Cost Accounting in Multiple-Source and Multiple-Sink Logistics Management From Network Flow Perspectives

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Transportation and logistics costs are becoming a large portion of the operating expenses for many businesses. Recently, supply chain disruptions caused by the COVID-19 pandemic and inflation crisis have brought challenges, especially, to many small- and medium-sized companies. Not only are companies struggling with logistics costs, but logistics bottlenecks are often preventing businesses from growing, expanding, and obtaining additional market shares. According to both academics and practitioners, there must be more literature and studies to address these logistics management challenges from cost accounting perspectives. This study focuses on multiple-source and multiple-sink scenarios, in which products are delivered from various production units to various stores. Optimized solutions to these cases may suggest optimal logistics strategies in terms of the minimized costs, as well as provide insights for later profitability analysis through common cost allocations and segment income statement reports. This paper can contribute to the practical examples in logistics management for businesses and is an addition to the current literature on cost accounting issues.

Keywords: network flow, minimum cost flow, logistics management, allocation of common costs, multiple sources and multiple sinks

INTRODUCTION

Logistics management is very important for retail businesses, since an effective logistics strategy can reduce operating expenses, allow for the delivery of products to customers in a timely fashion, and mitigate potential risks caused by unexpected disruptions. Many small- and medium-sized businesses fail to grow rapidly or transform into large enterprises due to bottlenecks in logistics management, which cause inefficiencies in terms of handling, warehousing, transportation, staffing, and shipping. As a result, these businesses cannot acquire additional marketing opportunities and lose competitiveness to their rivals. On the other hand, demographic changes in various regions may require retail businesses to adjust their strategies to grow their markets and remain competitive, which involves supply chain and logistics management. Previous literature and research place heavy emphasis on business scenarios of single source and single or multiple sinks, such as ordering a bulk quantity of products from one supplier at a bargain price and receiving orders at one or various retail locations. This strategy is about lean operations, reducing purchasing and logistics costs, and minimizing coordination in order to further reduce management costs. Many businesses have gained significant profits and succeeded in the past decades by utilizing this approach.

As geopolitics and COVID-19 continue to affect business and reshape the global supply chain, ripple effects can be observed across all industrial sectors as well as multinational, domestic, regional and local businesses. For instance, there are several challenges faced by many businesses at all levels, including tariffs and trade wars, instability caused by geopolitics, production and logistics disruptions caused by COVID-19 case surges in specific regions, the inflation crisis, and local economic stress. As a result, many investors and businesses are striving to diversify not only suppliers, but also markets, since a single source of supply chain and logistics situations imposes a great risk to many businesses. Trends for managing multiple suppliers and logistics can be seen from small to large businesses. Another aspect of logistics management is dealing with tradeoffs between efficiency and operating costs as well as between risks and operating costs. From business operation perspectives, maintaining a diversified logistics system, including supply chains, purchases, distributions, and deliveries, is quite expensive, as building additional distribution facilities, exploring more distribution channels, and staffing positions requires large initial capital investment, subsequent maintenance, and operating expenses. The logistics management and design with related operating costs is highly integrated in the budgeting and planning process as well as the performance evaluations for any business, as these factors affect production, purchasing, warehousing, as well as sales and delivery activities (i.e., nearly all of the activities in the value chain).

Logistics management often needs to consider many factors, including infrastructure, demographics, labor laws, technology, and markets. Businesses may need to consider both financial and nonfinancial as well as quantitative and quality information when making decisions, hence there are multiple objectives. For example, operating costs, fast delivery, customer satisfaction, and more profits can be set as goals in the planning stage and later used in the performance evaluation. Computer information technology and cloud-based data governance allow businesses to collect a large volume of data and perform complex simulations for logistics planning and management. In general, logistics planning and management may be formulated as network flow and graph theory models, typically having objective functions, such as minimum costs or maximum flows, plus a set of constraints, including time, staffing, infrastructure, resources, and available routes.

In response to trends in adopting more diversified logistics systems, this research study focuses on using accounting objectives and data to more efficiently and effectively operate logistics, especially for multiple-source and multiple-sink cases (e.g., three factories and four stores). To better study these cases, network flow models in graph theory will be employed, as they can be formulated as linear programming or quadratic programming models. The example case in this paper can be formulated as a minimum cost flow problem. As a result, the objective function is the total logistics costs. As logistics costs may be common costs shared by different segments (either factories or stores), it is important to allocate logistics costs to these segments. Therefore, when optimized solutions are found, additional studies can be conducted, including on the allocation of common costs, segment analysis, and profitability analysis. This paper aims to introduce network flow models for logistics management from cost accounting perspectives and providing practical methods to study these models. The paper focuses on a more generic case with multiple-source and multiple-sink cases and tries to close the gap between theories and applications. The research results may provide insights to both accountants and logistics managers in businesses at all levels.

LITERATURE

Logistics management studies often deal with moving products from one location to another, such as from factories to distribution centers, from stores to customers, and from warehouses to factories. In addition, there are costs for moving products and there are capacity and resource constraints as well. These issues can be generally studied using graph theory models, especially network flow models (Galichon, A., 2018; Tutte, W. T., & Tutte, W. T., 2001). A network flow is a directed graph which has vertices and edges connecting these vertices. Each edge may have a capacity and a weight. For logistics management applications, graph theory can be particularly useful, as the vertices can represent locations, such as factories, distribution centers, and stores, and the edges can represent trips between these locations. Graph theory is an important area that has been applied to study many subjects, including public transportation (Derrible, S., & Kennedy, C. 2011; Sobczak, P.,2018), disposition decisions for corporate social responsibility (Agrawal, S., Singh, R. K., & Murtaza, Q., 2016;), corporate finance (Baxamusa, M., Javaid, S., & Harery, K., 2015; Miranda-Lopez, J., Orlova, S., & Sun, L., 2018), the tourism industry (Park, S. et al, 2021), and staffing production (Gouda, A., Hosny, O., & Nassar, K., 2017). Although graph theory or similar ideas could be studied much earlier, the history of graph theory can be formally traced back to the Konigsberg bridges problem in 1735 by Euler (Alexanderson, G., 2006). Later, as linear programming methods developed, many graph theory problems can be formulated and transformed to linear programming or quadratic programming problems (Lovász, L., 1979; Cardoso, D.M., 2001). Therefore, graph theory models became one of the most useful tools.

Originating in logistics that focus on the coordination of people, facilities, goods, supplies, objects and information, graph theory has become an important subject from which many models and theories have been developed and applied successfully to address challenges in logistics. On the other hand, other than traditional algorithms for solving graph theory models, linear programming and nonlinear programming have been greatly integrated into graph theory models, which brings together two subjects to provide powerful tools to impact the entire business world. In one application of graph theory models to study smart city issues (Gutierrez, Jensen & Riaz, 2016), researchers formulated GIS information into graph theory methods to model the data flow within a region and maximize the data coverage with constrained resources. Another important application of graph theory is in air traffic networks, as the model has many economic benefits that affect many people and regions on a daily basis. Air traffic is currently highly regulated due to constraints such as weather, the COVID-19 lockdown, geopolitics, staffing, technical issues, and other resource constraints. A smooth, flexible, and robust air traffic network should be efficient and economic, but not easily disrupted when there are issues. Graph theory models prove to be efficient tools to provide guidance on how to manage air traffic networks optimally as seen in many applications (Dunn, S., & Wilkinson, S. M., 2016; Farrahi, A. H., et al, 2017; Ren, P., & Li, L., 2018; Hu, C., et al, 2022). Water distribution systems are essential, as many regions face clean water crises and costs can be so high that they hinder local economic development. Graph theory models can be particularly useful to improve water distribution efficiency and reduce costs (Hwang, H., & Lansey, K., 2017; Meng, F., et al, 2018). Trash-collection issues can also be modeled by graph theory methods, even with the implementation of Artificial Intelligence technology, to improve cost and time efficiency as well as sustainability (Bonomo, et al, 2012; Maity, Bhattacharyya & Bhattacharyya, 2015; Petridis, N. E., Petridis, K., & Stiakakis, E., 2020; Yu, K. H., et al, 2021).

From accounting perspectives, there is limited literature on applications of graph theory models as most applications are focused on either one aspect of businesses, such as logistics, supply chain, sustainability, and capital flows or the entire business (Ogata, K, 2010; Khakzad, Landucci, & Reniers, 2017; Choi, Y., Li, J., & Wu, D., 2018; Catrini, P., et al, 2022; Wu, H., et al, 2022). Logistics costs and investments can be vital to business successes, as logistics infrastructure, such as transportation tools, facilities, and equipment, are typically costly and require large capital commitment. Furthermore, such infrastructure later impacts performance evaluation and cost efficiency at the enterprise level. A simplified graph theory model has been used to optimize logistics costs for small businesses, allocate common costs, and try to understand how the results will affect performance evaluations (Choi, Y., Li, J., & Wu, D., 2018). However, this method is focused on one source and multiple-sink network flow issues and can be very limited when businesses grow larger or try to enter additional markets. Therefore, more integration of logistics considerations into business budgeting, planning, and performance evaluation should be encouraged, especially from cost/managerial accounting perspectives. On the other hand, when using graph theory models in these tasks, cost and managerial accounting components should be incorporated into models and simulations to achieve the best overall practices. However, in both academia and practicing domains, there is a severe shortage of materials and literature for consideration and guidance. This research focuses on a more general case, multiple-source and multiple-sink models, and can be a great addition to efforts of addressing logistics challenges in business operations from cost/managerial accounting perspectives. The study will contribute to the existing literature in this area.

METHOD

In logistics modelling, a graph is topically defined and formulated mathematically. For instance, every location, such as factories, facilities, and stores, is considered to be a node. There are edges connecting two arbitrary nodes, then a basic graph is formed as *G=(V,E)*, where *V* represents a set of nodes and *E* represents a set of all available edges. Therefore, a basic graph describes connectivity and relationships between objects. A graph can contain more information than just nodes and edges. An edge may not be considered with equal weight, but a value that can describe how this relationship looks. For example, a weighted edge can describe how much it would cost to move one thing from one location to another location (i.e., moving costs) or up to how many units can be moved from one location to another (i.e., delivery capacity). Therefore, a basic graph can be expanded to a more complex graph, weighted graph *G = (V, E, W)*, in which *V* represents a set of nodes, *E* represents a set of all available edges, and *W* represents a set of weight-associated edges. Please note that an edge between two nodes can be directed. For example, there is a path from location A to location B, but not a path in reverse, as one example can be one-way roads in a city. Additional information can be added to the graph by assigning a number to each individual node to describe the function of each node. For example, a node may mean a factory that produces and supplies a number of products as a supplier, a distribution center that has zero net flows in general, or a store that receives inflows of products for sales. On the other hand, there may be a transportation limit from one location to another, such as an infrastructure limit. Hence, a directed and weighted graph can be *G = (V, E, W, T, C)*, in which *V* represents a set of nodes, *E* represents a set of all available edges, *W* represents a set of weight-associated edges, *T* represents a set of edge capacities associated with all edges, and *C* represents a set of capacities associated with nodes. There are more complex graph theory models, and more information can be considered. In the field of logistics management, especially in this study, the focus is more on applications of network flow models. For instance, how to efficiently and effectively move product units through a company's logistics network, such as maximum flow problems and minimum cost flow problems. On the other hand, applications may include one source and one sink, one source and multiple sinks, and multiple-source and multiple-sink cases.

Multiple-source and multiple-sink cases in network flow models have wide applications, as they cover broad cases. These network flow models can be easily formulated as linear or nonlinear programming problems that contain global optimal solutions. This study focuses on multiple-source and multiple-sink cases with minimum cost flow objectives, as integrating cost issues into logistics management from a managerial accounting perspective is essential to performance evaluation.

For instance, given a directed and weighted graph $G = (V, E, W, T, C)$, in which *V* represents a set of nodes, including both sources S_1 and sinks S_2 or $V = S_1 \cup S_2$; *E* represents a set of edges connecting these nodes as $E = \{e_{ij}\}, i, j \varepsilon V$; *W* represents a set of weights, say costs, associated with edges as $W = \{w_e\}, e \varepsilon E$; *T* represents a set of weights, say costs, associated with edges as $T = \{T_e\}, e \varepsilon E$, and *C* represents a set of capacity, either demand or supply, associated with nodes as $C = \{C_{ij}\}, i, j \varepsilon V$.

When the objective is to minimize all the transportation costs, a minimum network flow model can be formulated as follows:

$$\min \sum_{(i,j)} w_{ij} x_{ij}, \text{ where } i, j \varepsilon V \qquad (1)$$

$$\text{s.t} \sum_k x_{ki} - \sum_j x_{ij} = C_i \text{for } i \varepsilon S1 \quad \text{(Sink Capacity Constraints)} \qquad (2)$$

$\sum_j x_{ij} \leq$ for $i \; \varepsilon \; S2, j \; \varepsilon \; V \backslash i$ (Source Capacity Constraints) (3)

$0 \leq x_{ij} \leq T_{e_{ij}}$, (Edge Capacity Constraints) (4)

Please note that this linear programming problem can be solved with an optimal answer when the feasible region is bounded, as seen in this case. If any variables need to be integers or binary, then integer programming and binary programming methods can be applied.

Another consideration is that, in applications, if there is only one transportation vehicle, which leaves a source, delivers products to sinks, and then returns, then there will be just one edge leaving this source. To force this constraint, users have two options: either make a constraint or add a penalty term in the objective function. The latter is more highly recommended, as a feasible solution region of bounded linear constraints can be easy to use to find optimal solutions. Therefore, in this case, the problem objective can be modified as the following expression:

$$\min \sum_{(i,j)} w_{ij} x_{ij} + P\left(\sum_i \left(\left(\sum_j x_{ij}\right)^2 - \left(\sum_j x_{ij}{}^2\right)\right)^2\right) \quad (5)$$
s.t (2)- (4)

In applications, users should focus on how to incorporate various costs into the network, such as gas prices, tariffs, labor costs, facility costs, shipping and handling costs, administrative costs, and allocated overhead costs. From ESG and CSR perspectives, reducing carbon dioxide or one's carbon footprint in business operations requires companies to focus on more sustainable logistics management solutions. Please note that the methods described here can be further applied to other areas, such as manufacturing, nonprofit processes, off-shore operations, and transfer pricing, which may be discussed in future research papers.

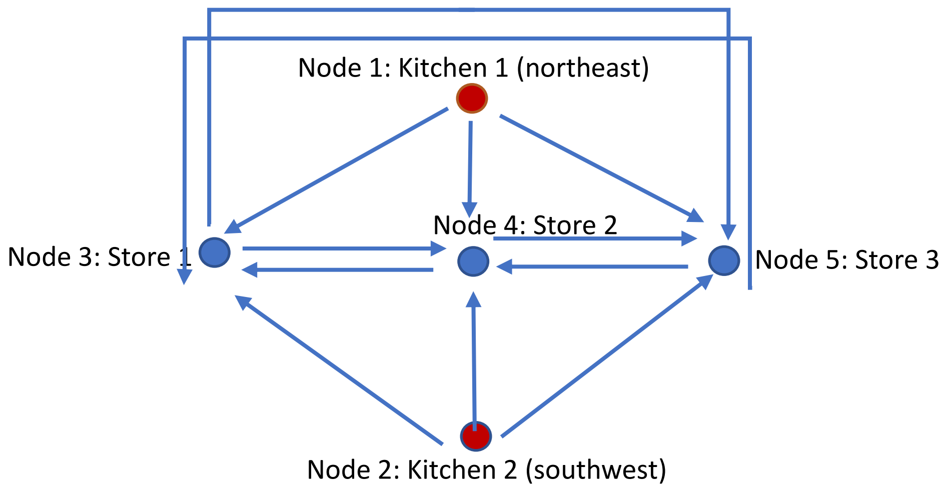
CASE STUDY

Description

Olive Donuts is a family-owned business that has just recently started to make and sell donuts to local stores. Recently, Olive Donuts entered a contract with a chain bakery business with three stores in the downtown area of a metropolitan city. As per this contract, Olive Donuts will deliver fresh donuts to each store daily. Specifically, according to the contract, Olive Donuts only sells one dozen boxes of regular donuts and the negotiated wholesale price is $3.50 per dozen. Olive Donuts will be responsible for handling and delivery. Each store will receive a delivery of 150 boxes of donuts each morning.

Olive Donuts has two kitchen locations in the metropolitan city. One is in the northeast section of the city and about 30 miles away from the downtown area and the other is in the southwest section of the city and about 35 miles away from the downtown area. These three stores, although in the downtown area, are about 8-10 miles away from one another. Olive Donuts just started its business and faces both challenges and constraints in terms of its capital investment and financing. As a result, Olive Donuts kitchen has a maximum production capacity of 250 boxes of donuts. The total production capacity of 500 boxes from these two kitchens will meet this contracted demand from the bakery stores. Olive Donuts has a delivery van for each kitchen. The graphic illustration of the business and contract can be seen in Figure 1. Therefore, this issue is a multiple-source and multiple-sink question in the network flow field.

FIGURE 1
GRAPHIC ILLUSTRATION OF KITCHENS AND STORES



The recent inflation crisis and supply-chain issues have brought about many challenges to businesses across different industry sectors, including Olive Donuts. High gas prices, traffic issues in metropolitan areas, rising labor costs, and other business expenses force Olive Donuts to be cost efficient and risk intelligent when planning business operations. For instance, having a delivery van for each kitchen is important, as Olive Donuts focuses on quality products and the timely delivery of fresh donuts. This will also save on gas, maintenance, and labor costs. Olive Donuts operates its business as follows: making fresh donuts every afternoon, packaging them in boxes, loading those boxes early in the morning the next day, leaving the kitchen, visiting stores, unloading the boxes, and then returning to the kitchen. Considering the use of only one delivery vehicle for each kitchen, long distances from each kitchen to every store, as well as time constraints, it is more realistic to have one delivery vehicle from each kitchen carry all the loads and visit stores in one trip. Please note that a standalone trip from every kitchen to each store is impractical as there is only one delivery vehicle.

TABLE 1
CATEGORIZED EXPENSES FOR OLIVE DONUTS

Daily	**Kitchen 1**	**Kitchen 2**
Variable Manufacturing Costs per Box	$1	$1
Fixed Manufacturing Costs	$75	$65
Fixed Operating Expenses	$50	$45
Variable Operating Costs (excluding logistics)	$.2	$.2

The business expenses of Olive Donuts include variable manufacturing costs for donuts, fixed manufacturing costs for donuts, fixed operating expenses for each kitchen, and logistics expenses. Furthermore, variable manufacturing costs for donuts, fixed manufacturing costs for donuts, and fixed operating expenses for each kitchen are relatively simple (as shown in Table 1).

TABLE 2
UNIT VARIABLE LOGISTICS COSTS

Node	Kitchen 1 (250 boxes)	Kitchen 2 (250 boxes)	Store 1 (150 boxes)	Store 2 (150 boxes)	Store 3 (150 boxes)
Kitchen 1 (250 boxes)	0	NA	\$1.5	\$1	\$1.15
Kitchen 2 (250 boxes)	NA	0	\$1.2	\$1.5	\$1.05
Store 1 (150 boxes)	NA	NA	0	\$0.2	\$0.3
Store 2 (150 boxes)	NA	NA	\$0.2	0	\$0.25
Store 3 (150 boxes)	NA	NA	\$0.3	\$0.25	0

However, logistic expenses are more complex to study, as several factors may affect them, including road conditions, distance from one location to another, traffic conditions, speed limits, and toll fees. Please note that delivery drivers are paid per hour and gas expenses can vary. Therefore, Olive Donuts must develop an optimal strategy in terms of its efficient delivery of donuts from kitchens to stores, so that the total logistical expenses can be minimized. Optimizing logistics will also allow Olive Donuts to gain insights into segment profitability analysis by kitchen and store, respectively. Olive Donuts investigates logistics, including gas prices, mileage, road conditions, truck depreciation costs, and maintenance costs. As a result, Olive Donuts has the following variable logistics costs, as seen in the table.

Simulation and Solutions

Given the business conditions and objectives of Olive Donuts, this case can be modeled as a minimum cost flow problem by minimizing logistics expenses and meeting all necessary constraints. Please note that all the fixed expenses are irrelevant in this study, as they will not affect the results regardless of the activity level. Table 2 has the information of weighted arcs when moving units along each flow. Therefore, a weighted graph $G = (V, E, W, T, C)$ is developed. Please note that, in this graph, $V = K \cup S$, in which $K = \{1,2\}$ and $S = \{3,4,5\}$. $K = \{1,2\}$ represents two kitchens and $S = \{3,4,5\}$ represents three stores. The constraints include store demand, which is 150 units for each store, kitchen production capacity, which is 250 units for each kitchen, and trivial constraints that require all flows to be nonnegative and integral. However, one delivery vehicle per kitchen and one trip requires additional considerations. In this case, there are two approaches: (1) the quadratic constraint approach and (2) the penalty function approach. Considering the simulations will be done in Excel, the penalty function approach is used so that all the constraints are linear, which makes it easier to find an optimal answer.

For instance, this model is developed as follows:

Objective equation: $\min \sum_{(i,j)} w_{ij} x_{ij} + P(\sum_i ((\sum_j x_{ij})^2 - (\sum_j x_{ij}{}^2))^2)$, in which x_{ij} are flows between two nodes, l_{ij} is available in Table 2, $x_{ij}$are flows from each kitchen to each store, $i \in K, j \in S$, and P can be a arbitrary large positive number, hence a penalty term:

s. t constraints:

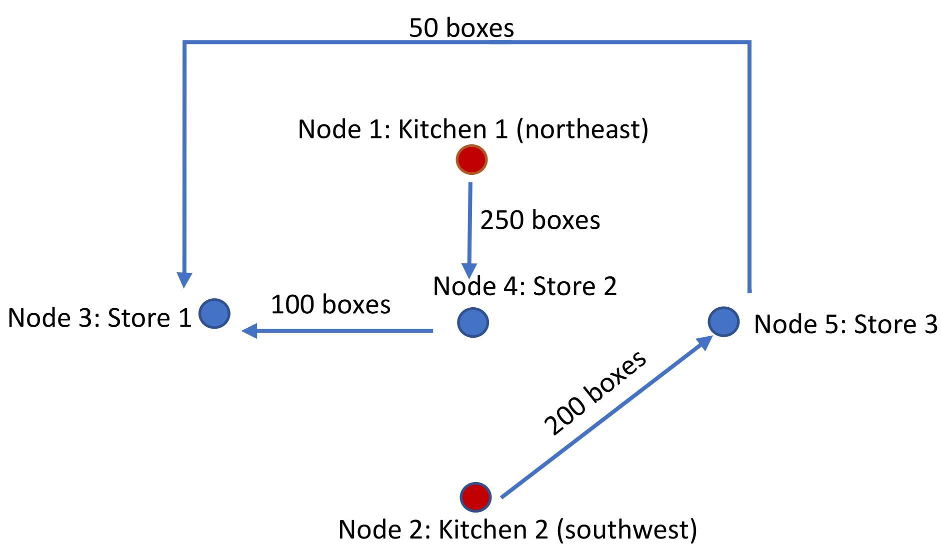
1) Store Demand, $\sum_k x_{ki} - \sum_j x_{ij} = 150$, where $i \in K,\ k, j \in V \backslash i$
2) Kitchen Capacity, $\sum_j x_{ij} \leq 250$, where $i \in K,\ j \in S$
3) Trivial Constraints, $0 \leq x_{ij} \leq 250$, where $i, j \in V$
4) Integer Constraints, all x_{ij} are integers, where $i, j \in V$

TABLE 3
OPTIMIZATION SOLUTION

Node	Kitchen 1 (250 boxes)	Kitchen 2 (250 boxes)	Store 1 (150 boxes)	Store 2 (150 boxes)	Store 3 (150 boxes)
Kitchen 1 (250 boxes)	-	-	-	250	-
Kitchen 2 (250 boxes)	-	-	-	-	200
Store 1 (150 boxes)	-	-	100	-	-
Store 2 (150 boxes)	-	-	-	-	-
Store 3 (150 boxes)	-	-	50	-	-

This constructed model has a quadratic objective function with linear constraints and is also an integer programming problem since all the variables are integers. Solutions to this optimization problem explain how to deliver products from kitchens to stores for minimized variable logistics costs, which have gas, maintenance, labor, depreciation, and setup costs. There are different approaches for solving a quadratic programming problem as reviewed in previous sections. There are also software tools that can be used to find optimal solutions. As this problem has a feasible and bounded solution region as well as a well-defined objective function, the problem will have an optimal solution. An Excel spreadsheet can be applied to solve this problem given that the problem size is not too large and only contains two sources and three sinks. For instance, the optimal solution to this case is $495, as the minimized total variable logistics cost. The delivery strategy is that a delivery vehicle will leave Kitchen 1 with 250 boxes of donuts for Store 2 first, unload 150 boxes, and then deliver the remaining 100 boxes to Store 1, while another delivery vehicle will leave Kitchen 2 with 200 boxes of donuts for Store 3 first, unload 150 boxes, and then deliver the remaining 50 boxes to Store 1. This logistics schedule has the least total variable logistics expenses. Table 3 shows the optimized logistics path, which is further visualized in Figure 2.

FIGURE 2
GRAPHIC ILLUSTRATION OF OPTIMIZED LOGISTICS ROUTE



Please note that the objective function in this case focuses on the minimized logistics costs and that the weighted arcs for the flows are associated with the variable logistics costs, but other applications may include the optimized trip time, optimized carbon emissions, or optimized store visits with additional constraints. As gas prices and supply chain concerns continue to be issues, many businesses face challenges with increasing costs. As a result, this study can be insightful and useful to similar modeling cases and practical applications.

Profitability Analysis

The results from solving this optimization problem can be particularly helpful for Olive Donuts in terms of conducting a profitability analysis, such as the allocation of logistics costs, segment profitability analysis, and budgeting/planning. Please note that from financial reporting perspectives, how to allocate common costs will not impact the profitability of the entire business at all, but from managerial accounting perspectives, it is quite important for a business to understand its operations in terms of efficiency, opportunities, risks, and performance evaluations.

More importantly, considering this multiple-source and multiple-sink network flow case, this study can complement existing studies. The first noteworthy analysis is conducted to evaluate each individual kitchen performance. As most transaction records can be directly traced within each kitchen in this case, it is relatively simple to prepare the financial statements for each kitchen-operated standalone location. Kitchen 1 seems to have better profitability than Kitchen 2 (30.5% vs 28.1%), although the overall logistics costs seem higher. It is also important to point out that the daily logistics costs were reduced from $555 to $495, on average, which accounts for at least 10.81% cost savings for logistics and at least 4.72% savings for all costs. This contributes to a profit increase of at least 12.77% (from $470 to $530). This is significant and can help businesses remain competitive, improve cash flow, and potentially expand. The analysis can be reviewed in Table 4.

TABLE 4
OLIVE DONUTS KITCHEN INCOME STATEMENT

Daily	Kitchen 1	Kitchen 2	Total
Sales	$4*250 = $1,000	$4*200 = $800	$1,800
Less Cost of Goods Sold			
Variable Manufacturing Costs	$1*250 =$250	$1*200=$200	$450
Fixed Manufacturing Costs	$75	$65	$140
Total	$325	$265	$590
Gross Profit	$675	$535	$1,210
Gross Profit Ratio	67.5%	66.9%	67.2%
Less Operating Expenses			
Fixed Operating Costs	$50	$45	$95
Variable Operating Costs (excluding logistics)	$.2*250=$50	$.2*200=$40	$90
Variable Logistics Costs			
Kitchen 1 to Store 2 (250 boxes)	$1*250=$250		$250
Store 2 to Store 1 (100 boxes)	$.2*100 = $20		$20
Kitchen 2 to Store 3 (200 boxes)		$1.05*200=$210	$210
Store 3 to Store 1 (50 boxes)		$.3*50 = $15	$15
Total	$370	$310	$680
Operating Income	$305	$225	$530
Profit Ratio	30.5%	28.1%	29.4%

Olive Donuts can also report segment income statements by store, which is a common practice in managerial accounting as it will provide additional insights for businesses to determine how customers contribute to supplier's profitability.

Standalone Method

The first step is calculating the average logistics costs of receiving 150 boxes from each kitchen for a particular store as standalone logistics costs, and then determining the weight of each standalone logistics cost compared to all the standalone logistics costs for each store. Therefore, the allocated logistics costs to every store will be the total actual logistics costs multiplied by each percentage for each store. The results indicate that Store 1 is most allocated with logistics costs and has the largest logistics costs per unit. This analysis can be found in Table 5.

TABLE 5
STANDALONE METHOD TO ALLOCATE LOGISTICS COSTS TO EACH STORE

	Store 1		Store 2		Store 3		Total
	Kitchen 1	Kitchen 2	Kitchen 1	Kitchen 2	Kitchen 1	Kitchen 2	
Standalone	$225	$180	$150	$225	$172.5	$157.5	
Average	$202.5		$187.5		$165		$555
Percentage	36.49%		33.78%		29.73%		100%
Allocated Costs	$180.63		$167.21		$147.16		$495
Unit Cost	$1.20		$1.11		$.98		$1.1

Shapley Value Method

The Shapley value method starts with all the permutations of the incremental method, ranking all the stores in any order, and then reimbursing the joint logistics costs to every store until all costs are fully allocated. However, during this process, the last stores may not receive the full amount. Once, after all the permutations are used, all the costs for each store will be averaged respectively. Since there are three stores in this case, six permutations will be available. The results are quite close to those obtained through the standalone method with similar conclusions. This shows that either approach may be carefully used for performance evaluation. The detailed analysis can be seen in Table 6.

TABLE 6
SHAPLEY VALUE METHOD TO ALLOCATE LOGISTICS COSTS TO EACH STORE

Permutation	Total	Primary	Secondary	Last
1	$495	Store 1, $202.5	Store 2, $187.5	Store 3, $105
2	$495	Store 1, $202.5	Store 3, $165	Store 2, $127.5
3	$495	Store 2, $187.5	Store 1, $202.5	Store 3, $90
4	$495	Store 2, $187.5	Store 3, $165	Store 1, $142.5
5	$495	Store 3, $165	Store 1, $202.5	Store 2, $127.5
6	$495	Store 3, $165	Store 2, $187.5	Store 1, $142.5
Average		Store 1, $182.5	Store 2, $167.5	Store 3, $145
Percentage		36.87%	33.84%	29.29%
Unit Cost		$1.22	$1.12	$0.97

TABLE 7
STORE INCOME STATEMENT VIA STANDALONE

Daily	Store 1	Store 2	Store 3	Total
Sales	$4*150=$600	$4*150=$600	$4*150=$600	$1,800
Less Cost of Goods Sold				
Variable Manufacturing Costs	$1*150=$150	$1*150=$150	$1*150=$150	$450
Fixed Manufacturing Costs (allocation of $140 = $75+$65)	$140*0.3649 =$51.09	$140*0.3378 =$47.29	$140*0.2973 =$41.62	$140
Gross Profit	$398.91	$402.71	$408.38	$1,210
Gross Profit Ratio	66.49%	67.12%	68.06%	67.2%
Less Operating Expenses				
Fixed Operating Costs (allocation of $95 = $50+$45)	$95*0.3649 =$34.67	$95*0.3378 =$32.09	$95*0.2973 =$28.24	$95
Variable Operating Costs (excluding logistics)	$.2*150=$30	$.2*150=$30	$.2*150=$30	$90
Variable Logistics Costs	$180.63	$167.21	$147.16	$495
Operating Income	$153.61	$173.41	$202.98	$530
Profit Ratio	25.6%	28.90%	33.83%	29.4%

As both methods are being applied, Olive Donuts can study the segment income statement by store. However, fixed operating expenses must be allocated to each store. There are two different approaches under consideration: (1) the average method and (2) weighted allocation based on logistics costs. The latter is recommended, as it is more activity-based and slightly more accurate. For instance, the results can be seen and compared in Tables 7 and 8. Results obtained from both the standalone and Shapley value methods, although slightly different, indicate that Store 1 has the least profitability overall due to the highest allocated logistics costs, while Store 3 has the largest profitability overall due to the least allocated logistics costs, which could motivate Olive Donuts to dive deeper into logistics efficiency. For example, should Olive Donuts downsize its delivery vehicles, especially from Kitchen 2 to Store 3, for only 200 product units? Should Olive Donuts use a different approach for moving products between stores? Should Olive Donuts look for outsourcing options? All these considerations should take place and be revisited regularly to help Olive Donuts remain competitive, cost efficient, and risk intelligent.

TABLE 8
STORE INCOME STATEMENT VIA SHAPLEY VALUE METHOD

Daily	Store 1	Store 2	Store 3	Total
Sales	$4*150=$600	$4*150=$600	$4*150=$600	$1,800
Less Cost of Goods Sold				
Variable Manufacturing Costs	$1*150=$150	$1*150=$150	$1*150=$150	$450
Fixed Manufacturing Costs (allocation of $140 = $75+$65)	$140*0.3687 =$51.62	$140*0.3384 =$47.38	$140*0.2929 =$41.00	$140
Gross Profit	$398.38	$402.62	$409	$1,210
Gross Profit Ratio	66.40%	67.10%	68.17%	67.2%
Less Operating Expenses				
Fixed Operating Costs (allocation of $95 = $50+$45)	$95*0.3687 =$35.03	$95*0.3384 =$32.15	$95*0.2929 =$27.83	$95
Variable Operating Costs (excluding logistics)	$.2*150=$30	$.2*150=$30	$.2*150=$30	$90
Variable Logistics Costs	$182.5	$167.5	$145	$495
Operating Income	$150.85	$172.97	$206.17	$530
Profit Ratio	25.14%	28.83%	34.36%	29.4%

In summary, logistics management is important for many businesses. For instance, in this case, an optimal logistics management, from a cost accounting perspectives, contributes significantly to business profitability and efficiency. Graph theory models can be extremely helpful and convenient to incorporate cost accounting issues in logistics planning and management, as this case study demonstrates. Using the standalone and Shapley value methods based on the optimal logistics management provides additional insights for businesses to conduct further analysis and develop strategies to continue improving their competitiveness and efficiency.

MANAGERIAL IMPLICATIONS

A business can simulate its delivery plans efficiently by setting up its network flow models. These network flow models represent or interpret business conditions and constraints. Furthermore, optimized solutions to these network flow models can explain how businesses should allocate their limited resources to achieve their objectives. Therefore, this study has important managerial implications from both logistics management and managerial accounting perspectives, especially for businesses with large logistics components.

First, the study greatly integrates managerial accounting considerations into logistics management. Considering the current challenges and industry trends, such as geopolitics, COVID-19 disruptions and the inflation crisis, businesses see rising costs in logistics. Developing reliable and efficient logistics strategies are essential to business operations from cost accounting perspectives, which can provide guidance to businesses in many other parts of operations, such as supply chain management receiving products from suppliers, sending materials from various warehouses to shop floors, staffing various positions, transferring products from factories to distribution centers or stores, and providing customer services. From a holistic perspective, businesses should, as early as possible, integrate logistics management consideration into business planning from a managerial accounting perspective.

Second, an effective and efficient logistics management strategy depends on business conditions and resources. It is important to collect transaction data and business data (internally and externally) related to logistics operations, especially accounting-related data. With more and more companies adopting and upgrading their ERP systems, which try to integrate business operations, IT, accounting, and finance into a universal platform, businesses can have sufficient data for formulating complex models. As a result, after the implementation of logistics management models, companies can focus on variance analysis and performance evaluation using generated data to make necessary adjustments. However, as businesses conditions and environments change all the time, businesses also need to consider flexibility, such as building slack in the plans.

Third, from technical perspectives, using network flow models is quite straight forward as in logistics management, managerial accounting considerations can be easily integrated into network flows as shown in this study. Network flow models in graph theory can always be easily converted to linear or quadratic programming problems, which can provide optimal solutions. Hence, these models allow businesses to improve their data analytics processes. Another technical perspective is that network flow models allow businesses to visualize logistics management to gain additional insights on operations. It should be emphasized that simulations and optimization can be executed in most existing platforms or software tools, such as Excel. Many computations demonstrated in this research are completed in the Excel by Solver functions. Therefore, the results in this research may provide an instrument for businesses to further improve logistics management since the measurement scales in this study are a great starting position for continuous improvement and updating.

Finally, the research results and case study contribute to the existing literature of managerial accounting fields for both academics and practitioners. There is a severe lack of resources when it comes to studying logistics management from managerial accounting perspectives due to the incompatibility between these two fields. This research study is an addition to the efforts that showcase the importance of integration of data analytics, technologies, human resources, and critical reasoning in managerial accounting tasks.

CONCLUSIONS

Logistics management is an essential component of business operations, as it affects how businesses design operation processes, allocate resources, conduct performance evaluations and improve profitability. On the other hand, logistics management can be affected by both internal and external factors, such as geopolitics, COVID-19, natural disasters, infrastructure issues, technological advancements, and supply-chain stability. For retail businesses, efficiency and effective logistics management systems can provide customers with timely delivery and great customer experience, which positively impacts both future market growth and customer loyalty. With technology advancement and accounting information systems like ERP, businesses can incorporate abundant accounting data into logistics management. With all these possibilities and opportunities, businesses need to investigate how to design effective and efficient logistics models to maintain and gain competitiveness. Businesses that would like to expand their markets and business scales will also need to put logistics among the first topics to consider, such as reducing waste, eliminating congestion, removing bottlenecks, and being highly efficient.

This research is among the first to investigate how to incorporate managerial accounting issues into the investigation of logistics management systems and how to align accounting outcomes with logistics efficiencies. Considering the capacity constraints, limited resources, efficiency, and profitability, businesses need to carefully balance all these objectives and constraints. Compared to one source and multiple-sink cases, this research pitches more advanced applications, such as multiple-source and multiple-sink cases. Therefore, the results can be more insightful and practical from business operation perspectives, especially for small- and medium-sized businesses that would like to expand their markets. Although the existing models still have limitations and can be relatively simple, the simulations and results provide an important starting point for users and researchers to further improve applications of network flow models in managerial accounting. These applications may not necessarily be limited to logistics management alone, but may demonstrate great potential in other managerial accounting issues. From technical perspectives, this research shows the process of how to proceed with logistics management from managerial accounting perspectives, defining business problems, formulating objectives and constraints, setting up network flow models, and using technological tools to find optimal solutions. Excel Solver is a highly effective tool for such applications. On the other hand, this paper also demonstrates how to explore additional managerial accounting issues after optimal logistics management solutions are obtained, such as the allocation of common costs via the standalone method and Shapley value method, profitability analysis, and segment financial reporting.

Recent developments in technology and data analytics demand high integrations of managerial accounting issues into every aspect of business operations and decision-making processes at a holistic level. However, there is a lack of resources and studies to address these applications, such as logistics management and managerial accounting. This research aims to close the gap by employing network flow models with managerial accounting considerations, visualizing logistics management, optimizing outcomes, and making a comprehensive analysis of performance evaluation possible. This research has few limitations, and the results may also suggest a few future directions. For instance, GIS and AIS can be further integrated and employed to provide additional data for businesses to develop efficient and effective logistics systems. Data mining techniques should be used to further analyze input data into models, while taxation and transfer pricing issues may be important for multinational companies that operate offshore.

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