

A PERSPECTIVE FOR A NEW MULTIPLE-PARTY LOGISTICS MODEL FOR E-COMMERCIAL LOGISTICS

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Xiechun Lu
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Committee:

_____	Dr. Ruixin Yang, Thesis Director
_____	Dr. Paul Delamater, Committee Member
_____	Dr. Kevin Curtin, Committee Member
_____	Dr. Anthony Stefanidis, Department Chairperson
_____	Dr. Donna M. Fox, Associate Dean, Office of Student Affairs & Special Programs, College of Science
_____	Dr. Peggy Agouris, Dean, College of Science
Date: _____	Summer 2017 George Mason University Fairfax, VA

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by

Xiechun Lu
Bachelor of Geographic information System
Wuhan University of Technology, 2014

Director: Ruixin Yang, Associate Professor
Department of Geography and GeoInformation Science

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George Mason University
Fairfax, VA

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ABSTRACT

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Xiechun Lu, M.S.

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Thesis Director: Dr. Ruixin Yang

With the rapid development of e-commerce, the requirement for logistics becomes much stricter: the traditional third-party logistics (3PL) model cannot meet consumers' high demand, and it also exposes some other problems. To improve logistics distribution efficiency and service quality, this study will test a new model, multiple-party logistics (MPL) model, which employed superiorities of different traditional models. The MPL model divides the whole distribution process into two phases (inter-warehouses shipping and delivering), employs different strategies to guarantee controllability for sellers and consumers during the whole process, and potentially increases profit. In this study, a comparison analysis of 3PL and MPL models is carried out in order to test the potential of the MPL model, and find out in which situation it can compete with traditional 3PL model.

1. INTRODUCTION

With the development of technology and the Internet, online shopping has become extremely popular (Stevens, 2016). Consumers no longer need to visit stores to pick up what they want. They can place their order online, anytime and anywhere. Sellers then take measures to move their products to consumers. This process includes packing, processing in circulation, selection and transportation.

The business logistics have been defined as having the right item in the right quantity at the right time, at the right place, at the right price, in the right condition, to the right customer (Suman, 2010). Most research focuses on how to improve logistical efficiency (Lin et al. 2011; Ahluwalia & Nema, 2006), aiming to increase profit for sellers and provide more services to consumers. Sellers need their products to be sent to consumers on time and also provide good quality and reasonable prices. A logistics model is the expected logistics system which includes the whole process management to move products from sellers to consumers. It provides an unobstructed material flow, which tries to guarantee that the entire process is efficient and smooth. Also, it minimizes the cost, including reducing the amount of material handling cost and transportation cost.

A logistics model can be generally classified by the number of parties in the model. The third-party logistics (3PL) model is the most popular model in the world (McDowell, 2016). In this model, there are three parties: the seller, the consumer, and the

logistics service provider. Sellers send their products to the service provider and the service provider takes charge of all the logistical management, from packing products to shipping them to consumers (Leahy et al., 1995). The 3PL model relieves the stress of the sellers and maintains the stability of the entire process. Sellers can focus on their products and services, throwing the distribution work with expert service providers. These experts have enough experience and resources to maintain their routes. However, there are also some disadvantages of the 3PL model: Sellers lose control over shipping functions and extra transportation costs are a regular phenomenon.

As the major logistical model in the world, the 3PL model's disadvantages have a big influence on consumers' experiences, and sellers' profit. Most literature focuses on how to apply the 3PL model into specific situations, or how to mine data that can be applied to the 3PL model (Lin et al., 2011; Ahluwalia & Nema, 2006). Few pieces of literature aim to improve this model, or "evolve" it into a new logistics model. These issues should draw more attention. This project introduces a Multiple-Party logistics (MPL) model, which has the potential to take the place of the 3PL model in some situations.

The objectives of this study are: 1. Introduce how to apply the MPL model. 2. Test whether the MPL model can have a better performance than the traditional 3PL model by sellers making more profit, savings on transportation costs, or consumers experiencing a better logistics service. To test it, this project carries out a comparative analysis by calculating simulated transportation costs and predicting the profits for the

two models. This work also discusses which party (or parties) in the logistics chain will benefit from the MPL model and whether it is worth applying.

2. LOGISTICS MODELS REVIEW

2.1 3PL model

With the market competition intensifying, the pursuit of efficiency and division of labor in organizations has been refined. In order to improve their core competitive ability, reduce costs, and increase the flexibility of enterprise development, more and more enterprises, who not familiar with the business of subcontracting, are willing to give their logistic work to other organizations. Because of this, some transporting and storing companies begin to expand their traditional business, enter the logistics system, and gradually grow to become logistics service enterprises, able to provide some or all of the logistics services. This service is the "third-party logistics."

The benefit for applying 3PL is clear: sellers can throw the distribution jobs to the 3rd parties which have many logistics experts, and sellers can focus on their goods. The 3rd party service providers have a high-quality guaranteed international logistics service and they remove the costs of building extra warehouses or maintaining the trade routes (Hosie et al., 2012). There are also some disadvantages for this logistics model: the sellers and the consumers have less control over the delivery process, which means when there is any error in the delivery process, it is hard to find it and solve it immediately (Weng, 2013). For the 3rd party service providers, they need provide service for multiple sellers, and consider routes required by different sellers, and potential increase the error

factors which may also affect the sellers and the consumers. The more routes they maintain, the more errors they may make.

Inbound Logistics reports that the recent development of 3PL is slow (McDowell, 2016). McDowell (2016) used the survey data collected from 6,600 consumers in 3PL to clarify that at the beginning of the 21st century. For several years prior, this number increases strong and steady, going all the way back to 2011, in which survey reported only 73 percent growth, and in 2014, 92 percent of users thought it was worthwhile. But in 2016, only 84 percent of respondents reported growth. There may be various reasons for this trend of decline but mainly, two major deficiencies in 3PL model exist.

First, a large number of requests from consumers place a burden on the service providers. High demands for new logistics and distribution facilities are observed in many countries (Yu et al., 2010). There are only a few companies that can play this vital role, because their service must cover the whole region and the service must be reliable. Thus, when more sellers and more individuals employ their service, they need to invest in locating new warehouses and pay more to maintain their routes for increasing capacity. If the route's capacity cannot meet requirements or meet a peak-time demand, the whole logistics chain will be affected. The services will, therefore, be questioned by consumers. Multiple sellers applying 3PL service from the same company also will urge the service provider chose an eclectic plan, which means the providers establishes the routes minimizing the total cost, but for the individual 3PL user, the cost is increased. For instance, service providers transfer goods to their own distribution center, then ship them to consumers instead of just ship goods from sellers to consumers. The objective of a

service provider is to optimize the routes with the lowest total cost for all the sellers, but the transportation cost for each seller has not be optimized. In other words, consumers cannot receive their packages in the shortest time, because providers need serve other sellers' consumers.

Second, the internal deficiency cannot be improved easily. Most research related to the 3PL model is focused on how to apply 3PL into specific fields, or how to adjust these models to meet specific situations. These research can deal with practical issues, but cannot improve the 3PL model. The participation of the third party, and the rigid model pattern, block the direct connections between sellers and consumers. Sellers lose their control over the shipping functions. In addition, the 3PL model ignores some potential resources for sellers who have physical stores. Physical stores have not been taken into consideration as a part of the logistics chain. To improve current logistical models, the rigid “party-pattern” needs to be broken, and contact between sellers and consumers increased.

2.2 Alternative logistics models

Other than the 3PL model, there are some other models which impact the current logistics market, and are taking the market share. Although these models also have their own disadvantages, their specialties can cover the shortages of the 3PL model.

With the development of information technology and computer network technology, logistics information and knowledge has been engaged in the logistics service industry (Win, 2008). This leads to 4PL model. The fourth-party logistics model means that a new organization is engaged in the logistics service business. For these

organizations, they do not need to bear the responsibility for goods transportation or storage, neither need to join in the real logistics procedures. Instead, they provide information support and technical assistance.

Engagement of a fourth party can change the whole logistics chain structure. Compared to the 3PL service, the 4PL model is not rigid. The 4PL logistics chain is similar to 3PL, but 4PL companies can offer valuable information and suggestions to the other three parties. Sellers can also participate in the delivery phase so that they can get more useful feedback and suggestions. The 4PL model also includes broader areas: it not only focuses on providing management service for logistics chains, but also creates solutions by evaluating the supply chains and the whole system. 4PL model is more like the “new intelligent” 3PL model, which can alter the logistics chain based on situations. The disadvantages of 4PL model are also clear: the whole logistics system is more complicated than other logistics models. So only a few companies are able to play this role. Most 4PL models are only employed by international businesses (Guo, 2006).

Another logistics model which has been employed by a small number of enterprises is the 2PL model. Chinese online retailer JD is a good example that employs 2PL model. JD has the fastest shipping speed in China, compared to other e-commerce companies. The reason why JD has the fastest speed is that it has many warehouses. Five prime warehouses, located in the major cities, and 34 local-level warehouses in all the provinces. This logistics distribution model guarantees that the seller takes a participation in the logistics chain, and uses their own routes. Their goods will be shipped from warehouses to consumers directly, so consumers get their packages from their nearest

warehouse, which follows the utility-based accessibility measures: people select the alternative with the lowest time cost (Chen, 2012). However, JD is not an expert in the logistics field. The disadvantage of 2PL is that JD cannot carry on doing all the distribution jobs, and it cannot balance supply with demands. JD's local-warehouses are more like independent: The logistics flow is only from prime-warehouse to local warehouses, so there is no connection between two local warehouses and two prime warehouses. This is an unbalanced distribution model, which means if there is any "emergency" in one local warehouse, it cannot get any assistance from other places. For instance, if a Beijing consumer wants to buy a smart phone from JD, but this product is out of stock in the Beijing warehouse, he/she cannot order it, even this product is available in the Shanghai warehouse.

2.3 Multiple-party logistics model introduction

Most logistics studies and research focus on one kind of model application and its improvement. Only a few of them focus on comparing different models, and try to learn from others' strongpoints to offset weaknesses. The MPL model is an exploratory model that tries to combine the advantages of different models. Like 3PL, it contains three parties; like 4PL, it breaks the rigid pattern so that sellers are engaged into every phase of the logistics chain; and like 2PL, it provides the nearest start point for delivery to consumers to minimize time cost. This MPL also can be viewed as subspecies of 3PL. "Multiple" means that there are multiple parties in this model handling the shipping job. There are also three parties in this logistics model, but sellers and the third parties both need to handle part of the shipping work.

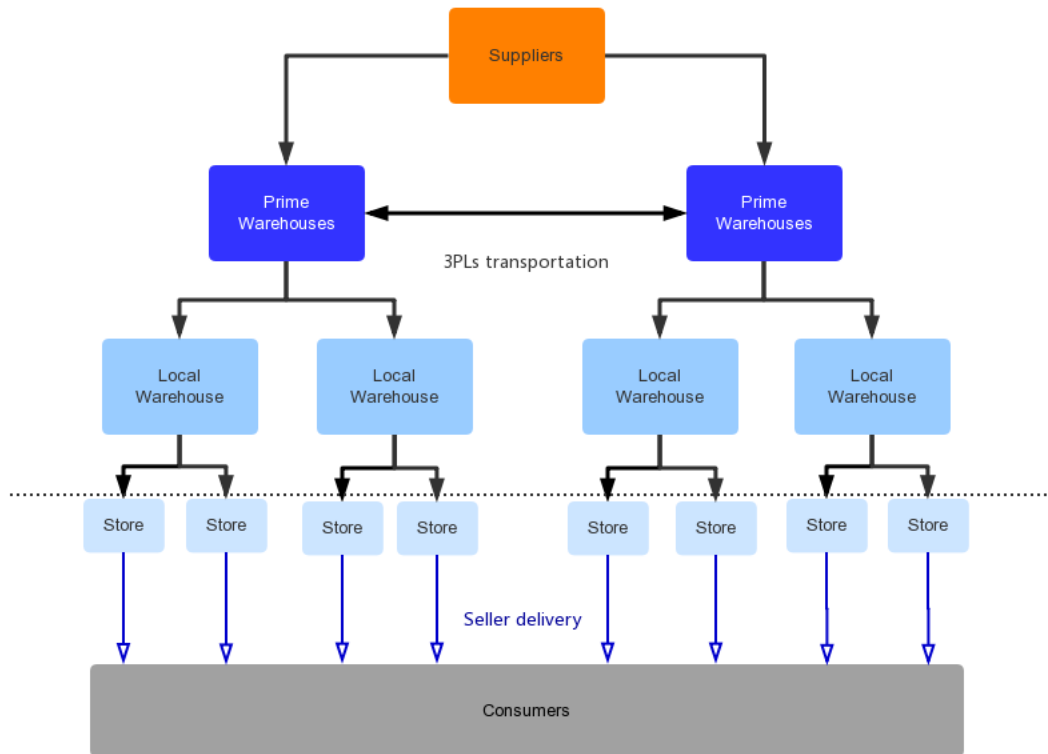


Figure 1. MPL model structure. The solid arrows represent transportation service provided by service provider. The hollow arrows represent sellers' delivery process.

In the MPL model, there will be two kinds of warehouses, prime warehouses and local warehouses. For each prime warehouse, it has a serving region in which there are several local warehouses. The transportation routes from a prime warehouse can only link to another prime warehouse, or the local warehouses in its own servicing region. Each local warehouse belongs to its nearest prime warehouse. It also has a serving area where there are several physical stores. The transportation routes from a local warehouse can only link to its prime warehouse or the physical stores in its own servicing area. This study argues that part of the current logistics distribution can be brought back to the 2PL

model: sellers deliver the goods to the consumers from their nearest physical store, by themselves, which can guarantee that consumers get their packages in a shorter time. The rest is still at the 3PL level, or even at a higher level, to guarantee completeness and specialty. The service provider will play the role between the warehouses (include the prime-warehouses and the local-warehouses), and from warehouses to the physical stores, as shown in Figure 1.

In comparison to the traditional 3PL model (Figure 2), MPL has a huge difference in the delivery phase from warehouses to consumers. Because in the MPL model, the whole logistics chain has been divided into several phases, and in each phase, there are only two parties involved, which means in the delivery part, sellers should take on delivery work by themselves. In this situation, the seller can guarantee that they will participate in the logistics of every phase. They can therefore get more complete feedback from consumers and won't lose their control over shipping functions.

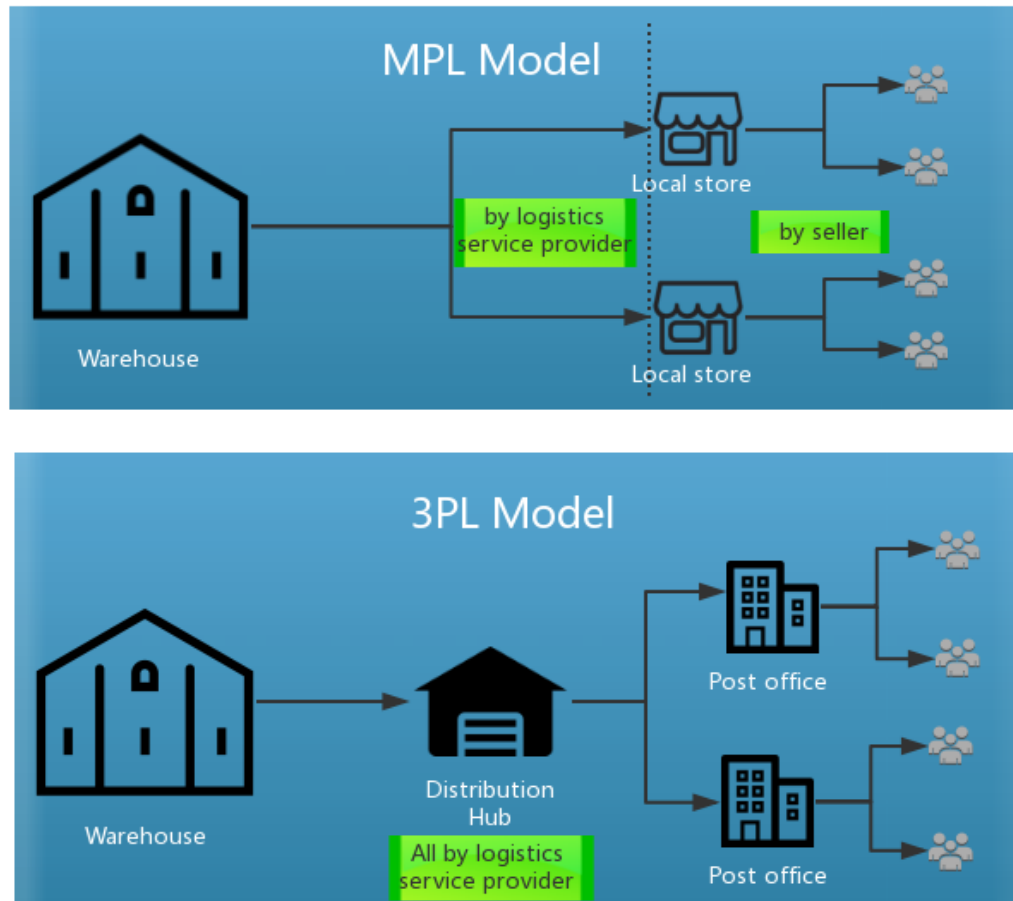


Figure 2. Summaries of the MPL and 3PL models in delivery phase (from warehouse to consumers).

The advantage of this model is multifaceted. The service providers can reduce their workload, save much more space and do not need to build more warehouses for expanding inventory capacity. If they do not need to ship goods from warehouses to consumers because the sellers handle this part now, the distribution management will be much easier and errors can also be reduced. For the sellers, although they need to invest in running the new system and maintaining their delivery routes, the savings from paying the providers and loyal consumers may fill this hole.

For the consumers, this model can provide a user-based solution, and consumers can get the goods from the nearest warehouse, which can provide the quickest way.

Table1 presents different performance of MPL and 3PL with “time” as the standard metric. MPL model has an obvious ability for saving time. As long as orders have been placed; the goods can be shipped from the nearest store directly. Relatively, in 3PL model, there is an extra wastes time for the Warehouse to Distribution center process.

Table 1. Logistics Chain for 3PL Model and MPL Model.

Day	MPL model			3PL Model		
	Consumer's Order	Warehouse to shops	Shops to Consumers	Consumer's Order	Warehouse to Distribution center	Distribution center to Consumers
1	Prepare goods	replenish stock in period 1		Prepare order 1		
2	Prepare order 1&2	replenish stock in period 1		Prepare order 2	Ship order 1	
3	Prepare order 3	replenish stock in period 1	Delivery order 1&2	Prepare order 3	Ship order 2	Delivery order1
...
x	Prepare order x	Finish replenish	Delivery order x-1	Prepare order x	Ship order x-1	Delivery order x-1
...
y-1	Prepare goods& order y-1	replenish stock in period 2	Delivery order y-2	Prepare order y-1	Ship order y-2	Delivery order y-2
y	Prepare order y	replenish stock in period 2	Delivery order y-1	Prepare order y	Ship order y-1	Delivery order y-1

This study assumes “y” day is one period for MPL model. In this case. This study assumes day 1-x replenish stock for all the demands in period 1, and after day x, there is no replenish work in period 1. Delivery work start at day 2, and after the first delay (in this table is order 1), all the orders can be delivered on the second day after consumers ordering. Suppliers will restart replenishing work before the next period, which aims to avoid late delivery.

The short time delivery will bring them more consumers, and much more profit. Another advantage is that this model coincides with the view of “sustainable accessibility” (Bertonili et al., 2005), which looks for the stability and sustainability of the transportation system. Because the origin, the destination, and the most parts of this model, are controllable by the seller and the consumer, this system is more observable and more sensitive to errors. This model is only a theoretical model at present. Although the accessibility measures can support the advantage, it still needs more particular and rigorous testing, both on geography and economy. It is necessary to find out to what degree it can improve the current model and how much profit gain or loss will be felt by the sellers and the service provider. Thus, MPL can be viewed as a logistics model based on consumers’ benefits.

Because it is sellers that decide which logistics model they prefer to apply, the rest study will have the analysis on seller’s side. It will compare the transportation cost in MPL and 3PL models. If MPL model can provide a lower transportation cost, it can be proved that MPL model has a better performance. If the MPL model cannot provide a lower cost, this study also need to consider the extra profit which is brought by the new consumers who have been attracted by a shorter time benefits. It is also expected to explore how these new consumers can affect sellers’ decision for choosing logistics models from this study.

3. DATA AND METHODS

The case study uses the *Target Corporation* as an example to evaluate the MPL model as a contrast to the traditional 3PL model. Due to the difficulty of collecting all the data, including regular distributing routes for both e-commercial companies and logistics service providers, and investment for maintaining delivery routes, this project uses only warehouse location data found on the official websites of corresponding companies, and uses the economic data from census to simulate “consumer demand” values. In the case study *Target Corporation* is used the seller and FedEx is selected as the service provider. Its distribution process is the “FedEx SmartPost Zone Skipping” (<http://www.fedex.com>) which means goods are shipped from sellers to FedEx distribution centers, and then they will be shipped from distribution center to United States Postal Service (USPS) local post office, and finally to consumers.

The study can be divided into two parts. In the first part, this study establishes a distribution network by applying the MPL model. This part aims to explore how to choose the right place to locate prime warehouses and how to manage the routes to satisfy different demands in different regions. It is important to emphasize that the demand-supply equilibrium is vital in the MPL model, because stores are also playing the distribution center role in this model, which means they need to have sufficient inventory to supply their own service region. The inventory in this study means how many goods

manufacturers supply in one period. Thus, the two objectives for establishing a distribution network are, 1. balancing supply and demand for all the warehouses and 2. minimizing the transportation cost between warehouses. In the second part, this project makes a comparative study between the 3PL model and the MPL model, in the warehouse-to-consumers part. It aims to test whether the MPL model can save costs for sellers and save time for consumers.

The two parts studies are independent: First focuses on the transportation phase inter-warehouses, and the second part focuses on the delivery phase in which goods are shipped from warehouses to consumers. Thus, the analysis methods and constraints also are independent in the study.

3.1 Establishing an MPL model for the Target Corporation

For building a new logistics chain, the primary task for sellers is to locate prime warehouses. Although it is the service provider that provide logistics service between warehouses in the MPL model, sellers need to allocate prime warehouses by themselves using their own data and market requirements, and then tell the provider how many goods they need to ship, and where are the origin and destination. In this logistics chain, the demand-supply equilibrium is vital; every store or warehouse should have sufficient inventory to supply its own service region. Due to different demands among regions, the warehouses may store more or less than regional demands. If a warehouse has a lower inventory than required to meet demand, it needs assistance from other warehouses. If a warehouse has a higher inventory (than demand), it will play a supply role. In this situation, the prime warehouses play a transfer station role: the positive flow comes from

exceeded-supply warehouses to the nearest prime warehouse, and then to short-supply warehouses. This structure aims to reduce the network's complexity and reach a demand-supply equilibrium.

3.1.1 Theoretical model

The objective of this study is to find an optimal solution, which has the lowest transportation cost. Consider a set G of warehouses and among them, a set of M prime warehouses, $M \subset G$. If there is only one prime warehouse needed in this case, this problem will be a typical p -median problem, which is described by locating prime to minimize the demand weighted average distance between local warehouses and the prime selected warehouse (Teitz & Bart, 1968). The objective is to minimize the sum of these transportation costs with the given distance between warehouse i and prime warehouse m (d_{im}), and the absolute value of expected material flow (F_i) for each warehouse i . F_i denotes the quantity of goods needed or supplied from warehouse i . If it is a positive value, it means warehouse i has a larger demand than supplied, and it will receive goods from other warehouses. If it is a negative value, it means warehouse i has a lower demand than supplied, and it will need to be a provider, to assist other warehouses. The objective is to minimize the total cost,

$$Z = \min \sum_{m \in M, i \in G} |F_i| d_{im}. \quad (1)$$

The total demands should be equal to total supply, i.e.,

$$\sum_{i \in G} F_i = 0. \quad (2)$$

Where more than one prime warehouses is expected to be located, the optimized routes between prime warehouses also should be taken into consideration. For each prime warehouse in M , it has a service set S_m , containing all the local warehouses severed by m (m is also in the set S_m). This study supposes that each local warehouse is only served by one prime warehouse which is the closest one to it. Each set, S_m , has a total expected flow (F'_m) which is equal to the sum of the inner expected flow in S_m . Thus, the total cost (C) constitutes the sum of the transportation cost between the prime warehouse and local warehouses for each prime warehouse m (C_{pl}) and the transportation cost between prime warehouses (C_{pp}). The objective is to minimize the total cost,

$$Z' = \text{Min}C = \text{Min}(C_{pl} + C_{pp}). \quad (3)$$

The transportation cost between prime warehouse and local warehouses is the sum of all the service region cost (C_i),

$$C_{pl} = \sum_{i \in M \in G, m \in M} C_i = \sum_{i \in M \in G, m \in m} |F_i| d_{im} X_i c, \quad (4)$$

where c is the cost for shipping per unit good for per unit distance and X_i is the decision variable, which guarantee every local warehouse are linked to the prime warehouse which is the closest one.

$$X_i = \begin{cases} 1, & d_{im} = \min(d_{im}) \quad m \neq i \\ 0, & \text{otherwise} \end{cases}. \quad (5)$$

The transportation cost between prime warehouses includes the total expected flow (F'_m) for each service region,

$$F'_m = \sum_{i \in S_m} F_i. \quad (6)$$

The transportation cost between prime warehouses just go from the regions which have sufficient inventory to the regions which do not,

$$C_{pp} = \sum_{m,n \in M} Y_{mn} d_{mn} c, m \neq n \quad (7)$$

where Y_{mn} is a decision variable representing the flow from m to n . Since the flow only come from the region which has a sufficient inventory ($F'_m < 0$) to the region which has insufficient inventory ($F'_n > 0$), it has

$$Y_{mn} = \begin{cases} 1, F'_m < 0 \text{ and } F'_n > 0; \\ 0, \text{ otherwise} \end{cases} \quad (8)$$

For each S_m . assume it has a minimal number of elements inside, say 5 here, which determine the set size,

$$\text{card}S_m \geq 5 \quad \forall m \in M \quad (9)$$

By imposing the constraint described by Equation (2), it is assumed that goods can be exactly allocated to all the warehouses, and further, Equation (8) means flow between prime warehouses should not be negative. Equation (9) says each prime warehouse must serve at least 4 local warehouses, and the total warehouse number in a serving region should be more than, or equal to, 5.

3.1.2 A simple artificial example for establishing MPL transportation network

Figure 3 shows an artificial example for the MPL model network. In this example, there are 9 warehouses. Three (3) prime warehouses (IV, V, VII) and 2 local warehouses for each, constituting 3 service regions. Those numbers are selected randomly for this study. In this case, c is assigned equal to \$1,000 per unit flow, per unit distance.

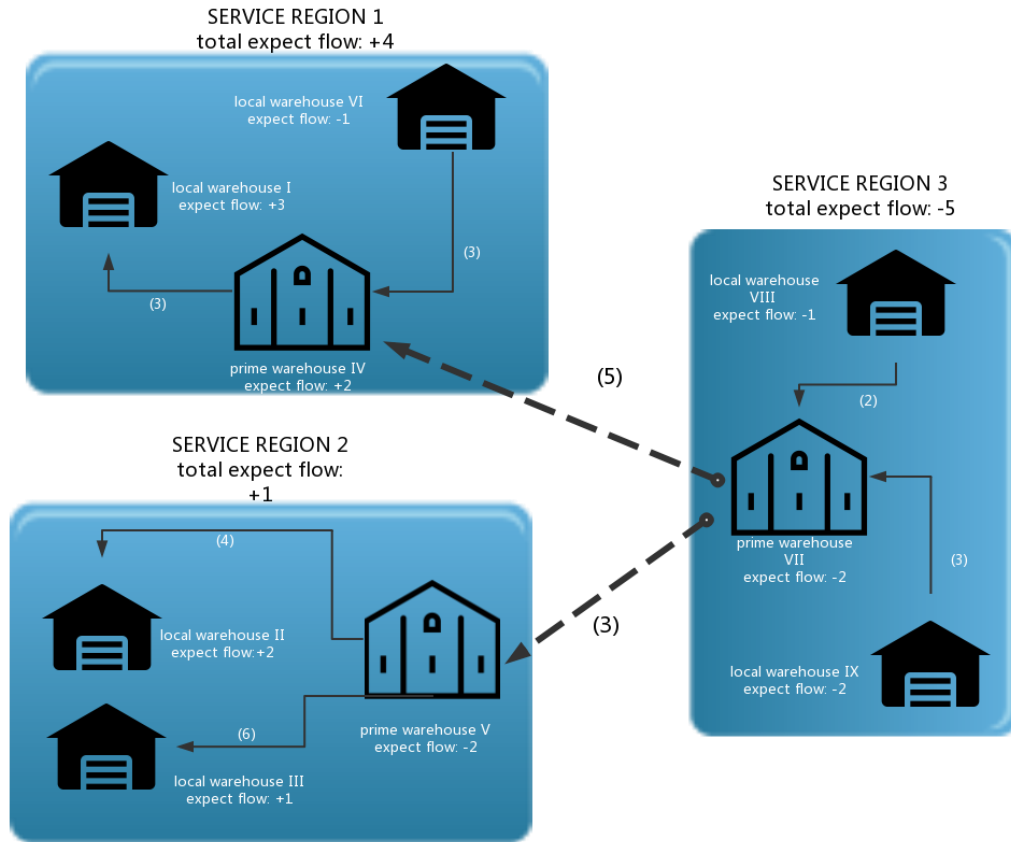


Figure 1. MPL model network for an artificial example. The numbers in the brackets between warehouses are the number of unit distance.

In the first service region, assuming that the F values are -1 (demands $<$ inventory) and $+3$ (demands $>$ inventory) for local warehouses VI and I, respectively, and the distances to the nearest prime warehouse are both 3 units. Then the total transportation cost for Region 1 is

$$C_1 = \sum_{i \in S_1} |F_i| d_{i1} c = 1 \times 3 + 3 \times 3 = 12.$$

Similarly, the costs for Regions 2 and 3 with the given demand/inventory and distance are

$$C_2 = \sum_{i \in S_2} |F_i| d_{i2} c = 2 \times 4 + 1 \times 6 = 14, \text{ and}$$

$$C_3 = \sum_{i \in S_3} |F_i| d_{i3} c = 1 \times 2 + 2 \times 3 = 8,$$

respectively. And the total cost from prime warehouses to local warehouses will be

$$C_{pl} = \sum_{i \in G} C_i = 12 + 14 + 8 = 34$$

For each service region, the total expected flow is the sum of all the warehouse expected flow in the service region. Therefore, I have

$$F'_1 = \sum_{i \in S_1} F_i = 2 - 1 + 3 = 4, F'_2 = -2 + 2 + 1 = 1, \text{ and } F'_3 = -1 - 1 - 2 = -5.$$

To simplify this project, I only consider the total expected flow from negative to positive. In the example above, the flows are only from prime warehouse VII. Thus,

$$C_{pp} = \sum_{m,n \in M} Y_{mn} d_{mn} = Y_{31} d_{31} + Y_{32} d_{32} = 4 \times 5 + 1 \times 3 = 23$$
 Therefore,

The total transportation cost $C = C_{pl} + C_{pp} = 34 + 23 = 57$. Since the cost is \$1,000 per unit, the transportation cost is \$57,000 in this situation. This is the only one result for choosing 3 prime warehouses. With the other prime warehouse locations, or different number of prime warehouses, there will be other cost values. The final output only reports the situation with the lowest cost. For instance, if there is a combination of prime warehouses I, IV, VIII, and the total transportation cost is \$50,000 which is smaller than \$57,000, the combination of IV, V, VII will be ignored. Then, use the \$50,000 to test rest combinations until all the combination of 3 prime warehouses have been tested. The objective of this part of the study is to find the lowest cost and the situation meeting that cost.

3.1.3 Case study by using *Target Corporation data*

Data set for *Target Corporation* case includes the U.S. base map and economic data at a county level, from Tiger data (<https://www.census.gov/geo/maps-data/data/tiger-data.html>), and Target warehouse location data from *Target Corporation* (<https://corporate.target.com/careers/global-locations/distribution-center-locations>). There are, in total, 34 Target warehouses in the U.S. The warehouse data from the *Target Corporation* shows the address for each warehouse. This study creates a shapefile to convert them into spatial data, and then use the data in ArcGIS.

To determine the F_i , this study assumes the inventory of all the warehouses are initially the same, and the total inventory equals to the total demands in the global view. In this situation, the demands of each warehouse i (D_i) can reflect the expected flow of warehouse i . The demands are based on economic indicators. Because individual demand has a positive correlation with people income (Quah, 1997), this study assigns the total demand of each service area equal to household number times mean household income in the area. The total income values are standardized into z-scores and are used as regional demand values. In the 34 Target warehouses, 13 warehouses have positive values (Z-demand), and 21 have negative values. Because this study assumes the inventory for all the warehouses are the same at the beginning, Z-demands can also indicate the expected flows (F_i). The positive value means the demand in this warehouse's serving region is larger than the mean demand (inventory) value; they need to get goods from other warehouses. The negative value means the demand in this warehouse's serving region is lower than the mean demand (inventory) value, so they need to send goods to other warehouses. Table 2 lists the values of Z-demand for each warehouse. In the following

study, it is assumed that the flow F_i for warehouse i is equal to Z-demand for that warehouse.

Table 2. 34 Target warehouses' Z-demand.

Name	Savannah, GA	Midway, GA	Lacey, WA	Shafter, CA	Indianapolis, IN
Z-Demand	-1.24	-1.19	-1.03	-1.02	-0.93
Name	Fort Worth, TX	Stuarts Draft, VA	Newton, NC	Cedar Falls, IA	Woodland, CA
Z-Demand	-0.86	-0.81	-0.80	-0.70	-0.69
Name	Fridley, MN	Pueblo, CO	DeKalb, IL	West Jefferson, OH	Lake City, FL
Z-Demand	-0.65	-0.51	-0.51	-0.47	-0.40
Name	Galesburg, MI	Suffolk, VA	Rialto, CA	Woodbury, MN	Fontana, CA
Z-Demand	-0.38	-0.24	-0.16	-0.09	-0.08
Name	Albany, OR	Tucson, AZ	Phoenix, AZ	Tyler, TX	Topeka, KS
Z-Demand	-0.03	0.07	0.11	0.17	0.45
Name	Tifton, GA	Ontario, CA	Madison, AL	Midlothian, TX	Lugoff, SC
Z-Demand	0.51	0.64	0.73	0.86	0.91
Name	Oconomowoc, WI	Wilton, NY	Amsterdam, NY	Chamburg, PA	
Z-Demand	1.03	1.78	2.58	2.93	

In the *Target Corporation* case, when this study assumes $m=7$, there will be 5 servicing regions. Due to the constrain (9): for each prime warehouse, it must serve at least 4 local warehouses, and the entire warehouse's number in a serving region should be more than or equal to 5. The minimum warehouse number should be 35 which is more than 34 making the maximize number of prime warehouses be 6. In this study, we choose $m=1-4$ for testing purpose.

Table 3 shows the prime-to-prime (C_{pp}), prime-local (C_{pl}), and the total cost (C) for building distribution network with different number prime warehouses after calculating all the prime warehouses combinations from $m=1$ to 4, and reports the solutions with the lowest transportation cost. This result is calculated by the formulations

in *section 3.1.1* with the Z-demand (F_i) data and a 34*34 distance matrix including all the *Target* warehouses. Due to the long distance between warehouses, I assigns \$1 for shipping per unit good 1 kilometer.

Table 3. The selected prime warehouses for cases with 1-4 prime warehouses and minimum transportation cost.

m	Prime warehouse ID	Local warehouse number in service region	$C_{pl}(\$1,000)$	$C_{pp}(\$1,000)$	$C(\$1,000)$
1	Indianapolis, IN	33	29,324	0	29,324
2	Stuarts Draft, VA	23	18,946	6,060	25,007
	Ontario, CA	9			
3	Tifton, GA	8	18,348	5,677	24,025
	Pueblo, CO	12			
	Galesburg, MI	11			
4	Tifton, GA	6	16,261	5,852	22,114
	Pueblo, CO	11			
	Cedar Falls, VA	5			
	West Jefferson, OH	8			

When two prime warehouses have been allocated at Stuarts Draft and Ontario, the total transportation cost is approximately 15% off. When the prime warehouse number increases to 3, it is 18% off, and when the prime warehouse number increases to 4, it is 25% off. In the 3 and 4 prime warehouses situations, Pueblo is a very important location.

Figure 4 shows z-demands distribution in the U.S. The eastern parts have higher values, especially Amsterdam and Chamburg that have the two highest value, which means they need goods from other regions. The 9 warehouses on the west coast have lower z-demands (sum is -2.19), so they need to supply. The global transportation trend is from west to east, and Pueblo plays a hub role. Thus when 3 or 4 prime warehouses need to be allocated, Pueblo should be one of them. In all the multiple prime warehouse's situations, there is a very long route crossing the map from west to east due to the big blank in the middle region. If there are more warehouses located at this blank region, the distribution network should be more balanced.

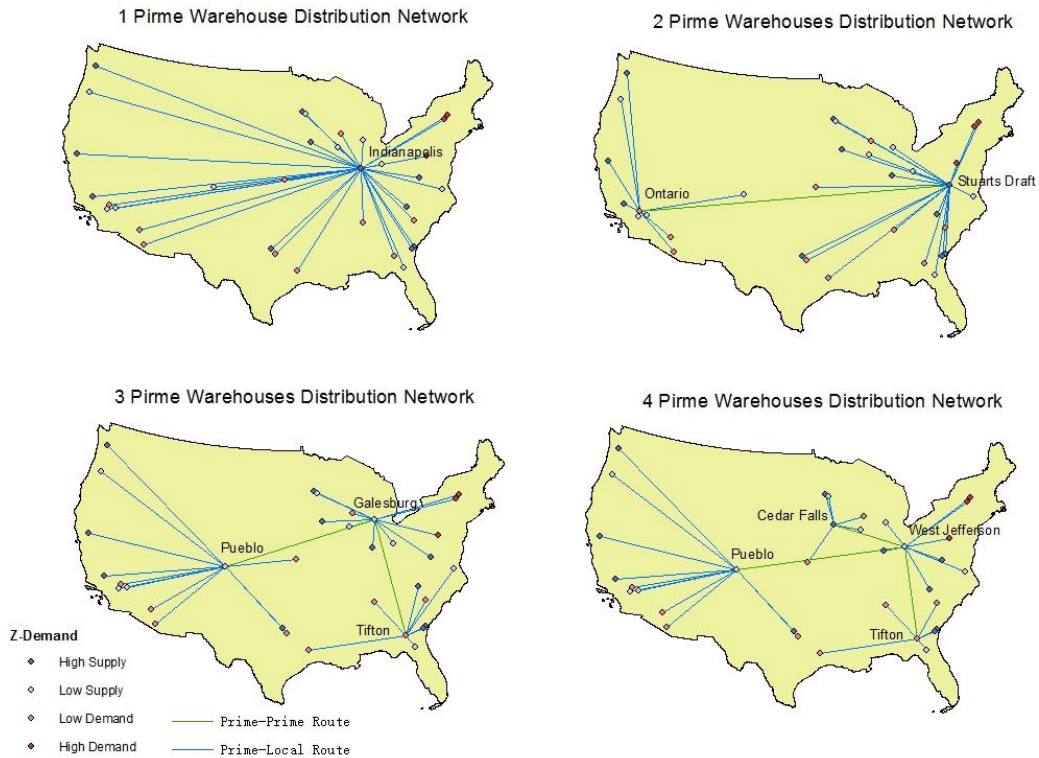


Figure 2. Warehouse locations, their demand ranges, and the distribution network for different number of prime warehouses.

Table 3 and Figure 4 show the result for building an optimal distribution network by applying the MPL model with Target case, and it aims to demonstrate how to build this distribution network by using MPL model. This study supposes that the inventory for all the warehouses are the same, therefore, the z-demands can represent the expected transportation flow for each warehouse. However, in real situation, each warehouse's inventory is not the same. This value can be based on population density, economic level, special requirements from sellers, product manufactures delivery speed and other potential factors. This study only provides a model, and demonstrates it with data available to the author, so sellers who are willing to use MPL model need to use their own inventory data to build their network. In addition, for this case, *Target Corporation* also needs to consider how many prime warehouses they want to allocate. Although the 4 prime warehouses situation provides a lower total transportation cost, they also need to consider their investment for extra warehouses allocation compared to the 2 and 3 prime warehouse situations. Only after calculating all the factors, can the seller proposes the optimal plan.

3.2 Comparison between MPL model and 3PL model in the delivery phase

The second part of this study is a comparison analysis between application of MPL and 3PL model in the delivery phase. For sellers, what attract them is how much profit that the logistics model can bring to them. The aim of this study is to test whether MPL and 3PL models have different performance to sellers, and to identify what factors make (or can make) the difference. This part study will contrast transportation cost and extra profit in two models. The transportation cost contains two parts cost: goods shipped

from seller's warehouse to the transfer stations (different in the two models), and from transfer stations to consumers. Thus, it is necessary to find the distribution routes and then calculate the cost. Since acquiring real routes is unattainable, simulated delivery routes will be provided in a small region in this study by applying existing mathematic model. The flow chart is shown in Figure 5.

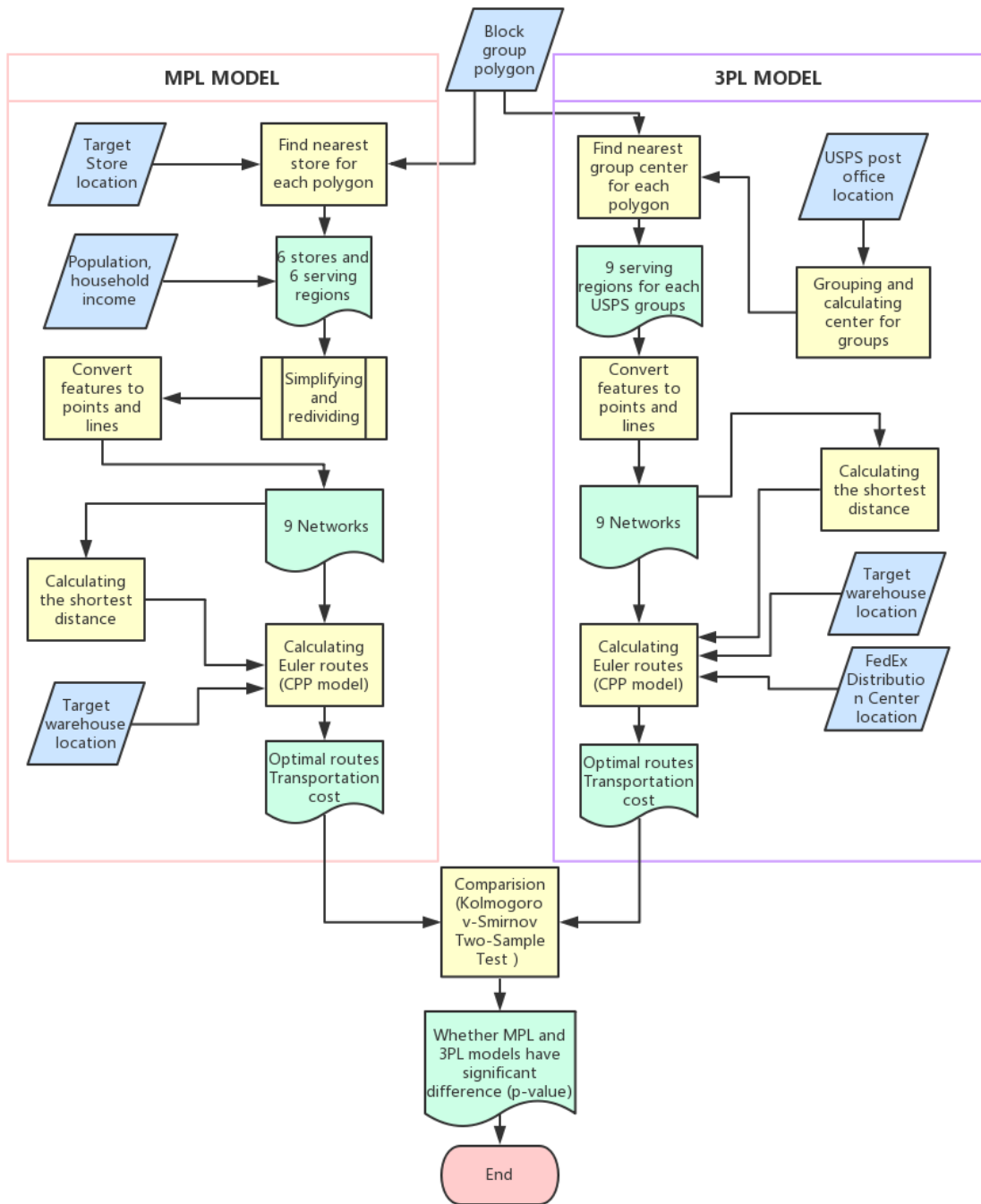


Figure 5. Flowchart of comparison analysis.

3.2.1 Data source

This project applies Washington DC as the study region and Target Corporation as the seller. To make a comparison study, this project chooses FedEx Corporation and USPS as the logistics service providers in the 3PL model. Target warehouse data comes from Target corporation website (<https://corporate.target.com/careers/global-locations/distribution-center-locations>). Target stores location and FedEx distribution center data come from Google Map (presented by address, and then add to ArcGIS manually). Local USPS post office data come from USPS's website (<https://tools.usps.com/go/POLocatorAction!input.action>). There is 1 Target store in the study region and 11 stores near the study region, which may serve the DC area. There is 1 Target warehouse in Maryland which is the nearest warehouse to the study region. There are 1 FedEx distribution center and 53 USPS post offices in the study region. The base map data comes from Tiger data (<https://www.census.gov/geo/maps-data/data/tiger-data.html>). It is block and block group levels data including census data (household and income data) used to calculate the local demand.

3.2.2 Data preprocessing

In the MPL model, every store has its own service area with no intersections. The study region also has been divided into several parts. To determine the service areas of the stores, this study assumes consumers can get service from the nearest store, so each block group in study region has its serving store with the shortest distance (from polygon centroid to the store). After calculating the distance values, the result is a distance table showing the nearest store ID, and distance value for every block group. After calculating, there are 6 stores having at least one block group for servicing in the study region

(Washington DC area). The rest 6 stores do not have a service area in this study region, so they will not be considered in this study. The block groups which share the same store ID constitute service area for that store.

Due to the high population density in certain service areas, this study considers that Target stores will apply multiple carriers and maintain multiple routes in each service area. In the study region, only one store has its entire service area, and the rest stores have a part of their service areas in the given region. To set a reasonable number of carriers, this study calculates the demand (D'_r) in each block group as,

$$D'_r = \sum_{p \in P} x_p n_p c'_p \quad (10)$$

where r is the block group index, p is the index of household income level, x_p is mean annual household income in level p (when the income range is over \$200,000, set x_p to \$200,000), n_p is the household number in level p , and c'_p is a coefficient for level p . This study assumes that c'_p has a linear relation with p as showed in Table 4. The demand has a liner relationship with household income (Quah et al. 1997), so the household with a higher income will have a higher demand. D'_r in this study can be viewed as how much money people willing to pay buy something which they need from *Target*, and this value has an upper limit which equal to $200,000 * 0.1 = 100,000$ (\$), which means the richest family will pay one of ten of their whole income to buy something from Target. This study assumes that people who have no income won't buy anything from Target, and the α_p is 0. The people who has more than \$200,000 income will have the highest demand, α_p is 0.1. D'_r represented how much people in block group r will pay for buying something from Target. For instance, there are 5 households in level 1, 2 in level 2, 6 in level 3, 11

in level 4, 9 in level 5, 4 in level 6, 4 in level 7, and 2 in level 8. The demand in this region (D'_r)

$$D'_r = 37.5 \times 5 \times 0.0125 + 62.5 \times 2 \times 0.025 + 87.5 \times 6 \times 0.375 + 112.5 \times 11 \times 0.05 + 137.5 \times 9 \times 0.0625 + 162.5 \times 4 \times 0.075 + 187.5 \times 4 \times 0.0875 + 200 \times 2 \times 0.1 = 495.9375$$

(\$1000)

Table 4. Linear relation between household income level and the assuming spending coefficient.

p	1	2	3	4	5	6	7	8
Income range(\$1000)	25-50	50-75	75-100	100-125	125-150	150-175	175-200	200-
x_p (in \$1000)	37.5	62.5	87.5	112.5	137.5	162.5	187.5	200
α_p	0.0125	0.025	0.0375	0.05	0.0625	0.075	0.0875	0.1

Table 5 shows the demands in each service area. Store 1 is located at the center of the study region. It is the only store with whole serving area located in the study region, and the service areas of other stores are partially located in the study region. In this case, the first service area's demand is much higher than the others', so this study divides the service area one into several parts for multiple routes and keeps other service areas completely apart. The demand values for this dividing should be more than 7,916 (\$1000) which is the highest value except for service area 1. Because 35,337 is approximately four times of 7,916, this study divides service area one into 4 sub-areas of near-equal demand value of around 8,834 (\$1000), which is quarter of 35,337. After dividing service area one into four sub areas, there were total 9 serving areas calculated for the MPL model.

Table 5. The properties of the Six Service Areas in MPL Model.

Service Area (i)	Total ousehold income in study region (\$1,000)	Area in study region (m ²)	Area ratio (service area in study region/ whole service area)	Demands in study region D _i (\$1,000)
1	74699	79005142	100%	35337
2	6235	15408260	23%	2475
3	17637	24018590	59%	7916
4	5762	13963626	28%	2550
5	14580	9528814	43%	3069
6	16012	16426146	37%	5136

For dividing area 1, this study uses block group polygons as neighbors: choose four polygons around the store as the start point, and search the neighbors for these polygons. Then use the polygons which are the unique neighbor of the start polygons to do the neighbors searching. Repeat the neighbors searching with the last searching result as the start polygons and report the unique neighbors as the results until there is no unique neighbors left. After this procedure, there are four discrete areas, and the shared neighbor polygons between these areas. Then assign the shared neighbors polygons to exist areas based on demands in these areas. For instance, there is a neighbor polygon shared by sub area #1 and #2. The demand of area #1 is smaller than #2, so assign this shared neighbor polygon to #1, which aims to make all areas have similar demands. When all the block groups have been allocated, there are new 9 areas.

For comparing transportation cost in two different models, it is required to keep the same route numbers in two models. Because there are 9 routes in the MPL model, to guarantee that the two models data are comparable, this study divides the study region into 9 pieces, and creates 9 routes in the 3PL model. There are too many USPS post offices (53) in the study region. If the 3PL data is also processed by establishing serving

area based on each office, there will be 53 areas and 53 routes, which makes it harder to be compared to the MPL model. Thus, this study groups 53 post offices into 9 groups, and then divides the study region based on these group by using k-means clustering method only based on geographical location. The input for the clustering algorithm is the 53 post offices' coordinate. After grouping the post offices, this study uses their geometry center as a hypothetical post office. Similar to the MPL model, people will get service from the nearest hypothetical office. Figure 6 shows the nine divisions for both MPL and 3PL cases, respectively.

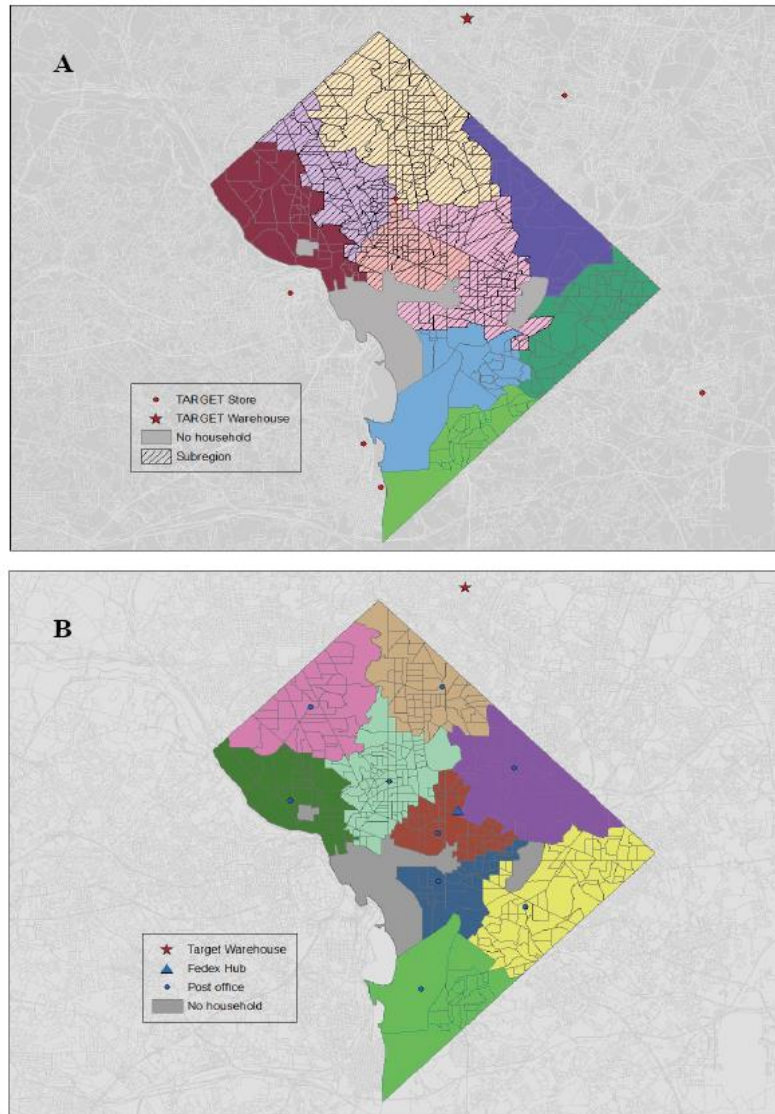


Figure 6. Nine serving areas for MPL (A), and 3PL (B) model. The shadow area (Sub-region) is the serving area #1 in MPL model with a Target store at the center of the study region. It has been divided into 4 sub-regions with four different colors under the shadow.

The transportation cost is based on the driving distance, carriers may need to go through some arcs in the graphic for multiple times. This study applies Chinese postman problem (CPP) model to find the optimal routes for calculating the transportation cost in each serving area. CPP model aims to find the shortest routes which go through every arc

in the network at least one time, and back to the starting point (Eiselt et al., 1995).

Edmonds & Johnson (1973) converts CPP problem to find Euler tours. If the network is a Euler graph, there is only one route which goes through every arc one time and back to the start point. If the network is a non-Euler graph, there are some arcs which need to be chosen several times. If there are zero or two nodes have an odd degree (a node connects with an odd number of arcs), the network is an Euler graph. Otherwise, it is not. To convert a non-Euler to Euler graph, it is important to find nodes which have odd degrees in the graph and then pairing them optimally. The arcs between one pair nodes with odd degree can be viewed as a new arc which converts the nodes to even degrees. By adding one arc to each pair of singular points, it translates to a new Euler graph. New arcs are the shortest distance between singular points, and they are the repeat arcs in the optimal routes.

The output of the CPP model are the Eulerian tours for 18 independent areas (9 for each model). It contains optimal routes and the transportation distance. The total transportation distance combined with two parts: the first one is the distance from Target warehouse to stores (MPL), and to post offices (3PL); the second one is from the last points to consumers. Because this is a comparison study, this study assumes that the transportation cost is \$1 per kilometer, which has no influence on the final results. Thus, the transportation distance and transportation cost have the same numerical value. The CPP model results also report the transportation cost for delivery in the 18 serving areas.

3.2.3 Analysis method

All the previous steps aim to make models comparable in this study. This study applies Kolmogorov-Smirnov (K-S) two-sample test to do the comparison analysis. The K-S test is a non-parametric test which aims to test where two observations follow the same distribution (Fasano & Franceschini, 1987). The test statistic is:

$$D_{p,q} = \sup_x |F_{1,p}(x) - F_{2,q}(x)|, \quad (11)$$

where F_1 and F_2 are the empirical distribution functions, and “sup” is the supremum function indicating the maximum absolute difference between the two distributions. The null hypothesis means there is no significant difference between the two sample distributions, and it would be rejected at level α if

$$D_{p,q} > c(\alpha) \sqrt{\frac{p+q}{pq}} \quad (12)$$

where $c(\alpha)$ is a parameter depending on α and can be determined from Kolmogorov’s distribution.

Transportation cost is an important factor to sellers. Lower cost can attract sellers to apply the model. Another important factor to sellers is the profit. A model from which consumers can get benefit will attract more consumers, and it will bring more profit to sellers. Thus, a comprehensive evaluation should include both factors.

This study assumes that MPL model can bring extra profit (P) to sellers, and this extra profit can counteract the transportation cost (C). C' is the cost after subtracting the extra profit,

$$C' = C - P. \quad (13)$$

If the results show there is no significant difference between transportation costs in two models, this study will test the extra profit value: what value of extra profit can make two cost (C') different. Because the transportation cost (C) is a simulation value, this study prefers to build a relationship between C and P by assigning

$$P = \beta C, \quad (14)$$

where β is a parameter. Thus, the final result may show that: When MPL model can bring an extra profit which equal to “ β ” times C, there are significant difference between two logistics models.

4. RESULTS

The transportation cost is the basic result of previous steps. In this study, transportation cost means shipping unit good from Target warehouse to all the consumers in Washington DC in one period.

Table 6 shows the transportation cost (distance) in two models based on the CPP method. Because there are different numbers of nodes for the same area ID, the distance is not the same. Basically, the more the nodes there are in the network, the more the repeated arcs in the optimal routes. Thus, the area with more nodes will match a more complicated optimal route, and has a larger distance.

Table 6. Transportation cost for two models in the 9 serving areas.

Serving area ID	MPL				3PL			
	1st Cost(\$)	2nd Cost(\$)	Total Cost(\$)	Nodes	1st Cost(\$)	2nd Cost(\$)	Total Cost(\$)	Nodes
1	26.20	248.80	274.99	216	35.12	147.86	182.98	134
2	26.20	115.75	141.95	147	40.62	225.47	266.10	253
3	26.20	169.99	196.18	149	54.59	187.49	242.08	107
4	26.20	285.79	311.99	240	48.30	168.43	216.73	164
5	26.34	123.55	149.89	41	40.30	178.10	218.40	97
6	48.18	157.50	205.68	108	52.34	147.81	200.15	86
7	64.16	210.49	274.65	113	41.23	98.43	139.66	75
8	66.97	102.97	169.94	72	56.34	142.68	199.01	65
9	72.65	175.49	248.14	141	46.99	274.22	321.21	230
Sum	383.09	1590.32	1973.41	1227	415.83	1570.49	1986.32	1211

1st cost means transportation cost from Target warehouse to stores (MPL), and USPS post office (3PL). 2nd cost means transportation cost from stores (MPL), and USPS post office (3PL) to all the consumers in that serving area.

After applying Kolmogorov-Smirnov (K-S) two-sample test in SPSS 22 to test if there any significant difference between transportation cost in the two models, the result shows that p-value is $0.979 > 0.05$, which fails to reject the null hypothesis (H_0) at the level of significance of 0.05. There is no significant difference between the two models. Thus, MPL and 3PL have a similar performance in transportation cost, so it is necessary to test extra profit value which can make the costs (C') significant different.

Table 7 shows that when $\beta=0.28$, it means when the extra profit brought from new consumers by applying MPL model is equal to 28% of the transportation cost, there are significant differences between the MPL and the 3PL models ($p=0.038 < 0.05$, which rejects the null hypothesis (H_0) and accept the alternative hypothesis (H_1)); the MPL model has a higher score. These values answer the question that whether MPL and 3PL models have different performance in the delivery phase, and when the MPL is better than the 3PL.

Table 7. p-values from the Kolmogorov-Smirnov (K-S) Two-sample Test with different extra profit coefficient (β) values.

β (extra profit coefficient)	0.1	0.2	0.27	0.28
p-value	0.699	0.336	0.124	0.037

5. DISCUSSION

Transportation cost is an important issue for sellers in the logistics chain. It is the main cost for maintaining their own routes. The results show that MPL and 3PL have similar performance to minimize the transportation distance and the cost (p-value = 0.979). Thus, it may be hard for sellers to make a decision that which model is better when only considering the transportation cost.

Another important character in the logistics chain is the consumers. They are the destination of a logistics flow, and the consumer's number determines sales volume and how much profit sellers can earn. A better service to consumers can help sellers attract more consumers, and time is vital standard for evaluating logistics service. This study uses a tentative coefficient (β) to test how extra profit brought by new consumers who are attracted by a "short time delivery" superiority in MPL model, and the coefficient value can affect sellers' decision. This study uses Kolmogorov-Smirnov (K-S) two-sample test with different β values. When assigning $\beta=0.3$, the test result shows p-value = 0.037. This value is small to reject H_0 , but not accurate enough. When assigning middle β values which between 0.2 to 0.3 in percentile degree. The output shows when $\beta= 0.27$, the test result shows p-value = 0.124. when $\beta = 0.28$, the test result shows p-value = 0.037 which means it rejects H_0 , and accepts the alternative hypothesis. There is significant difference

between C'_{3PL} and C'_{MPL} , and C'_{MPL} is smaller than C'_{3PL} , so MPL model is more valuable in this situation.

These results prove that MPL model is comparable to the mainstream 3PL model. They have a similar performance on minimizing transportation cost, but the MPL brings much more benefit to consumers, which can attract more consumers and increase profit for sellers. It is necessary to emphasize that this study is not arguing that the new model is better than the others, but only throw out a new point to draw more attention to this problem. Some data are unavailable for me in this study, such as the basic profit and the cost for maintaining delivery routes. This may affect the accuracy of the results. However, the objective of this study is not to provide an optimal solution for Target Corporation. Instead, it aims to use this case study to show how the MPL model can be applied, and what parameters can draw the sellers' attention. Sellers should have private data which is missing in this study. Thus, they can apply the MPL model to find the optimal solution for their own case.

As a pioneer to bring the MPL into view, this study also has many limitations and the author hopes further studies can pay more attention to these points. First, in the first part of this study which establishes a distribution network for Target Corporation, this study used the method to convert existing warehouses into prime warehouses. It also needs to be pointed out that locating new warehouses as the prime warehouses could be taken into consideration. In the Target case, there is a big blank in the middle of the U.S. Because the west coast areas have a lower expectation flow, the prime warehouses in the middle can play a hub role which links the west and the east. Pueblo is the only

warehouse that plays this vital role, so it might be reasonable to consider locating new warehouses in the middle to improve this unbalanced structure.

Second, in the first part, this study used inventory values as the expected flow. However, the inventory is different for different goods based on demands. For instance, there should be a high demand for short sleeve shirts and low demand for down jackets in California, but it is an opposite case in Michigan. Sellers may get two different optimal situations for using different goods inventory data. Thus, further studies are expected to provide methods to integrate different goods data.

Third, in the second part, this study only used transportation cost as the total cost for the delivery phase and ignored the cost of maintaining the routes. In 3PL, routes maintenance work belongs to the service provider, but in the MPL model, sellers need to handle this job by themselves. If further studies can find relative data for estimating this part cost, the comparison result can be refined.

Fourth, this study used CPP model to calculate transportation distance for each areas, which aimed to guarantee every consumers can be served in one route. However, in the real life, consumers won't place their orders at the same time, and carrier don't need to visit every consumer in one route. Because this is a comparison analysis, CPP model won't affect result. A proper approach is still expected from further research, which may expose deeper differences between two logistics models.

Last but not least, this study only makes a comparison study between the MPL and the 3PL model. The 4PL model could also be a mainstream logistics model in the future. With the big data technology, 4PL model has the potential to expand their territory

from the global business market to the general business market. Basically, MPL and 4PL models are similar in some degree: they both aim to make the logistics structure more flexible. 4PL model employs experts from other fields to make the system capable of dealing with all the situations but it is more complicated. The MPL model keeps the simplicity, but it only endows a new role for sellers. Further research is expected to make a comparison between the MPL and 4PL models. This trend should be more complicated, but how to balance the benefit of all the parties in the logistics chain will be an interesting issue.

6. CONCLUSION

This study provides the possibility for a new MPL model which could be applied in the current business logistics distribution. MPL model can potentially shorten the delivery time for most cases and gives both sellers and consumers certain controls of the processes. For the service provider, this model can also release sellers' stresses for goods delivery and storage because they don't need to build more warehouses and complicate their routes. Although there are three parts in the MPL model, there are only two parts in each process: the distribution between warehouses only include sellers and logistics companies, and the delivery to consumers only involves sellers and consumers. The final results of this study showed that: First, MPL and 3PL have a similar ability to minimize transportation cost. Second, the MPL model has better performance on saving delivery time. Third, the short-time advantage of the MPL model can attract more consumers for Target Corporation, and if the extra profit made by these new consumers is equal or larger than 0.28 times the transportation cost, the MPL model will be better than the 3PL model.

This study wants to bring a new perspective to view the current logistics issues. There is still a big blank in MPL study. Future research are expected to fill these blanks and improve the model.

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BIOGRAPHY

Xiechun Lu graduated from Hubei, China. He received his Bachelor of Geographic Information System from Wuhan University of Technology in 2014.