2014) presented a two-vehicle cost varying transportation model. In the model they noted that the transportation cost varies based on the capacity of vehicles and the amount of transport quantity.

Khurana et al., (2015) considered a transshipment problem with the objective to minimise the duration of transportation. They proposed an algorithm that solves the original transshipment problem by transforming it into an equivalent transportation problem and the optimal solution of the original problem is obtained from the optimal solution of the transformed transportation problem. It involves a finite number of iterations that is easily applicable. The algorithm finds out the optimal time for transportation from origins to destinations with transshipment. With this transshipment variant managers are provided with another alternative solution to a variety of production distribution problems.

In another 2015 study by Archana Khurana, she used the transshipment technique to find the shortest route from one point in a network to another point and is very useful to reduce the cost of transportation. The study focused on the shortest route as against the minimum-cost and minimum-duration from earlier studies. She formulated a three-dimensional linear transshipment problem. This was due to constraints that may sometimes arise from the production budget or politically induced, the total flow of transportation is specified by some external decision maker which thereby results in restricted and enhanced flow in the market. The optimal solution of the specified problem is obtained by transforming it into an equivalent transportation problem by adding an additional row and a column and avoiding the trouble of determining a least-cost route for every origin-destination pair. She was also confident that arriving at the optimal solution of such a problem would be of practical interest to decision makers with such peculiar challenge (Khurana, 2015b).

Akilbasha et al. (2016) proposed a new method for finding an optimal solution for integer transportation problems where transportation cost, supply and demand are intervals. They called it the split and separation method based on zero point method. This method can served as an important tool for the decision makers when they are handling various types of logistic problems having rough variable parameters.

Bretschneider (2013) studied transshipment problem as an example of the dynamic flow problem which is applicable for the model flow for evacuation planning. He, referring to the work done by Hoppe and Tardos, (1994) noted that the dynamic network flow models can be used to describe evacuation problems and that the question of how to obtain the quickest flow with multiple sources is often referred to as the evacuation problem. For the case of evacuation planning, the quickest transshipment problem determines the evacuee flow such that all evacuees leave the danger zone in a minimum amount of time or, in other words, the clearance time of the evacuation zone is minimized (Bretschneider, 2013).

Pascoal et al. (2006) studied the single path from a source to sink while minimizing the network clearance time. Hoppe and Tardos (1994) considered the quickest transshipment problem with multiple sources and a single sink called the evacuation problem. Fleischer (2001) investigated the quickest transshipment problem, where the transit times of all arcs are zero, but the inflow is still assumed to be capacitated.

Ameln and Fuglum (2015) introduced the use of transshipment to the liner shipping network designs which was less common a few decades ago. They noted that as at 1991 transshipment was not included in the studying route planning for liner shipping network. Ameln and Fuglum citing Notteboom and Rodrigue (2008) stated that the use and influence of transshipment on the liner shipping network design was described and whether or not transshipment operations are allowed between the routes differ based on each researcher while Meng et al. (2014) noted that 8 out of 12 of the studies on fleet deployment did not consider transshipment. Reinhardt and Pisinger (2011) argue that transshipment of goods is frequently occurring in liner shipping and the associated cost should not be ignored when designing the network. They claim that their paper presents the first exact solution methods to the LS-NDP (Liner Shipping Network Designs Problem) with transshipment cost (Ameln and Fuglum, 2015).

More researchers have also studied the transshipment problem with mixed constraints i.e. equality and inequality constraints, impaired/restricted and enhanced flow (Thirwani et al. 1997; Khurana and Arora, 2006, 2011; Khurana, 2015).

4. Variants and Corresponding Models of Transshipment Problem

4.1 The General Model

The general linear programming model of a transshipment problem is

$$Min \sum_{allarcs} c_{ij} x_{ij}$$

Subject to

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = s_i \text{Original nodes} i$$

$$\sum_{arcout} x_{ij} - \sum_{arcin} x_{ij} = 0 \text{ Transshipment nodes}$$

$$\sum_{arcin} x_{ij} - \sum_{arcout} x_{ij} = d_i \text{Destination nodes} j$$

Where

X_{ij} = Amount of unit shipped from node *i* to node *j*

C_{ij} = Cost per unit of shipping from node *i* to node *j*

S_i = Supply at origin node *i*

d_j = Demand at sink node *j*

From the above model we understand that the supply point is the point(s) that can only send goods to another point(s) but cannot receive goods. While the demand point(s) is/are also a point(s) that can only receive goods from other points but cannot send any. Then the transshipment point(s) is that point(s) that can receive goods from other points and also send goods to other point(s). In this model all goods within the network must be transported/shipped without any reservations until all constraints are fully satisfied.

Another method that uses the above model considers the absence of an obvious transshipment point. The model therefore assumes the possibility of transshipments. In this case all the source and sinks can serve as transshipment points i.e. they can both receive and give shipments. This is unlike models with very clear points for transshipments to take place.

The model is to minimize Z

$$\sum_{i=1}^{m+n} \sum_{j=1}^{n+m} c_i \, x_{i,j}, \quad i \neq j$$

subject to:

- $x_{r,s} \geq 0; \; \forall r = 1 \dots m, s = 1 \dots n$
- $\sum_{s=1}^{m+n} x_{i,s} - \sum_{r=1}^{m+n} x_{r,i} = a_i; \forall i = 1 \dots m$
- $\sum_{r=1}^{m+n} x_{r,m+j} - \sum_{s=1}^{m+n} x_{m+j,s} = b_{m+j}; \forall j = 1 \dots n$

$$\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_{m+j}$$

4.2 The Unbalanced Model

In some cases the transshipment of the total supply (from the origin) does not equal the demand (in the destination) thereby making it an unbalanced transshipment problem.

$$\sum_{i=1}^{m} a_i \neq \sum_{j=1}^{n} b_{m+j}$$

This model is converted to a balanced model by the addition of dummy supply or dummy demand depending on the where the short fall exists.

4.3 The Impaired flow Transshipment Model

This model arises in situations where a particular level of stock is reserved at the source for certain reasons like emergencies. The total flow of the shipments is restricted. The level of restriction may be set at point Q which gives the following mathematical model.

$$\sum_{i=1}^{m}\sum_{j=m+1}^{m+n} x_{ij} = Q$$

Or

$$\sum_{i=1}^{m+n}\sum_{j=1}^{m+n} x_{ij} = Q'$$

Where $Q' = Q + (m+n)T$

And T = $\max\left(\sum_{i=1}^{m} a_i , \sum_{j=m+1}^{m+n} b_j\right)$

The model is given

Min Z =

$$\sum_{i=1}^{m+n}\sum_{j=1}^{n+m} t_i\, x_{ij,\ i\neq j}$$

Subject to

$$\sum_{j=1}^{m+n} x_{ij} \le a_i + T; \quad \forall i = 1,2,\dots,m$$

$$\sum_{j=1}^{m+n} x_{ij} = T; \quad \forall i = m+1, m+2, \dots, m+n$$

$$\sum_{i=1}^{m+n} x_{ij} = T; \quad \forall j = 1,2,\dots,n$$

$$\sum_{i=1}^{m+n} x_{ij} \le b_j + T; \quad \forall j = m+1, m+2, \dots, m+n$$

$$\sum_{i=1}^{m+n}\sum_{j=1}^{n+m} x_{ij} = Q'\left(Q' < \min\left\{\sum_{i=1}^{m} a_i + (m+n)T, \qquad \sum_{j=m+1}^{m+n} b_j + (m+n)T\right\}\right)$$

(Impaired flow)

$$x_{ij} \ge 0 \qquad \forall i,j = 1,2,\dots,m+n\ (i \neq j)$$

$$t_{ij} \geq 0 \qquad \forall i, j = 1,2, \dots, m + n$$

It will be noted that the impaired flow constraint shows that a total $\{\sum_{i=1}^{m} a_i + (m+n)T - Q'\}$ of the source reserve will have to be kept at the various sources while at the destination the total $\{\sum_{j=m+1}^{m+n} b_j + (m+n)T - Q'\}$ destination slacks will be retained at the various destinations.

The above model clearly differs from the general model as it takes into accounts an extra constraint known as the impaired flow constraint. The flow constraint fulfils the desire of the operations manager without necessarily altering the basics and standards of the original transshipment model. In this case an extra destination to receive the source reserves and an extra source to fill up the destination slacks are introduced which gives the model the needed balance.

4.4 The Enhanced flow Transshipment Model

Another model worthy of note is the enhanced flow model. Unlike the impaired flow where reservations are made in the source, the model comes to play with extra quantities needed at the demand point(s). The enhanced flow model therefore occurs when due of an extra demand in the market, the total flow has to be enhanced (increased), forcing the factories (supply points) to increase their productions so as to meet the extra demand. In this case the Q' value is maximized. Mathematically put

$$\left(Q' > \max\left\{\sum_{i=1}^{m} a_i + (m+n)T, \qquad \sum_{j=m+1}^{m+n} b_j + (m+n)T\right\}\right)$$

The model is given

Min Z =

$$\sum_{i=1}^{m+n} \sum_{j=1}^{n+m} t_i \, x_{ij,\ i \neq j}$$

Subject to

$$\sum_{j=1}^{m+n} x_{ij} \geq a_i + T; \quad \forall i = 1, 2, \dots, m$$

$$\sum_{j=1}^{m+n} x_{ij} = T; \quad \forall i = m+1, m+2, \dots, m+n$$

$$\sum_{i=1}^{m+n} x_{ij} = T; \quad \forall j = 1, 2, \dots, n$$

$$\sum_{i=1}^{m+n} x_{ij} \geq b_j + T; \quad \forall j = m+1, m+2, \dots, m+n$$

$$\sum_{i=1}^{m+n} \sum_{j=1}^{n+m} x_{ij} = Q' \left(Q' > \max\left\{\sum_{i=1}^{m} a_i + (m+n)T, \qquad \sum_{j=m+1}^{m+n} b_j + (m+n)T\right\}\right)$$

(Enhanced flow)

$$x_{ij} \geq 0 \qquad \forall i, j = 1,2, \dots, m+n \ (i \neq j)$$

$$t_{ij} \geq 0 \qquad \forall i, j = 1,2, \dots, m+n$$

To deal with the enhanced flow in the above model, a related transportation problem has to be formulated by adding an additional row with availability equal to $Q' - \{\sum_{i=1}^{m} a_i + (m+n)T\}$ and an additional column with demand equal to $\{Q' - \sum_{j=m+1}^{m+n} b_j + (m+n)T\}$. These were discussed extensively by Khurana et al., (2015).

The tilt from the impaired and enhanced flow models gives the decision maker more decision options for the challenging and dynamic market needs.

4.5 Bi-Criteria Multistage Transshipment Models

Another model worthy of note is the bi-criteria large scale transshipment problems studied by Alkhulaifi et al. (2014). They extended the use of the transshipment problem to cover cases of more than one objective functions (bi-criteria) in large scales. We consider 2 cases and are given thus:

1) ***Bi-Criteria Multistage Transshipment Problem of the First Kind (BMTSP 1)***

This case shows a multistage transshipment problem without any restrictions on intermediate stages. This can be represented mathematically with certain assumptions.

Min Z_1 =

$$\sum_{i=1}^{n} \sum_{j=1}^{n} c_{ij}\, x_{ij}$$

Min Z_2 =

$$\sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij}\, x_{ij}$$

Subject to

$$\sum_{j=1}^{n} x_{ji} - x_{ji} = a_j; \;\; j = 1, 2, \dots, ni \neq j$$

$$\sum_{j=1}^{n} x_{ij} - x_{ij} = b_j; \;\; j = 1, 2, \dots, ni \neq j$$

$$x_{ij} \geq 0 \; \forall i, j$$

Where

a_j= availabilities (Supply), j= 1, 2, 3, ..., n

b_j = requirements (Demand), j= 1, 2, 3, ….., n.

n = number of sources and destinations

c_{ij} and d_{ij} = The minimum transportation costs and deteriorations from i to j respectively, i and j= 1, 2, 3, …., n.

X_{ij} denotes the quantity shipped from i to j;

x_{ji} is the neat amount transshipped through point j where $x_{ij} \geq 0$.

$c_{ij} = 0$ for the quantity shipped from the source S_i to itself and from destination d_j to itself

2) ***Bi-Criteria Multistage Transshipment Problem of the Second Kind (BMTSP 2)***

The second kind (BMTSP 2) deals a situation where the transportation at any stage is independent of the transportation of the other stages. This is a multistage system characterized by independence in transportation. It assumes a k^{th} stage in the transportation and K = 1, 2, ..., N.

The model is given as:

Min Z_1^k=

$$\sum_{i_k=1}^{n_k}\sum_{j_k=1}^{n_k} c_{i_k j_k}^k \, x_{i_k j_k}^k$$

Z_2^k =

$$\sum_{i_k=1}^{n_k}\sum_{j_k=1}^{n_k} d_{i_k j_k}^k \, x_{i_k j_k}^k$$

Subject to

$$\sum_{i_k=1}^{n_k} x_{j_k i_k}^k - x_{j_k j_k}^k = a_{j_k}^k;\ \ j_k = 1, 2, \ldots, n i_k \neq j_k$$

$$\sum_{i_k=1}^{n_k} x_{i_k j_k}^k - x_{j_k j_k}^k = b_{j_k}^k;\ \ j_k = 1, 2, \ldots, n i_k \neq j_k$$

$$x_{ij} \geq 0 \ \forall i, j$$

Where

$c_{i_k j_k}^k$ = 0 for the quantity shipped from the source (S_i) to itself and from destination (d_j) to itself

And the minimum transportation cost given as

Min $Z = \sum_{k=1}^{n} MinZ^k$

It will be well noted that the above models covers transshipment at a very large scale. Operations managers who deal on large scale would do better maximizing these models for their operations.

4.6 Other Transshipment Models

The transshipment problem is dynamic in the sense that it also offers the operations manager a model that covers not just the cost and/or quantity to be transported that satisfies the supply and demand constraints but a variant that can be used for locating the transshipment points.The capacitated transshipment location problem under uncertainty was studied by Tadei et al. (2009). The model is given below.

$$min_y \sum_{k\in K} f_k y_k + \acute{\mathrm{E}}_\theta \left(min_s \sum_{i\in I} \sum_{j\in J} \sum_{k\in K} \bar{r}_{ij}^k(\theta)\, s_{ij}^k \right)$$

Subject to

$$\sum_{j\in J} \sum_{k\in K} s_{ij}^k = P_i, \qquad i \in I$$

Supply constraint

$$\sum_{i\in I} \sum_{k\in K} s_{ij}^k = Q_j, \qquad j \in J$$

Demand constraint

$$\sum_{i\in I} \sum_{j\in J} s_{ij}^k \le U_k y_k, \qquad k \in K$$

capacity restriction at each transshipment facility k

$$x_{ij}^k(\theta) = s_{ij}^k, \forall \theta_{kl}, i \in I, j \in J, k \in K, l \in L_k$$

$$x_{ij}^k(\theta) \ge 0, \forall \theta_{kl}, i \in I, j \in J, k \in K, l \in L_k$$

$$y_k \in \{0,1\}, k \in K$$

Where

I: set of origins

J: set of destinations

K: set of potential transshipment locations

L_k: set of throughput operations scenarios at transshipment facility $k \in K$

P_i: supply at origin $i \in I$

Q_j: demand at destination $j \in J$

U_k: throughput capacity of transshipment facility $k \in K$

f_k: fixed cost of locating a transshipment facility $k \in K$

y_k: binary variable which takes value 1 if transshipment facility$i \in I$ is located, 0 otherwise

c_{ij}^k: unit transportation cost from origin $i \in I$ to destination $j \in J$ through transshipment facility $k \in K$

θ_{kl}: unit throughput cost of transshipment facility $k \in K$ in throughput operation scenario $l \in L_k$

s_{ij}^k: flow from origin $i \in I$ to destination $j \in J$ through transshipment facility $k \in K$

$\acute{E}_\theta$denotes the expected value with respect to θ;

The Capacitated Transshipment Location Problem under Uncertainty (*$CTLP_U$*)is balanced if

$$\sum_{i \in I} P_i = \sum_{j \in J} Q_j = T$$

5. Discussion and Conclusion

The literatures above clearly show the different views and approach of researchers on the transshipment problem. Though there are more variants than those reviewed in this work. However, each model explains the peculiar approach of the researcher to meet the dynamic needs of the operations manager in various industries where the transshipment problem is applied.

The transshipment problem is unique in the sense that it offers a wide variety of decision alternatives to accommodate the changing trends in dealing with shipments of goods to measure up to modern and global practices. It also takes into accounts the scale (small and large) of transshipments for small, medium and large firms.

Another advantage in the transshipment problem based on the objective function is its ability to cover varying concerns. It is used for minimum costs problems, shortest route problems, minimum time problems and more importantly the facility layout/location problems amongst others. Also models that cover more than one objective function per time are available for the decision maker who is interested in solutions for multiple concerns at the same time.

Further more in cases of emergencies (fire outbreak, natural disasters, military services, etc) and peak seasons (festivities, marriages, etc) where the flow requires enhancing or from an alternate point of view for situations like recession, budget/political constraints where the operations manager is forced to hold or restrict the flow of goods, the transshipment problem with enhanced and impaired flow comes in handy.

Due to the dynamic nature of logistics, sometimes goods transportation may not move directly from suppliers to customers. When such arises, the decision maker can optimize the transshipment problem into more than one stage. He/she may wish to consider all efficient extreme points and their related distributions that will form basic parts of the operations policies.

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