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RESEARCH ARTICLE

The Optimization of Transportation Costs in Logistics Enterprises during the Covid-19 Pandemic

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Abstract: The Covid-19 pandemic has had a significant impact on every industry globally, especially the transportation industry being severely disrupted. With people's travel demand at an all-time low, maintaining the country's transportation infrastructure is crucial to ensure the movement of essential goods. However, the Vietnamese government's decision to apply social distancing measures to limit and prevent the spread of the disease has generated extreme challenges in the freight transport industry, which have harmed the Vietnamese economy by restricting levels of business activity, causing the movement and distribution of essential commodities to be halted. Based on the practical needs of transportation enterprises, this study proposes a low-cost freight allocation strategy using mix-integer linear programming approaches to ensure an efficient operation for businesses in order to resume normal operations in the context of the Covid-19 epidemic's complex development. The research focuses on developing a mathematical model with an objective function that minimizes total cost and associated constraints. The findings of the study point to the development of a solution that solves businesses problems in determining the optimal transportation plan and assist in making decisions on allocating goods to suitable locations, ensuring the quantity of serving the needs of each district in Ho Chi Minh City, minimizing transportation time while still saving costs. Furthermore, the article aids a decision-making process for other transportation industries.

Keywords: Linear Programming, Logistics, Optimization model, COVID 19

1. Introduction

Currently, Covid-19 is becoming more complicated, appearing in the majority of countries. (World Trade Organization [WTO], 2021) With increasingly dangerous strains such as, Alpha, Beta, Gamma, Delta, the possibility of the pandemic ending is uncertain. Additionally, there is currently no effective vaccine. As of September 1, 2021, there are more than 217 million cases of Covid-19 globally and resulted in more than 4.5 million deaths (WTO, 2021). Covid-19 has caused great damage globally both in terms of economy and socially (Kazunobu & Hiroshi., 2020). Vietnam is also greatly affected by this pandemic. The most recent outbreak spread rapidly, affecting over 79,000 manufacturing businesses temporarily suspended as of July 2021. Stores closed along entertainment and tourism activities being suspended for a noticeable time led to a negative impact on the economy.



Transport costs have significant impacts on the structure of economic activities as well as on international trade. Empirical evidence underlines that raising transport costs by 10% reduces trade volumes by more than 20%. According to the statistics, transportation costs occupy one-third of the amount in the logistics costs and largely influences the performance of the logistics system. Transporting is inevitable in logistics as it is required in the whole production procedure, from manufacturing to delivery to the end consumers and at times, even returns, otherwise called reverse logistics. It constitutes to about 40-50 percent of the total logistics costs and 4 to 10 percent of the selling price of the final products. With this, it is pretty much clear that the transportation decisions directly affect the total logistics costs, and cost in other functional areas of the firm. For the service provider, the difference between costs and rates results in a loss or a profit.

From the foregoing, it shows that the transportation costs for international trade are significant directly to businesses and the Covid-19 pandemic caused the increase in transportation costs, for example the recent increase in the price of containers, forced businesses to export losses in order to maintain business. With the current domestic situation, Vietnam implements a long distance method, restricting the use of movement and forcing health inspection checkpoints, which prolongs the transportation time. Therefore, reducing the efficiency of transportation of enterprises.

Applying Linear Programming model is a method that solves this problem. Linear Programming is a branch of mathematical programming which is designed to solve optimization problems where objectives and all the constraints involved can be expressed as a linear function. It was developed by George Dantzig, in 1947 for finding optimal solutions to problems of supplies for the US Army Force during World War II. It is a powerful tool in management science and operations research for decision making under certainty. Linear Programming can also be used for verification and a checking mechanism to ascertain the accuracy and the reliability of the decisions which are taken solely on the basis of manager's experience without the aid of a mathematical model (General Statistics Office of Vietnam, 2021). It is useful in allocation of scarce resources like materials, machine, man, time and others (Ozsan, Simsir, & Pamukcu, 2010).

The research objectives are to deliver goods to locations with the lowest cost, and to provide a general model to apply to businesses, thereby helping them to come up with optimal transportation options. This study uses a model applied to enterprises transporting agricultural products from Da Lat to Ho Chi Minh City.

2. Literature Review

The linear programming (LP) method is a mathematical technique that is known to utilize resource scarcity in the vast majority of sectors or most sectors, in particular logistics and supply chain management. An Excel solver is utilized to solve this LP problem which is to minimize transportation costs during the pandemic outbreak. In order to tackle both basic and complicated transportation issues, several LP computer programs are developed. The classical LP algorithms can solve these issues considerably faster.

LP approaches are frequently applied to solve real-world logistics and supply chain situations by developing optimization methods since then. Decision-makers provide solutions which help supply chain be more effective and efficient, such as a proposed Mixed-Integer Linear Programming (MILP) based on partial optimization that is dynamic and iterative to decide enhanced warehouse location and minimize transportation cost (You et al, 2019). Mixed integer linear programming is also used to assess robotic deployment in order picking (Lee, Hung-Yu and Murray, 2019). The paper shows that based pick, place, and transport vehicle routing diminishes congestion in the aisles and considerably the amount of time to bring all of the goods on a pick list to packing station. Solaja et al. addresses application of LP techniques in production planning to maximization of available resource, which will increasingly improve company's performance. The study

concludes that LP should be used rather than heuristic technique in solving production planning problems (Solaja et al, 2019). Lu et al shows an approach to Fuzzy MILP (FMILP) based on piece-wise membership to design optimally an integrated assembly-recycling system. This report demonstrates this network can easily drive the recycling process such that faulty materials may retrieve the residue value by optimizing the future and reverse logistics of the assembly station at the same time (Lu et al, 2020). Klosowski et al applied integer LP to optimize waste by building a controller of decisions. The paper shows the notion of waste optimization at the cost of the regulated rise in work-in-process stock limitations for the manufacture of furniture (Klosowski et al, 2017). Guo & Oblój solved the Martingale Optimal Transport (MOT) problem through a LP series (Guo & Oblój, 2019).

Yuan et al offers an integrated and long-term MILP model for optimum bike-sharing scheme planning. The findings revealed that the suggested model worked effectively with regard to solution quality and time, especially in response to the unpredictable demand (Yuan et al, 2019). Using a weighted sum technique, the Hub-and-Spoke based Road–Rail Intermodal Transportation (HS-RRIT) network design issue is solved by reformulating the single-objective, cross integrated LP model (Wang et al, 2018). Wang et al provides a MILP model, which minimizes total cost, and a FMILP model, which minimized inaccurate total cost in situations of uncertain information used in intermodal freight transportation (Wang et al, 2020). A Geographical Information System (GIS) mixed MILP has been developed to optimize a supply chain of biodiesel in Northern Great Plains (Jeong, Sieverding, and Stone, 2018). The study model replicates the least cost routes directly using the GIS network analysis and proposes the combination of different transport modes for infrastructure locations. Nurprihatin, and Montororing used LP under the Capacitated Vehicle Routing Problem model (CVRP) to measure distribution efficiency of subsidized rice in the outbreak of Covid-19 in Indonesia by proposing solution enhanced choice on vehicle route (Nurprihatin, and Montororing, 2021).

Binh addresses vehicle routing problem (VRP) under Hockey Stick Effect of transportation optimization, which dominates the supply chain in emerging nations (Binh, 2016). By picking the mixed integer programming (MIP), the article shows savings for 3PL that might enable 3PL handle surge demand successfully at the conclusion of the time is up-and-coming. Zheng et al offer a bi-objective mix integer programming (MIP) optimization model to ensure the safe navigation of ships and minimize overturning of container transit via various ports of the Yangtze River in China through the building of stowage planning during container transportation (Zheng et al, 2018). Xu et al present a mixed-integer programming approach to develop and solve a two-echelon location routing issue with diversity bio-waste transportation (Xu et al, 2021). The aim is to synchronously identify transit routes and sites of future treatment plants while maximizing bio-waste recycling profits. Akbaripo et al presented new mixed-integer programming (MIP) models to design the movement of service selection optimization and scheduling (SSOS) in Manufacturing-as-a-Service (MaaS), in a particular transportation in cloud manufacturing environment. This models also tackle optimization of routing decisions in hub-spokes transportation network when manufacturing resources have been allocated (Akbaripo et al, 2018). Ma et al applied a mixed-integer programming model to balance freight flow and enhance transport efficiency in China Railway (CR) Express, is significant container transit cross-continental between China and Europe. With respect to transport time constraint, the paper present the hierarchical multimodal hub location issue, reducing the overall costs of the trip (Ma et al, 2020). Komarudin et al used mixed integer programming to build a long-term sea transport logistics network in Indonesia, a archipelagic state but logistics costs are extremely expensive and not efficient., in different scenarios with profit maximization (Komarudin et al ,2017).

The purpose of this research is to create the MIP model to optimize transportation cost in supply chain and improve transport efficiently in the context of supply chain disruption in light of pandemic outbreak.

3. Research Method

LP is a branch of mathematical programming designed to solve optimization problems where the objectives and all associated constraints can be represented as a linear function. LP is an algorithm that finds the optimality of a method (or preferred alternative) from an infinite number of solutions. An optimal plan is one that satisfies the stated goals of a company, with limitations and constraints. It is a powerful tool in management science and operations research to make decisions with certainty. The LP model consists of two components:

1. Objective function: The enterprise must define specific goals to be achieved.
2. Constraints: The resources and limitations that the enterprise have currently in order to solve the problem.

As the name implies, both the objective function and the constraints must be linear. It was developed by George Dantzig, in 1947, to find the ultimate solution to the US Army Force's supply problems during the Second World War. It is useful in allocating scarce resources like materials, machines, people, time etc.

3.1. The Linear Programming Problem

The Linear Programming (LP) problem begins with defining the decision variables that will be used to determine the solutions of the problem and is defined below:

$$x_j; j = 1, 2, \dots, n.$$

For every LP problem, the main objective function is either to maximize or minimize an attribute in order determine the optimal solution and is defined below:

$$\zeta = c_1x_1 + c_2x_2 + \dots + c_nx_n.$$

LP problems is then defined with a set of constraints which are generally combined with the decision variables in order to show the limitations in resources for the overall problem as shown below:

$$a_1x_1 + a_2x_2 + \dots + a_nx_n \begin{cases} \leq \\ = \\ \geq \end{cases} b.$$

Therefore a general LP problem will have a pattern similarly below:

Maximize/Minimize: $c_1x_1 + c_2x_2 + \dots + c_nx_n$

Subject to: $a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n \leq b_1$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n \leq b_2$$

⋮

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n \leq b_m$$

$$x_1, x_2, \dots, x_n \geq 0.$$

3.2 Mathematical Model

The min-cost allocation model developed here addresses the difficult logistical challenges faced in this pandemic outbreak situation.

The model minimizes the total product shipping costs from a departure place to some other locations without exceeding vehicle weight capacities and production capacity.

The model employ balance equations that ensure that the needs of all destinations are met with the least number of transits and the lowest cost.

The cost-minimization model is formulated as follows:

$$\text{Minimize } \sum_i \sum_{j \in N} \sum_{m \in M} \sum_{t \in T} U_{ijmt} * C_{ijmt} + \sum_i \sum_{m \in M} X_{im} * F_{im} \quad (*)$$

Subject to:

$$\sum_{j \in N} \sum_{t \in T} U_{ijmt} \leq n \quad \forall i, m \quad (1)$$

$$\sum_{m \in M} \sum_{t \in T} U_{ijmt} \leq VC \quad \forall j, t \quad (2)$$

$$V_{ijmt} \leq Q_{ijmt} \quad \forall i, j, m, t \quad (3)$$

$$\sum_m V_{ijmt} * Q_{ijmt} \geq D_j \quad \forall i, j, t \quad (4)$$

$$\sum_i \sum_{j \in N} \sum_{m \in M} \sum_{t \in T} V_{ijmt} \leq P \quad (5)$$

$$V_{ijmt} \geq 0 \quad (6)$$

$$X_{im} = VC \quad (7)$$

Indices:

i	Destination node
j	Departure node
m	mode of transportation
t	departure time

Decision variables:

X_{im}	number of vehicles of mode m base at node i (integer)
U_{ijmt}	number of trips by vehicle of mode m at i to node j on time t (integer)
V_{ijmt}	amount of product shipped from i to node j by vehicle of mode m on time t (unit/times)

Inputs:

C_{ijmt}	Cost of trip from node i to node j by vehicle of mode m on time t
F_{im}	Fix cost of locating a base for vehicle mode m at node i
Q_{ijmt}	Weight capacity of vehicle mode m on time t (units/ trip)
D_j	Demand of node j
n	Number of trips per vehicle per day
P	Product supplied capacity of company (units/day)
VC	Vehicle capacity
N	set of destination node
M	set of transportation mode
T	Number of time period

The objective function (*) minimizes the sum of the following: total transport costs, fixed vehicle costs. This cost function implicitly assumes the cost of each vehicle trip is known and constant regardless of weight load.

Constraint (1) the total number of mode m vehicles traveling at point i to all points j in a day must be less than or equal to the total number of trips a vehicle can travel in a day.

Constraint (2) is concern with the number of vehicles.

Constraint (3) is about the volume of products and volume capacity of vehicles.

Constraint (4) concern the balance of capacity and customer demand

Constraint (5) is about the total product shipped to all destination nodes must equal or less than the product capacity.

Constraint (6) the volume of product shipped must greater than 0

Constraint (7) total number of vehicle at node i must equal the number of existing vehicle.

4. Case Study

The 4th wave of Covid – 19 epidemic is developing complicatedly in Vietnam, leading to many government regulations on tightening prevention measures including social distancing, restrictions on transactions and travel between provinces and cities. Ho Chi Minh City is the most severely affected city with around 220,000 cases, making it the country's epicenter.

With a large number of infected people and the strict order to tighten the distance in this most populated city in Vietnam, it is difficult for businesses in other provinces to transport goods, especially agricultural products to this city.

Da Lat is one of the main suppliers of agricultural products to Ho Chi Minh City, so agricultural enterprises here also face many difficulties during this pandemic, mainly due to transportation costs and long travel distance.

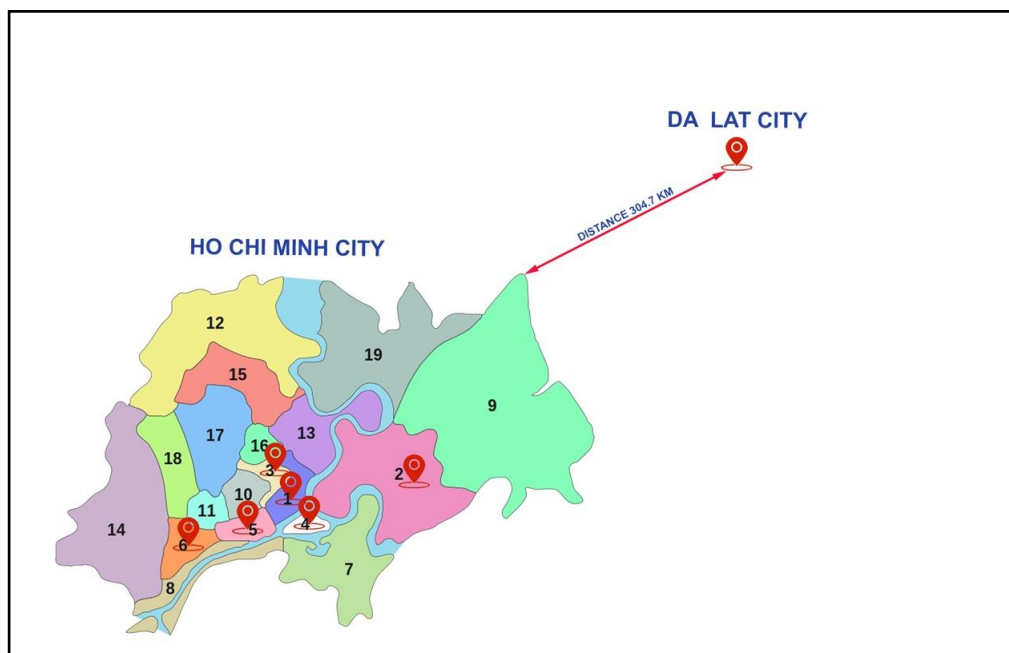


Figure 1. Distance map from Da Lat city to Ho Chi Minh City

Based on the minimization cost model above, a formulation was conducted for a business that transported agricultural products in Da Lat to 6 districts of Ho Chi Minh City. In which, operational information, which includes transportation cost and other concerned costs like demand and company capacity, were used to test the model.

Table 1 below shows the transportation cost of each vehicle mode to each district at a specific time period.

The capacity of each vehicle is different between time periods, it is shown in detail in Table 2.

The operational information about each district demand is shown in Table 3. Lastly, production and other concerned information is illustrated in Table 4.

Table 1. Transportation cost of each vehicle in each time period from DLC to 6 districts in HCMC (Unit: one million VND)

	D1		D2		D3		D4		D5		D6	
	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h
V1	3	2	2	2	1	4	1	1	1	1	1	1
V2	4	3	2	1	2	3	3	2	4	3	3	2
V3	1	2	3	2	3	4	1	4	4	4	1	4
V4	3	4	2	4	3	4	2	1	2	4	1	3
V5	3	2	4	4	3	2	1	2	3	4	1	4
V6	1	4	1	3	3	2	4	1	4	4	3	4
V7	3	1	3	4	4	3	1	2	1	4	3	1
V8	1	3	3	3	2	2	1	3	4	3	4	3
V9	4	2	2	1	4	1	4	4	1	3	4	3
V10	3	3	3	4	1	3	1	2	2	2	2	4

Table 2. Volume capacity of each vehicle in each time period from DLC to 6 districts in HCMC (Unit: Ton)

	D1		D2		D3		D4		D5		D6	
	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h
V1	5	7	5	7	5	7	5	7	5	7	5	7
V2	5	7	5	7	5	7	5	7	5	7	5	7
V3	5	7	5	7	5	7	5	7	5	7	5	7
V4	5	7	5	7	5	7	5	7	5	7	5	7
V5	8	10	8	10	8	10	8	10	8	10	8	10
V6	8	10	8	10	8	10	8	10	8	10	8	10
V7	8	10	8	10	8	10	8	10	8	10	8	10
V8	10	15	10	15	10	15	10	15	10	15	10	15
V9	10	15	10	15	10	15	10	15	10	15	10	15
V10	10	15	10	15	10	15	10	15	10	15	10	15

Table 3. Production demand of 6 districts in HCMC (Unit: Ton/ day)

District	D1	D2	D3	D4	D5	D6
Demand	10	8	12	9	10	9

Table 4. Production and other information

Information	Metrics
Production capacity	1000 (ton)
Number of existing vehicle	10
Number of time period	2
Number of trip per vehicle per day	2

The results of vehicle assigned are described in the Tab. 5 below. The optimal solution allocates vehicle X8 move to District 1 on time period 19h, vehicle X6 transport to District 2 on time period 19h, vehicle X9 transport to District 3 on time period 01h and to District 5 on time period 19h, vehicle X8 assigned to District 4 on time period 19h, and vehicle X7 travels to District 6 on time period 01h. This assignment optimize total transportation cost.

Table 5. Results of vehicle assigned

	D1		D2		D3		D4		D5		D6	
	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h
X1	0	0	0	0	0	0	0	0	0	0	0	0
X2	0	0	0	0	0	0	0	0	0	0	0	0
X3	0	0	0	0	0	0	0	0	0	0	0	0
X4	0	0	0	0	0	0	0	0	0	0	0	0
X5	0	0	0	0	0	0	0	0	0	0	0	0
X6	0	0	1	0	0	0	0	0	0	0	0	0
X7	0	0	0	0	0	0	0	0	0	0	0	1
X8	1	0	0	0	0	0	1	0	0	0	0	0
X9	0	0	0	0	0	1	0	0	1	0	0	0
X10	0	0	0	0	0	0	0	0	0	0	0	0

Corresponding to the allocation of transport vehicle is the amount of goods distributed to each district which is equal to the demand. The result of product volume transport was shown in the Tab. 6.

Table 6. Results of product volume shipped at each assigned vehicle

	D1		D2		D3		D4		D5		D6	
	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h	19h	01h
X1	0	0	0	0	0	0	0	0	0	0	0	0
X2	0	0	0	0	0	0	0	0	0	0	0	0
X3	0	0	0	0	0	0	0	0	0	0	0	0
X4	0	0	0	0	0	0	0	0	0	0	0	0
X5	0	0	0	0	0	0	0	0	0	0	0	0
X6	0	0	8	0	0	0	0	0	0	0	0	0
X7	0	0	0	0	0	0	0	0	0	0	0	9
X8	10	0	0	0	0	0	9	0	0	0	0	0
X9	0	0	0	0	0	12	0	0	10	0	0	0
X10	0	0	0	0	0	0	0	0	0	0	0	0

5. Conclusion

The Covid-19 pandemic, which broke out at the end of January 2020, caused heavy economic, cultural, social and human life losses around the world. Due to the pandemic, the supply chain has been broken and turned upside down, including logistics activities - the backbone of the supply chain. Air freight, road transport and rail transport services have been hardest hit. In this research, the authors proposed a low-cost freight allocation strategy to ensure an efficient operation for businesses ready to resume normal operations in the context of the Covid-19 epidemic's complicated development using mix - integer linear programming approaches. A case study have showed that the method has stronger robustness and convergence; it can achieve collaborative logistics network resource allocation rationalization and optimization. The method also solved the suitable goals achieved by declaring successfully the time and amount of goods each truck should deliver using the MIP problem solved. The contribution of this research is to propose a feasibility and validity of the model, which can provide the optimal resource allocation decisions and plans.

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