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Mobile vendor routing adoptions to wholesale market relocations considering cooperative and non-cooperative behaviours

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ABSTRACT

Wholesale markets are crucial in urban supply chains, serving as key distribution hubs for mobile vendors within the informal sector. This study examines how wholesale market relocation affects the routing efficiency of mobile vendors and innovates how cooperative and non-cooperative behaviours shape the spatial distribution outcomes. Methodologically, the study develops an adaptation of the Clarke and Wright Savings Algorithm (CWSA), modified to the operational characteristics of mobile vendors. This approach extends the classical vehicle routing algorithm to decentralised/dynamic informal distribution systems, allowing the potential to cooperate by sharing customer base. The findings reveal that strategically planned market relocations can significantly reduce travel distance, whereas poorly located markets exacerbate routing inefficiencies. Cooperative behaviour further amplifies efficiency gains by reducing redundant travel and balances load distribution. Empirical analysis of the Segiri market relocation in Samarinda (Indonesia) indicated distance savings of 5.27 % under inclusive scenario, which could rise to 34.91 % in selective scenario.

1. Introduction

The spatial configuration of cities plays a crucial role in shaping economic growth and trade efficiency. However, decisions regarding the placement and relocation of commercial facilities, such as warehouses and wholesale markets, often receive less attention compared to residential planning within integrated transport and urban development frameworks (Balbontin and Hensher, 2021). Whilst the warehouse location problem has been extensively studied in the past, discourse on wholesale market locations has only recently gained attention (Nugroho et al., 2024). Wholesale markets function as key distribution hubs linking producers, traders/retailers and mobile vendors. They facilitate large-scale transactions, foster competition, and ensure the steady availability of fresh goods for end consumers (Agwu and Ibeabuchi, 2011; Esmizadeh et al., 2021; Schwarz, 2022; Smith, 2002). However, determining an optimal location for wholesale markets is a complex process influenced by urban expansion, infrastructure growth, and shifts in economic activities and consumer demand.

Wholesale markets play a vital role in supporting urban informal economies, particularly for mobile vendors who ensure the distribution of goods to areas with limited retail access. However, wholesale market placement often increases vendor travel distances leading to higher operational costs, reduced profit margins and diminished competitiveness. Functional land use representations depict the socio-economic structure of urban areas by illustrating the interconnections between production, consumption, living conditions and transportation networks (Pandya and Katti, 2012). The distribution process through wholesale markets plays a pivotal role in moving goods to final consumers (Tollens, 2000). Suboptimal market locations not only impose economic pressure on vendors' business sustainability but also negatively affect travel times, fuel consumption, air pollution and overall transportation efficiency (Börjesson and Kristoffersson, 2014; Nugroho et al., 2024).

Although centrally located wholesale markets are easily accessible by vendors, the high concentration of distribution vehicles contributes significantly to urban congestion (Aljohani and Thompson, 2018). To mitigate these inefficiencies, many cities have opted to relocate wholesale markets to peripheral areas with improved transport infrastructure. Situating markets in areas with better transportation infrastructure can reduce travel distances, shorten delivery times, and enhance urban mobility (Aljohani and Thompson, 2020; Govindan et al.,

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2018). The road network connects production to consumption points through consolidation centres, which thereby reduces distribution costs and provides economies of scale (Etemadnia et al., 2015).

While wholesale market relocations are designed to enhance efficiency for large-scale distributors and formal retailers, their impact on vendors is often overlooked. Relocation enables businesses to leverage surplus production capacity and expand operations in response to market growth, considering factors such as accessibility, transportation costs, and consumer demand (Capello, 2011). However, location decisions must also account for competitive dynamics, resources, business needs, and operational costs (Damborský, 2008; Mukherjee and Bhattacharyya, 2021). When wholesale markets are relocated without considering vendor accessibility, vendors face longer travel distances, increased fuel expenditures, and reduced supply chain flexibility, all of which threaten their economic sustainability.

A key factor influencing how vendors adjust to market relocations may depend on their cooperative and non-cooperative behaviours. Cooperative behaviours include resource-sharing arrangements such as collective transportation, coordinated procurement, and joint route planning, all of which perhaps contribute to reducing inefficiencies and enhancing overall travel efficiency. These practices can be implemented through sharing information, customer exchanges, dynamically routing development, and perhaps even profit sharing (Baindur and Macário, 2013). Conversely, non-cooperative behaviours result in duplicated travel routes, increased congestion, and higher operational costs. As wholesale markets continue to evolve within urban landscapes, understanding vendor behavioural dynamics and their impact on logistical efficiency is crucial for fostering sustainable trade networks.

To address these challenges, this study applies the Clarke and Wright Savings Algorithm (CWSA) to optimise vendor travel routes in response to wholesale market relocations. Route optimisation is critical in minimising travel distances and reducing operational costs. Methods such as the Vehicle Routing Problem (VRP), solved through CWSA, offer effective solutions for achieving these objectives (Segerstedt, 2014). Mathematical models such as the CWSA help simplify distribution processes in relocation scenarios, by enhancing adaptability and supporting the operational sustainability for vendors (Clarke and Wright, 1964).

The findings have practical implications for urban planning and supply chain management. Through the adoption of more strategic relocation and routing models and the integration of vendor-based logistics into planning frameworks, cities can build resilient and efficient trade networks that benefit both large distributors and informal vendors, while deepening understanding of urban logistics, transport efficiency, and evolving wholesale market dynamics in rapidly growing urban centres.

This paper is structured into six sections. Following this introduction, Section 2 reviews vendor logistics challenges and wholesale market relocation implications. Section 3 develops novel CWSA strategies for vendor routing optimisation. Section 4 presents a comprehensive case study analysing relocation scenarios and cooperative versus non-cooperative behaviour. Section 5 discusses the research findings, while Section 6 concludes with strategic implications for enhancing vendor distribution efficiency.

2. Review of mobile vendors problem

The relocation of wholesale markets has been widely implemented as an urban planning strategy to address congestion, logistical inefficiencies and land use constraints (Nugroho et al., 2024). Traditionally, wholesale markets were situated in city centres to maximise accessibility (Smith, 2002). However, with increasing pressure on urban infrastructure, many governments and city planners have opted to relocate these markets to suburban or peripheral areas with better connectivity to major road networks and production zones.

While such relocations benefit large distributors and transport firms, their effects on vendors have received limited attention. Vendors depend on proximity to wholesale markets for daily operations, and relocation that overlooks vendor accessibility forces longer procurement trips, raising transport costs, lowering profitability, reducing product freshness, and increasing supply-chain uncertainty. Delays and fuel-price volatility compound these burdens, yet empirical evidence on vendors' mobility responses to market relocation remains scarce (Cadilhon et al., 2006).

Vendors play a vital last-mile role, especially where conventional retail access is limited (Dharejo et al., 2022). Operating in dynamic conditions, they must continually adjust to demand, transport constraints, and disruptions (Purvis et al., 2014), but typically lack structured route planning and supply chain support (Holz-Rau et al., 2014). As a result, routes are often redundant or overlapping, costs increase, and congestion/mobility regulations restrict access to high-demand areas at peak times (Håkansson and Snehota, 2006). Predominantly non-cooperative behaviour further concentrates vendors on the same corridors and wastes resources; informal groups exist, but no formal framework supports coordination. Competition among vendors exacerbates logistical inefficiencies too. Many operate in non-cooperative environments, where each vendor selects routes independently without coordinating with others. This leads to overlapping travel paths, excessive vendor concentration in specific locations, and inefficient resource utilisation.

Despite extensive research on urban logistics and supply chain management, studies focusing on vendors as independent economic agents remain scarce, research having focused on formal retail networks, depot-based distribution and structured urban delivery systems (Eshtehadi et al., 2017; Liu et al., 2003). However, the operational characteristics of vendors, who function independently, rely on wholesale markets and operate within informal trade models, call for a different analytical approach.

Several research gaps remain unaddressed in the literature. First, there is no structured route optimisation model existing that accommodates the autonomous nature of vendor operations, which fundamentally differs from depot-based systems through their lack of centralised coordination. Second, the impact of wholesale market relocation on vendor travel efficiency remains unexamined, despite its significant implications for urban supply chains. Third, there is limited research on how cooperative and non-cooperative strategies within vendor communities affect logistical efficiency. Understanding collaborative models, shared transport systems, and route coordination mechanisms could improve vendor distribution effectiveness. These gaps highlight the need for optimisation frameworks that address vendors' unique operational constraints, including their dynamic procurement patterns and independent decision-making process, which remain unaddressed by conventional depot location models designed for structured distribution networks.

As summarised in Table 1, existing route optimisation studies largely focus on single-depot-based distribution systems with structured coordination mechanisms, while informal vendor operations characterised by independent origin locations, autonomous route selection, and non-cooperative behaviour. While CWSA has been successfully implemented in formal depot-based distribution systems, its application to informal vendor networks with dispersed supply points remains underexplored. This study explores three interrelated methodologies. First, it extends the CWSA traditionally designed for single-depot operations to accommodate independent vendor locations plus a shared wholesale market as a supply source, thereby adapting the algorithm to a multi-origin configuration. Second, this study uses a framework that analytically captures the potential efficiency gains from cooperative routing among vendors who, in practice, operate independently and non-cooperatively, thus bridging formal logistics optimisation with informal mobility behaviour. Third, this study provides empirical evidence on the impact of wholesale market relocation on vendor travel efficiency, by comparing cooperative and non-cooperative routing strategies.

Table 1
Comparative summary of routing optimisation approaches.

Approach Type	System Characteristics	Decision making Structure	Limitations	How This Study Addresses It	Key References
Depot-based (Formal logistics)	Coordinated, single depot routing	Optimisation from fixed depot	Ignores informal, independent agents with multiple origins	Extends depot-based algorithm to vendor locations.	(Eshtehadi et al., 2017; Clarke and Wright, 1964 Liu et al., 2003; Segerstedt, 2014)
Multi origin vendor system (Informal logistics)	Independent routes, no shared planning	Individual autonomous decision making	Redundant routes, inefficiency	Simulates coordination through cooperative sharing of customers and route reassignment.	(Cadilhon et al., 2006; Dharejo et al., 2022; Holz-Rau et al., 2014; Purvis et al., 2014)
Non-cooperative Behaviour	Individual route selection	No data or resource sharing	Overlaps, competition, higher travel distance	Serves as baseline for evaluating cooperative efficiency gains.	(Damborský, 2008; Håkansson and Snehota, 2006; Mukherjee and Bhattacharyya, 2021)
Cooperative Behaviour	Shared routing, load redistribution	Coordinated planning with resource pooling	Rare in informal sector	Tested through modified CWSA under capacity constraint.	(Baindur and Macário, 2013; Etemadnia et al., 2015; Govindan et al., 2018)
This Study (Modified CWSA)	Analytical optimisation	Depot based framework adapted to informal context	Prior studies lack integration of both behavioural types	Provides unified framework linking cooperative potential	(Clarke and Wright, 1964; Nugroho et al., 2024)

Through this adaptation, this study offers a methodological framework that captures both the cooperative potential and autonomous operational realities of informal vendor systems, thus advancing the distribution optimisation literature beyond structured, depot-based networks to informal urban supply chains.

3. Strategies of CWSA considering mobile vendors

Among heuristic approaches in VRP, CWSA is widely recognized for its efficiency in optimising routes by minimising travel distances as highlighted by (Segerstedt, 2018). Consider a simple example - Wholesale Market ***WM*** from where four customers C_1, C_2, C_3, C_4 need to be served by a vendor. The following is example of route generated using the standard CWSA which concludes at the market in the end. This route in Fig. 1 illustrates how standard CWSA constructs an optimal path by merging locations based on the highest savings value, thereby reducing the total travel distance. However, the vendors in our context start from their home location and go to the market in the first instance to procure their supplies before starting to serve their customers. Moreover, at the end of the day after serving all of their customers they return to their home location instead of the market. These requirements make the vendor problem different to the standard VRP and thus some strategies for adopting CWSA have been introduced here.

Delivery systems within VRP have been a focal point of extensive research, with significant attention given to depot locations, fleet strategies, and cost-effectiveness (Royo et al., 2016). demonstrate that hybrid strategies often outperform single-distribution methods by balancing distribution and waiting times. Similarly (WU et al., 2002; Voigt et al., 2022), emphasise the importance of integrating location determination with vehicle scheduling to enhance logistical efficiency (Mitrović-Minić and Laporte, 2016). explore the role of transhipment points in reducing travel distances within time-sensitive operations, while (Escudero-Santana et al., 2021) highlight the potential for substantial cost savings through order consolidation.

Despite these advancements, there remains a gap in addressing the integration of vendors' locations into depot-based VRP frameworks. This study addresses this limitation by developing three vehicle routing strategies, accounting for vendor locations, and logistical requirements, providing a nuanced approach to route optimisation. By adopting these strategies, it becomes possible to enhance market operations, minimise travel distances, and support the informal sector's critical role within urban economies.

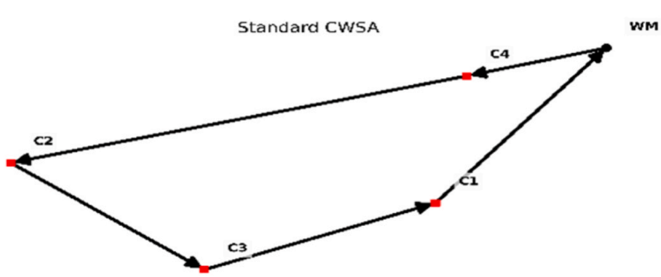

Fig. 1. Simple routing diagram generated by standard CWSA.

a. Strategy 1

Strategy 1 modifies the conventional CWSA by considering the vendor's location as the starting and ending point of the journey. This strategy is further refined into three adoption variants, each addressing different logistical requirements (see Fig. 2).

The savings S are calculated for all possible customer pairs C_k, C_j, using the standard CWSA formula. This determines the benefit of connecting two customers directly instead of routing them separately via the vendor V.

$$\mathrm{S}\left(\mathrm{C_k}, \mathrm{C_j}\right) = \mathrm{D}\left(\mathrm{WM}, \mathrm{C_k}\right) + \mathrm{D}\left(\mathrm{WM}, \mathrm{C_j}\right) - \mathrm{D}\left(\mathrm{C_k}, \mathrm{C_j}\right) \quad (1)$$

Where,

$\mathrm{S}(\mathrm{C_k}, \mathrm{C_j})$: Saving for pairs of customers C_k, C_j,
$\mathrm{D}(\mathrm{WM}, \mathrm{C_k})$: Distance from *WM* to Customer C_k,
$\mathrm{D}(\mathrm{WM}, \mathrm{C_j})$: Distance from *WM* to Customer C_j,
$\mathrm{D}(\mathrm{C_k}, \mathrm{C_j})$: Distance from C_k to C_j

After calculating savings, all customer pairs C_k, C_j are ranked in descending order based on their savings. The pair with highest savings is selected to form the initial route. Unassigned customers are added to the existing route iteratively based on the highest remaining savings. A customer can only be added to the beginning or end of the route.

Vendor routing is determined based on three adoptions to CWSA as described below.

Adoption 1 eliminates the need for vendor to return to the wholesale market (WM) before heading to their home location (*V*), reducing redundant travel and optimising the total distance covered. This approach streamlines operations, enhances efficiency, and minimises unnecessary resource utilisation. The final route structure is: Route = [V, WM, $Customers$ ($ordered\ by\ savings$), V]. With the total distance:

$$\mathrm{D\ total} = \mathrm{D}\left(\mathrm{V}, \mathrm{WM}\right) + \mathrm{D}\left(\mathrm{WM}, \mathrm{R_{first}}\right) + \sum_{k=1}^{n-1} \mathrm{D}\left(\mathrm{R_k}, \mathrm{R_{k+1}}\right) + \mathrm{D}\left(\mathrm{R_{last}}, \mathrm{V}\right) \quad (2)$$

Where,

D total: Total distance
$\mathrm{D}\ (\mathrm{V}, \mathrm{WM})$: Distance from *V* to *WM*
$\mathrm{D}\ (\mathrm{WM}, \mathrm{R_{first}})$: Distance from *WM* to the first customer

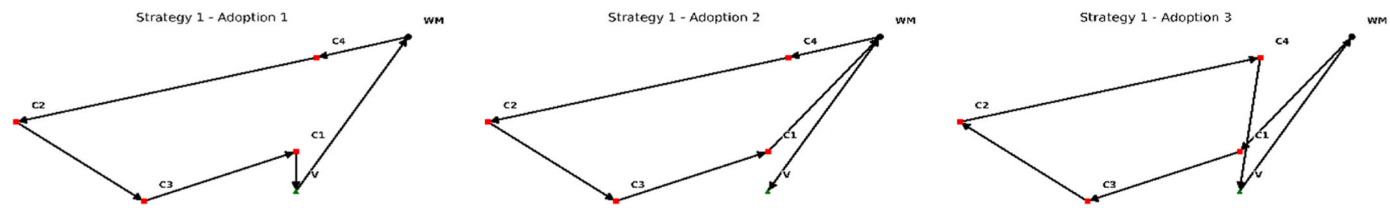

Fig. 2. Simple diagram for Strategy 1.

$\sum_{k=1}^{n-1} \mathrm{D}\left(\mathrm{R_k}, \mathrm{R_{k+1}}\right)$: Distance between consecutive customers

$\mathrm{D}\left(\mathrm{R_{last,}} \mathrm{V}\right)$: Distance from the last customer to *V*

Adoption 2 introduces a stop at the WM after servicing the last customer, enabling vehicles to restock or address operational needs before returning to *V*. This method balances efficiency with practicality, ensuring operational readiness for subsequent journeys. This approach is designed to represent operational situations where mobile vendors may need to restock or address logistical needs before ending their daily operation. Some vendors may find the route via wholesale market efficient, given the location of the existing/new market relative to their home location. It is also noted that mobile vendors also handle non-perishable items such as packaged items, dry goods, or secondary products, which can be topped up. If the market and vendor's home location are in the same direction, then it may make sense to stop by for topping up a few items when returning home. Thus, Adoption 2 offers an option to restock on their way back if they wish to. This adoption, therefore, reflects an operationally flexible scenario, whilst ensuring the efficiency of routing. The final route structure is: Route = [*V*, *WM*, *Customers* (*ordered by savings*), *WM*, *V*].

With the total distance:

$$\mathrm{D\ total} = \mathrm{D}\left(\mathrm{V}, \mathrm{WM}\right) + \mathrm{D}\left(\mathrm{WM,R_{first}}\right) + \sum_{k=1}^{n-1} \mathrm{D}\left(\mathrm{R_k}, \mathrm{R_{k+1}}\right) + \mathrm{D}\left(\mathrm{R_{last,}} \mathrm{WM}\right) + \mathrm{D}\left(\mathrm{WM}, \mathrm{V}\right) \tag{3}$$

Where,

$\mathrm{D}\left(\mathrm{R_{last,}}\mathrm{WM}\right)$: Distance from the last customer to *WM*

$\mathrm{D}\left(\mathrm{WM}, \mathrm{V}\right)$: Distance from *WM* to *V*

Adoption 3 reconfigures the route sequence by reversing the customer delivery order, which can reduce overlap and inefficiencies in specific scenarios. This strategy developed to handle situations where the initial route generated by the standard CWSA may be inefficient as we add the requirement of vendor collecting the goods from market in the morning and return to home location in the evening. By reversing the customers delivery sequence, the algorithm tests an alternative order that may reduce the total travel distance. For instance, if the original sequence follows $V \rightarrow WM \rightarrow C_1 \rightarrow C_2 \rightarrow C_3 \rightarrow V$, reversing it to $V \rightarrow WM \rightarrow C_3 \rightarrow C_2 \rightarrow C_1 \rightarrow V$ may shorten the route if customer C_1 is located closer to the vendor's home location with *WM* being closer to C_3. That is, if the distance by $(WM \rightarrow C_3 + C_1 \rightarrow V) < (\mathrm{W}\,M \rightarrow C_1 + C_3 \rightarrow V)$, reversing the route will be beneficial. This confirms that adoption 3 serves as an adaptive enhancement of the CWSA, improving route efficiency. These variants provide flexibility to adapt routing plans based on the vendor's logistical requirements and operational goals. The route structure is: Route = [*V*, *WM*, *Customers* (*ordered by savings* in reverse order), *V*]. With the total distance:

$$\mathrm{D\ total} = \mathrm{D}\left(\mathrm{V}, \mathrm{WM}\right) + \mathrm{D}\left(\mathrm{WM,R_{first\text{-}reverse}}\right) + \sum_{k=1}^{n-1} \mathrm{D}\left(\mathrm{R_k}, \mathrm{R_{k+1}}\right) + \mathrm{D}\left(\mathrm{R_{last\text{-}reverse,}} \mathrm{V}\right) \tag{4}$$

Where,

$\mathrm{D}\left(\mathrm{WM},\ \mathrm{R_{first\text{-}reverse}}\right)$: Distance from *WM* to first customer in the reversed route

$\mathrm{D}\left(\mathrm{R_{last\text{-}reverse,}} \mathrm{V}\right)$: Distance from the last customer in the reversed route to *V*

Utilising these methods can aid in devising effective and efficient distribution strategies. These three adoptions offer strategies to enhance vehicle routing efficiency by considering vendor locations and logistical needs which provides unique benefits and opportunities for cost savings and improved resource utilisation. The least distance solution from the three adoptions described above is the candidate solution to take forward.

b. Strategy 2

In Strategy 2, the vendor's location is integrated into the CWSA as a dummy customer with zero demand enabling the algorithm to account for the proximity of vendor to customers when calculating route savings. This prevents premature vendor visits, optimises overall travel paths and selects the route with the highest savings for implementation.

The route formation begins by associating each customer (C_k) with the vendor, forming initial pairs C_k, *V*. Additional customers are then integrated into the route based on precomputed savings, ensuring that new customers are added in front of existing customers in the route and not behind *V*. This ensures that *V* remains the definitive endpoint (Fig. 3). The strategy leverages the CWSA to maximise efficiency while minimising total travel distance.

Step by step process of strategy 2:

(i) Add a vendor *V* as a dummy customer with zero demand to the savings calculation. The savings for all possible connections are calculated to evaluate the distance efficiency of linking two customers directly, as opposed to routing them through Wholesale Market (*WM*). For a pair of customers (C_k, C_j), the savings formula is same with Strategy 1 (Equation (1)).

(ii) Calculate the value of savings using CWSA by considering the proximity of V to the customers. This involves discarding all solutions that include visiting V earlier in the chain. Each customer (C_k) is initially associated with *V*, forming pairs C_k, *V*. For example, if there are three customers C_1, C_2, C_3 the initial routes would be $[C_1, V]$; $[C_2, V]$; $[C_3, V]$.

(iii) Choose the route with the highest savings value from the routes formed. Customers are added to the route based on the pre-calculated savings values. The new customer is always added in front of the last customer in the route to ensure the vendor remains the endpoint. With the steps: starting with C_1, V, if saving $S(C_2, C_1)$ has the highest savings, C_2 is added in front of C_1, then

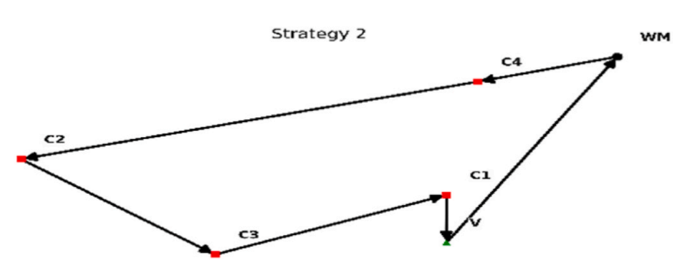

Fig. 3. Simple diagram for Strategy 2.

the route becomes C_2, C_1, V. This process repeated until all customers are integrated into the route.

(iv) After forming the route, the total distance is calculated. After all customers are added, the final route structure adheres to $Route = [V, WM, Customers\ (ordered\ by\ savings), V]$. The total distance of the route is calculated with the same formula as Strategy 1 adoption 1 (Equation (2)).

c. Strategy 3

Strategy 3 positions the vendor's location as the starting point of the route (see Fig. 4) and treats the wholesale market as a dummy customer in the CWSA. This configuration recalibrates the savings matrix to prioritise the vendor's proximity to customers, enabling the identification of optimal route combinations that minimise travel distances. The strategy ensures that delivery routes are tailored to the unique spatial dynamics of the vendor's operations, enhancing overall logistical performance. By addressing the spatial relationship between vendors, customers, and the wholesale market, this approach balances route efficiency with operational feasibility.

Step by step process of strategy 3:

(i) Calculate initial savings

Savings are calculated for all possible connections, including customer-customer C_k, C_j, vendor-customer V, C_k , and WM - Customer (WM, C_k). The savings formula determines the efficiency of connecting two points directly versus routing them through the vendor (V). With the savings formula:

a. Customer, Customer C_k, C_j :

$$S\left(C_k, C_j\right) = D\left(V, C_k\right) + D\left(V, C_j\right) - D\left(C_k, C_j\right) \tag{5}$$

Where $D(V, C_k)$ Distance between V to Customer C_k, $D\left(V, C_j\right)$ Distance between V to Customer C_j and $D\left(C_k, C_j\right)$ Distance from C_k to C_j.

b. WM, Customer WM, C_k :

$$S(WM, C_k) = D(V, WM) + D(V, C_k) - D(WM,\ C_k) \tag{6}$$

Where $D(V, WM)$ Distance between V *to* WM, $D(V, C_k)$ Distance between V *to* C_k, $D(WM,\ C_k)$ Distance between WM to C_k.

(ii) Forming initial route

All savings values are calculated and sorted in descending order to prioritise the most efficient connections. The pair with the highest savings is selected to initiate the route. If the pair involves a customer and WM, such as WM, C_k the initial route is: $\text{Route} = [V, \text{WM}, C_k]$. If the pair involves two customers, such as C_k, C_j, the initial route is: $\text{Route} = \left[V, C_k, C_j\right]$.

(iii) Add customers to route

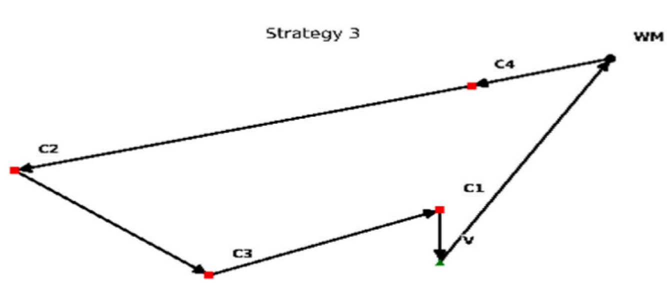

Fig. 4. Simple diagram for Strategy 3.

After forming the initial route, subsequent customers are added based on precalculated savings. These savings have been determined during the initial step and stored in a matrix, eliminating the need for recalculation. Customers are added in the order of highest remaining savings, ensuring that the route maintains the structure where V serves as the definitive endpoint.

(iv) Calculate the total distance

Once all customers have been added to the route, it is closed by returning to V. The final route structure adheres to:

$Route = [V, WM, Customers\ (ordered\ by\ savings), V]$. The total distance of the route is calculated using the same formula as Strategy 1 (Equation (2)).

Strategy 3 is particularly valuable in scenarios where the vendor's location plays a critical role in determining logistical success, providing a robust framework for optimising resource utilisation.

In addition, Fig. 5 provides the algorithmic flowchart illustrating the computational procedures of each strategy.

A consolidated summary of the basic assumptions of each strategy, route configuration and corresponding distance calculations is presented in Table 2.

4. Case study and analysis of results

When investigating the consequences of shifting wholesale markets and the complex links between markets and vendor operations, we present a case study of the Segiri Wholesale Market in Samarinda, Indonesia. This section describes the case study, investigates vendor impacts and evaluates candidate sites to identify an optimal relocation location.

4.1. Segiri Wholesale Market relocation

The Segiri Wholesale Market is Samarinda's primary hub for vegetables, meat and other essentials. Covering 54,090 m^2, it handles 8–10 tonnes of vegetables daily and consolidates flows from South Sulawesi, Surabaya, Mamuju and Thailand. Given its role in linking producers, vendors and customers, relocation/distribution optimisation are essential to ensuring supply and reinforcing Samarinda's position as East Kalimantan's trade hub. However, the relocation also brings longer vendor trips, higher costs and route adjustments.

Samarinda comprises 59 subdistricts (coded as L1 to L59). Specifically, the dataset used in this study consists of 50 mobile vendors obtained through a questionnaire survey conducted among vendors operating in the vicinity of the wholesale market area in Samarinda. Vendor data were collected based on information provided by respondents regarding their home locations and daily travel routes. Furthermore, the 66 customers included in the analysis were derived from the vendors' daily operational records, which indicate the subdistricts and neighbourhoods where typically they conduct their selling activities. Spatial strategies vary among vendors, reflecting different market penetration approaches. For instance, vendor V1 is based in Pelita (L11) and serves Sungai Pinang Dalam (L58) and Mugirejo (L57), demonstrating a broad reach and adaptability. In this case study, we have examined the optimal location to move the market WM from its current location to a small set of feasible locations identified based on the availability of land in Samarinda. In particular there are 12 potential locations for a New Wholesale Market: NWM1, NWM2..,NWM12. Fig. 6 illustrates the spatial distribution of the Wholesale Market (WM), New Wholesale Markets (NWMs), vendors and customers, plotted with latitude and longitude coordinates. To analyse vendor mobility, latitude and longitude coordinates are mapped, and distances are calculated using the Euclidean Distance method based on the Pythagoras Theorem (Baskar and Anthony Xavior, 2021), forming a distance matrix essential for route optimisation. Subsequently, we ran CWSA for all

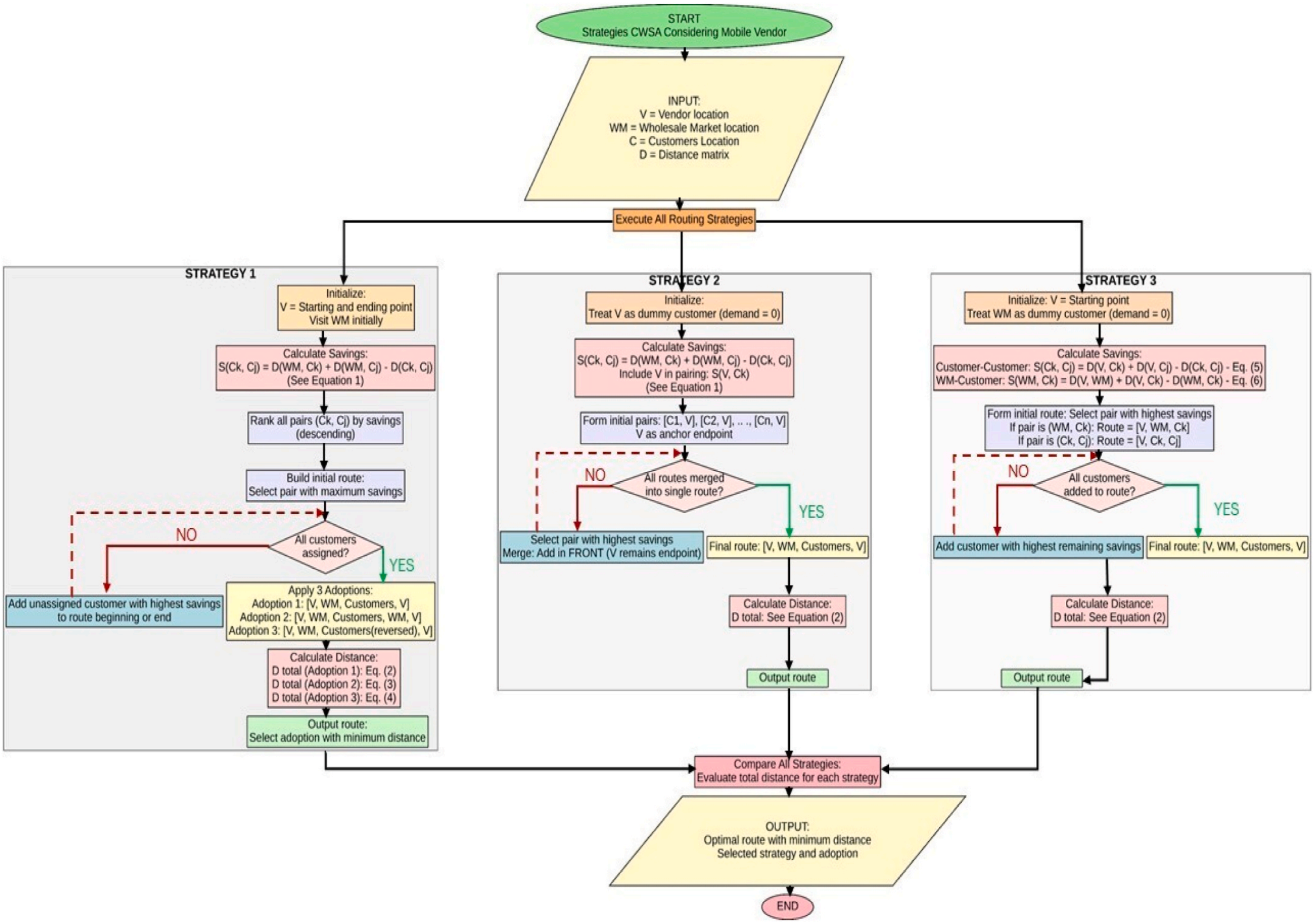

Fig. 5. Algorithmic flowchart of CWSA strategies.

Table 2
Comparative overview of CWSA strategies.

Aspect	Strategy 1	Strategy 2	Strategy 3
Key Assumption	Vendor starts/ends at vendor's location (V), visits WM initially. Variants differ on end-of-route arrangements.	Vendor included as dummy customer with zero demand to influence savings calculation.	WM treated as dummy customer
Route Structure (start-end point)	Adoption 1: [V, WM, Customers (ordered by savings), V] Adoption 2: [V, WM, Customers (ordered by savings), WM, V]. Adoption 3: [V, WM, Customers (ordered by savings), V].	[V, WM, Customers, V]	[V, WM, Customers, V]
Savings Calculation Basis	See equation (1)	Same as Strategy 1	See equations (5) and (6)
Total Distance Equations	Adoption 1: see equation (2) Adoption 2: see equation (3) Adoption 3: see equation (4)	Same as Strategy 1 Adoption 1	Same as Strategy 1 Adoption 1

adoptions/strategies, the solutions of which are discussed in the next section.

4.2. *Optimising wholesale market relocations*

This section examines how relocating the wholesale market (WM) to different locations affects vendor travel distances and operational efficiency. We frame relocation as an optimisation problem, where the objective is to minimise the total travel distance of all vendors while maintaining efficient distribution networks. The objective function can be formulated as follows:

$$Z = \min\left[Z^j\right] : \text{where}, Z^j = \sum_i \chi_i^j \quad i \in I; \quad j \in J \tag{7}$$

Where,

Z^j: The total distance across all vendors for any market location *j*,

χ_i^j: The distance travelled by vendor *i* when assigned to market location *j*

I, J: are the sets containing the vendors and market locations.

This objective function serves as the foundation for evaluating different market locations.

4.3. *Non-cooperative and cooperative vendor behaviour*

This section analyses vendor behaviour and addresses the question whether they could cooperate to offset the disbenefits of market relocations if any, and indeed even if the market stays where it is currently

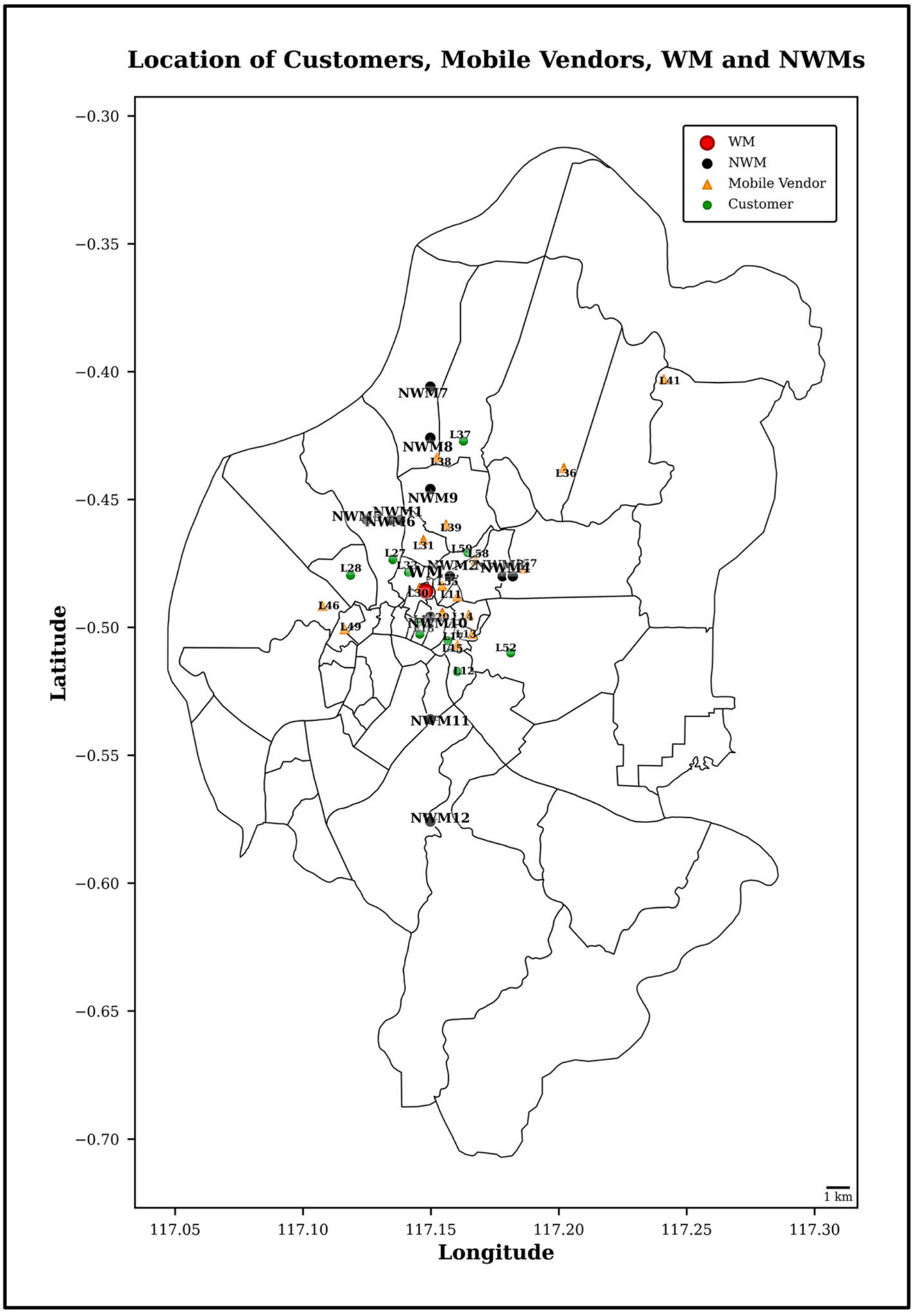

Fig. 6. Location of WM, NWMs, mobile vendors and customers.

located. Thus, two types of vendor behaviour have been modelled – *(i) Non-cooperative and (ii) Cooperative behaviour*. Non-cooperative behaviour of vendor follows the initial data wherein each vendor operates *independently* without sharing information with other vendors. In contrast, cooperative behaviour *distributes customers* among 50 vendors comparing individual performance with collaborative efficiency. Within the cooperative setting, two scenarios were introduced further: (a) *inclusive scenario*, with *all* vendors participating; and (b) *selective scenario* where service routes are exclusively provided by vendors closest to the routes. Customer allocation is based on the savings values, customer location, and the demand (constrained by limited vehicle carrying capacity), with an aim to reduce inefficiencies and optimise resource use. The system comprises 50 vendors aiming to serve 66 customers with varying demands, and the total demand works out to 3000 kg. Each vendor's vehicle capacity is 60 kg, as noted by the field survey.

a. Non-Cooperative Behaviour

In non-cooperative behaviour, vendors operate independently, prioritising individual efficiency. This approach allows vendors to maintain control over their respective areas, however it introduces challenges in route redundancy, where multiple vendors unknowingly serve nearby customers on separate trips, leading to overlapping travel and increased operational costs. The lack of coordination results in longer travel distances and uneven workload distribution among vendors, as observed in Table 3, where total distances vary significantly across different locations. Additionally, the fixed allocation of operational areas in non-cooperative behaviour makes the system less adaptable to dynamic changes, such as fluctuating customer demand. This limitation is further exacerbated by the lack of a mechanism to mitigate long-term operational inefficiencies, leading to high travel distances. The approach aims to evaluate the impact of non-cooperative behaviour on the overall

Table 3
Total distance (km) at various locations in non-cooperative behaviour.

Wholesale Market	Strategy 1	Strategy 2	Strategy 3	Optimum Total Distance
WM	555.28	539.43	539.43	539.43
NWM1	690.01	675.73	675.73	675.73
NWM2	**520.88**	**507.79**	**507.79**	**507.79**
NWM3	561.11	546.40	546.40	546.40
NWM4	581.28	571.23	571.23	571.23
NWM5	756.96	743.78	743.78	743.78
NWM6	662.33	652.01	652.01	652.01
NWM7	1022.39	1020.33	1020.33	1020.33
NWM8	831.58	829.55	829.55	829.55
NWM9	677.55	672.38	672.38	672.38
NWM10	586.21	568.47	568.47	568.47
NWM11	930.26	909.38	909.38	909.38
NWM12	1349.51	1332.56	1332.56	1332.56

performance of the logistics system. It seeks to understand how independent actions by vendors influence their operational efficiency and to identify potential inefficiencies that may arise.

Relocation of the WM has a differential impact on vendor routing, contingent upon the spatial distribution and proximity of customers, vendors and WM. Vendors located nearer to the newly relocated WM tend to experience a reduction in travel distances, thereby benefiting from lower operational costs, whereas those situated further afield incur increased distances and consequently, higher costs. Detailed results of the benefits and losses stemming from changes in location and routing performance are provided in Appendix A. This is exemplified by vendor L38, which experiences a 19.96 km increase in travel distance with NWM12, yet a 9.88 km reduction with NWM8. Finally, from Table 3 and it is noted that the new market location NWM2 saves about 6 % of the total distance by all vendors relative to the current market location WM. All other new market locations are less efficient than the current one. We will now explore cooperative behaviour to assess the improvement if any. These refinements could allow vendors to retain their ability to serve customers effectively while mitigating inefficiency in travel distance, ultimately improving the sustainability of the distribution network.

b. Cooperative Behaviour

Cooperation in distribution networks enables vendors to enhance operational efficiency and reduce expenditures by sharing operational information, resources and customer data. This contrasts with non-cooperative behaviour, leveraging synergies to minimise travel redundancies and create a streamlined, cost-effective system. The analysis presented herein examines how such collaboration impacts overall system performance, particularly in reducing operational inefficiencies and enhancing the responsiveness of the supply chain to customer demand. Under this model, a centralised mechanism redistributes customers among vendors at the outset. This process utilises a savings algorithm, which integrates individual vendor capacity and customer demands to identify routing solutions that minimise the total distance while adhering to capacity constraints. This study implements three distinct cooperative strategies, with the savings methodology and subsequent distance calculations detailed as follows.

In Strategy 1 and Strategy 2, each vendor operates within similar operational areas as both strategies yield identical savings (S) values. The savings matrix is calculated by assessing the efficiency of connecting customers C_k, C_j based on their proximity to the wholesale market WM. As a result, we observe that both strategies produce identical customers reallocations under cooperative behaviour, leading to the same level of residual demand of approximately 2 % in L30 when the market remains at its current location (WM). Meanwhile, Strategy 3 adopts a more dynamic approach by treating the WM as a dummy customer in the savings calculation. This approach results in high flexibility and optimal route adaptability. The calculation begins with each vendor starting at their respective locations, and savings are calculated for all relationships, including customer-to-customer C_k, C_j, vendor-to-customer V, C_k , and WM to Customer (WM, C_k). All savings values are calculated and compiled into a savings matrix, providing a comprehensive overview of potential savings across the distribution network. The values in the matrix are ranked in descending order to prioritise the most significant connections. The pair with the highest savings value is selected to form the initial route. Once the initial route is established, additional customers are iteratively added based on the next highest savings values in the matrix. This approach ensures that each step of customer integration considers both distance efficiency and the vendor's operational capacity. Consequently, it results in an unserved demand of 2 % in L58 and yields vendor locations with a net savings of zero.

Unserved demand in this result can be attributed to the redistribution of customer demand based on efficiency, which is then mitigated through cooperative behaviour. Unserved demand can be explained further as follows. For instance, if vendor V1 initially serves two customers, each with a demand of 30 kg, and vendor V2 serves three customers, each with a demand of 20 kg, then after the customer reallocation, the demand will be adjusted and served by these two vendors based on the savings values and available capacities. However, since each vehicle has limited capacity and as customer allocation is optimised, there is a possibility of not serving the demand fully. Thus, unserved demand represents a trade-off between route optimisation and capacity constraints, which is part of the adjustment required to achieve overall logistical efficiency. This can be mitigated by adding additional trips though generating a sub-optimal solution.

Thereafter, we calculate the optimal route using three strategies with the route starting and ending at each location of V, thereby producing a final route with maximum efficiency. Thus, the total travel distance in cooperative behaviour can be formulated as:

$$\mathrm{D\ total} = \mathrm{D}\left(\mathrm{V_i}, \mathrm{WM}\right) + \mathrm{D}\left(\mathrm{WM}, \mathrm{R_{first}}\right) + \sum_{k=1}^{n-1} \mathrm{D}\left(\mathrm{R_k}, \mathrm{R_{k+1}}\right) + \mathrm{D}\left(\mathrm{R_{last}}, \mathrm{V_i}\right) \tag{8}$$

Where, V_i is each vendor. Subsequently, the solution is derived using the objective function defined in Equation (7). This adjusted route reflects the redistributed customers between vendors minimising the total system distance.

In this study, we attempted to perform optimisations based on two scenarios. Firstly, an *inclusive scenario*, where the cooperative behaviour necessitates the engagement of all 50 vendors, and secondly a *selective scenario* where service routes are exclusively provided by the vendor(s) closest to the route. In Tables 4 and 5 respectively, we provide distinct operational perspectives. The inclusive scenario, utilising the entire vendor network, achieves a reduction of 5.27 % in total travel distance compared to the non-cooperative behaviour. Conversely, the selective scenario prioritises maximal operational efficiency by strategically restricting service provision, yielding different trade-offs.

The selective scenario minimises the potential redundancy and reduces total travel distances, mirroring real-world operational conditions where logistical efficiency considerations are paramount. It also facilitates an assessment of how vendor selection based on proximity can enhance overall system efficiency, resulting in a 34.9 % reduction over non-cooperative behaviour. This comprehensive approach is instrumental in evaluating the overall impact of collaboration on reducing total travel distance, while also testing the model's ability to manage the complexity and unserved demand within the system.

The findings confirm that the cooperative approach significantly reduces the total travel distance. As evidenced in Tables 4 and 5, NWM2 yields the lowest total distances of 481.05 km and 330.52 km, respectively, despite the marginal 2 % unserved demand. Furthermore, Strategy 3 consistently outperforms Strategy 2 by explicitly integrating vendor-customer proximity into its savings algorithm and

Table 4
Total distance (km) by inclusive scenario with cooperative behaviour.

Wholesale Market	Strategy 1	Strategy 2	Strategy 3	Optimum Total Distance
WM	526.20 (2 %)	522.57 (2 %)	514.04 (2 %)	514.04
NWM1	672.90 (4 %)	662.39 (4 %)	651.34 (2 %)	651.34
NWM2	**502.16 (2 %)**	**493.63 (2 %)**	**481.05(2 %)**	**481.05**
NWM3	537.31 (2 %)	528.35 (2 %)	525.62 (4 %)	525.62
NWM4	564.53 (2 %)	563.42 (2 %)	546.01 (3 %)	546.01
NWM5	721.66 (2.7 %)	720.03 (2.7 %)	718.25 (2 %)	718.25
NWM6	636.80 (4 %)	634.59 (4 %)	625.29 (4 %)	625.29
NWM7	1001.88 (2.7 %)	996.05 (2.7 %)	990.60 (3 %)	990.60
NWM8	817.80 (2.7 %)	816.01 (2.7 %)	800.23 (2 %)	800.23
NWM9	661.67 (2.7 %)	658.76 (2.7 %)	649.44 (4 %)	649.44
NWM10	557.66 (2 %)	548.16 (2 %)	533.51 (2 %)	533.51
NWM11	894.80 (2 %)	884.98 (2 %)	873.79 (2 %)	873.79
NWM12	1313.39 (4 %)	1305.47 (4 %)	1291.56 (2 %)	1291.56

Table 5
Total distance (km) for selective scenario in cooperative behaviour.

Wholesale Market	Strategy 1	Strategy 2	Strategy 3	Optimum Total Distance
WM	355.88 (2 %)	355.41 (2 %)	343.81 (2 %)	343.81
NWM1	489.73 (4 %)	487.38 (4 %)	477.15 (2 %)	477.15
NWM2	**339.76 (2 %)**	**339.62 (2 %)**	**330.52 (2 %)**	**330.52**
NWM3	426.08 (2 %)	425.89 (2 %)	418.54 (4 %)	418.54
NWM4	463.83 (2 %)	463.70 (2 %)	445.45 (3 %)	445.45
NWM5	557.08 (2.7 %)	557.07 (2.7 %)	543.78 (2 %)	543.78
NWM6	461.92 (4 %)	461.84 (4 %)	453.44 (4 %)	453.44
NWM7	878.42 (2.7 %)	877.98 (2.7 %)	872.39 (3 %)	872.39
NWM8	686.25 (2.7 %)	683.51 (2.7 %)	663.01 (2 %)	663.01
NWM9	500.96 (2.7 %)	500.93 (2.7 %)	493.22 (4 %)	493.22
NWM10	401.48 (2 %)	401.45 (2 %)	383.61 (2 %)	383.61
NWM11	749.44 (2 %)	748.73 (2 %)	731.08 (2 %)	731.08
NWM12	1169.88 (4 %)	1169.62 (4 %)	1155.89 (2 %)	1155.89

redistribution mechanism, enhancing spatial efficiency.

The solution with unserved demand could be seen as an operational benchmark for achieving efficiency, as it reflects a trade-off between maintaining route efficiency and adhering to vehicle capacity constraints. In this process, the algorithm performs a backward adjustment step that reallocates customers to the nearest vendors based on spatial proximity and remaining capacity. Consequently, while a small portion of demand remains unserved, the system achieves an optimal balance between efficiency and plausibility. In real-world operations, this minor gap can be effectively managed through supplementary trips, load adjustments and route rearrangements without reducing overall system performance. Fig. 7 compares the performance of cooperative and non-cooperative behavioural outcomes (panels (a) and (b)). Panel (c) of Fig. 7 shows the effect of adding additional trips to serve the 'unserved' demand at each market location under consideration.

The (dis)benefits of cooperation for each individual vendor are further illustrated in Fig. 8 and Appendix B, considering the relocation to NWM2. The results show the most significant travel reduction observed for vendor V31 (11 km), albeit with an increase for vendor V15 (7.2 km), underscoring the variable impact of cooperative behaviour.

The implementation of cooperative behaviour in this study not only significantly reduced the total travel distance but also highlighted the critical importance of capacity adjustment and the optimisation of distribution networks for vendors. These findings demonstrate that cooperative behaviour is substantive to creating distribution systems that are potentially more responsive, adaptive and sustainable within complex urban contexts.

5. Discussion on the results

The relocation of a wholesale market requires a holistic evaluation that extends beyond congestion alleviation to encompass its broader impact on stakeholders, particularly informal sector vendors. As these vendors constitute a critical linkage between the market and customers, optimal new market placement is paramount for minimising travel distances and sustaining operational efficiency. Given their narrow profit margins, any increase in travel distance poses a significant threat to vendor viability. This paper, therefore, investigates whether cooperative behaviour, entailing the shared use of information, resources and customer allocations, can mitigate these adverse effects and enhance system resilience.

Our study demonstrates that the adopted CWSA solution significantly reduces the total travel distance and improves the efficiency of distribution networks. The main results reveal that strategic market relocation to NWM2 under the selective scenario reduces total travel distance to 330.52 km (around 35 % reduction over the non-cooperative solution). A small proportion of unserved demand (approximately 2–4 %) was observed as a result of capacity balancing during the redistribution of customers among vendors in the cooperative scenario. Each vendor in this study operates with a vehicle capacity of 60 kg and the total demand being equal to the capacity of all vehicles put together also constrains the problem. During the reallocation process, some vendors did not fully reach their 60 kg capacity limit, while the others reached their maximum capacity, resulting in a small portion of demand remaining unserved. We have computed the additional travel required for serving the remainder of the demand and note that for NWM2 the total distance increases by 1.46 % in the inclusive scenario and 2.93 % in the selective scenario (Fig. 7 – Panel (c)), compared to the cooperative allocation with unserved demand. Importantly, even after incorporating these distance penalties, cooperative behaviour still produces a substantially more efficient result than the non-cooperative baseline.

Cooperative behaviour among vendors generally enhances efficiency by enabling shared routes. Although the impact on travel distance is not always uniform, some vendors experience significant reductions while others may see an increase, the overall benefits outweigh the drawbacks. This indicates that cooperation generally yields improved logistic performance in urban environments, creating a more coordinated, resource-efficient and sustainable distribution system, even if the benefits vary depending on vendor location and route optimisation.

The algorithm used in this study is not designed to replace individual or cooperative vendor operations. Instead, it demonstrates the potential efficiency improvements that can be achieved through coordination and information sharing among vendors. The model serves as an analytical framework that supports collaborative planning by identifying optimal route structures under integrated decision-making conditions. In the context of market relocation, this approach highlights how vendors can

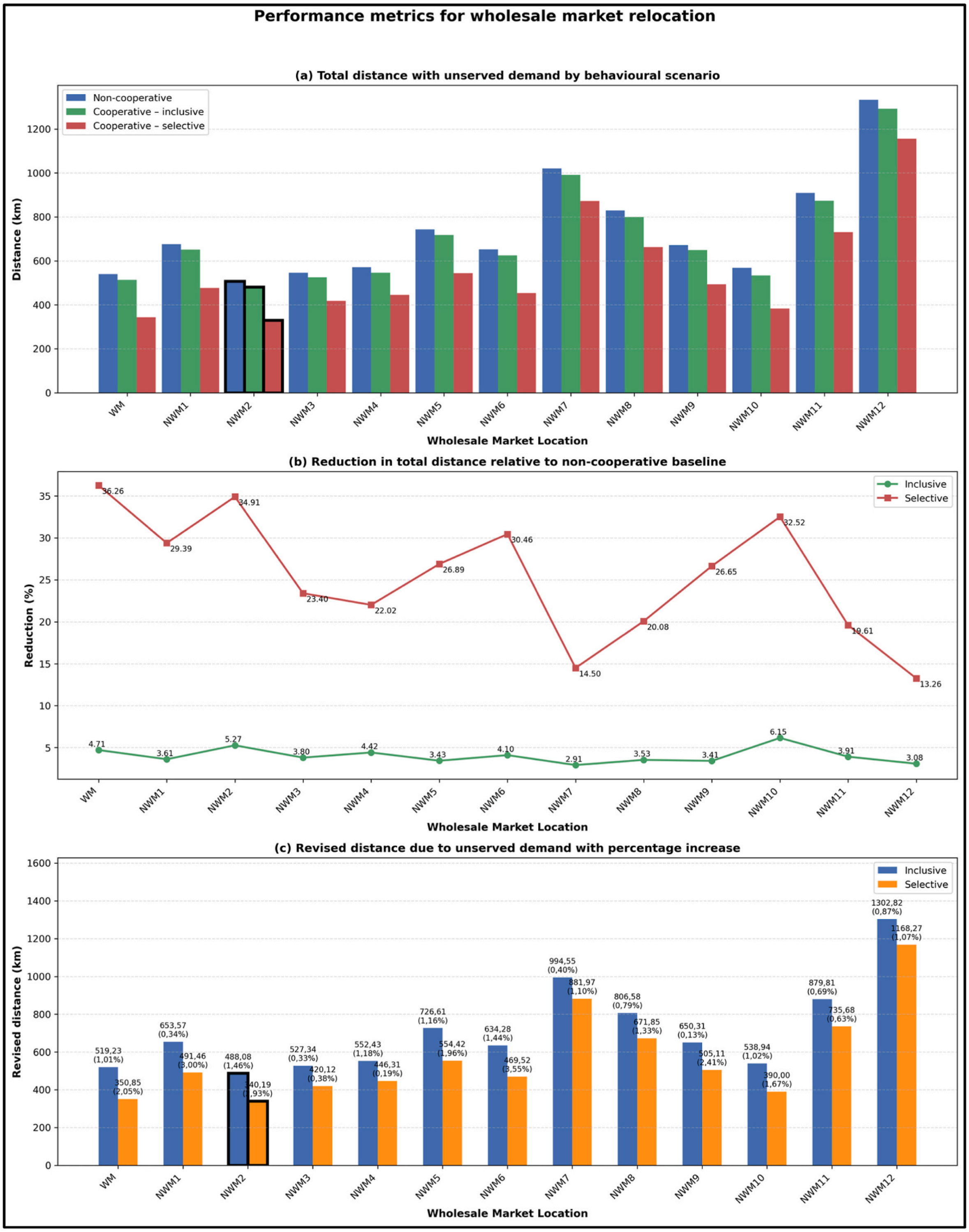

Fig. 7. Comparative performance analysis of cooperative and non-cooperative behavioural outcomes.

benefit from route sharing, trip consolidation or coordinated access to the wholesale market. Although the algorithm assumes centralised coordination for modelling purposes, it conceptually reflects collaborative rather than replacement-based strategies. The centralised framework also serves as a simulation tool to explore the benefits of route coordination, without implying institutional control or top-down management of the informal vendor system.

Algorithmically, the Clarke and Wright Savings Algorithm (CWSA) applied in the cooperative scenario reallocates customers to vendors based on available vehicle capacity and geographical proximity. Information regarding vendor capacity and operational areas was collected through questionnaire surveys of mobile vendors around the wholesale market area, with a vehicle capacity of 60 kg using motorcycles. This mechanism mathematically ensures that the cooperative solution space always includes the non-cooperative configuration as a subset, thereby guaranteeing that the cooperative model achieves equal or superior performance under various operational conditions.

The cooperative approach retains its advantage because proximity-

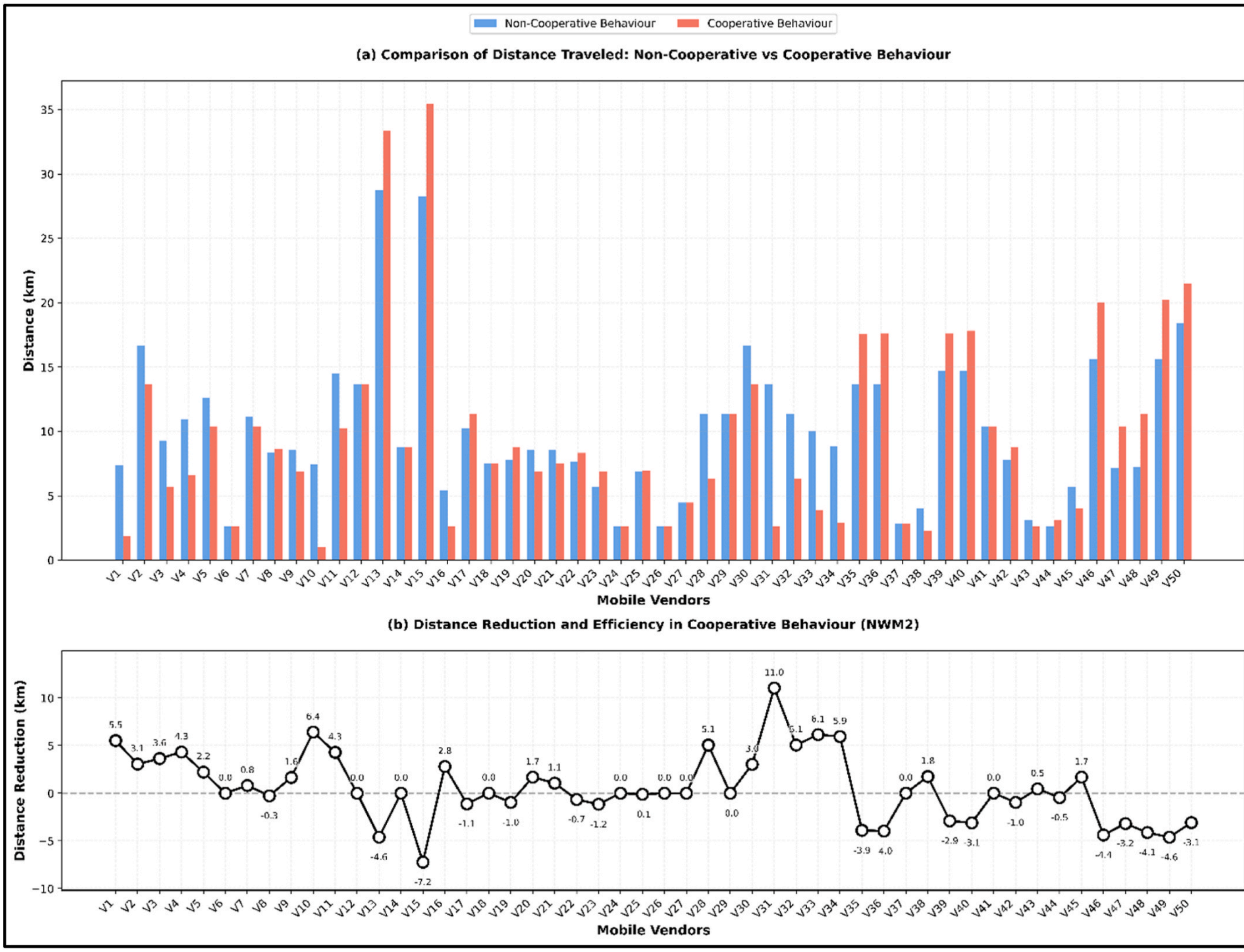

Fig. 8. Distribution of Benefits with NWM2 – Cooperative vs Non-cooperative Behaviour.

based reassignment cannot worsen and generally enhances routing efficiency compared with fixed allocation. When the system encounters diverse operational conditions either due to differences in spatial configuration (as in the 12 market location scenarios, which show a 2.6-fold variation in total distance) or potential changes in capacity and demand the cooperative mechanism continues to minimise total travel distance through optimal vendor–customer proximity.

Empirical analysis across the 13 market locations (WM, NWM1-NWM12) demonstrates that the cooperative scenario consistently outperforms the non-cooperative configuration in all cases. The range of savings noted were: 2.91–6.15 % by the inclusive scenario and by the selective scenario: 13.26 %–36.26 %, depending on the new location of market. Even in the largest and most complex scenario (NWM12: 1332.56 km), an efficiency improvement of 3.08 % would be achieved. These findings confirm that the cooperative advantage does not arise from specific spatial conditions but reflects the inherent algorithmic stability of the CWSA mechanism, which can adapt effectively to spatial, capacity and demand variations.

Regarding demand variation specifically, while vehicle capacity remains relatively fixed (60 kg motorcycles), demand levels may fluctuate due to seasonal or cultural factors (e.g., Ramadhan or Christmas), which often lead to temporary demand surges, while off-peak periods may experience reduced procurement volumes. Qualitatively, the cooperative mechanism is expected to maintain its efficiency advantage under such demand variations through several inherent adaptive properties.

During high demand periods, when total system demand exceeds baseline levels, the cooperative approach enables more efficient load balancing. Vendors operating below their capacity in non-cooperative scenarios can absorb additional demand through customer reallocation, thereby reducing the need for redundant trips or additional vehicles and maximising vehicle utilisation whilst minimising total system distance. Conversely, during low-demand periods, the cooperative mechanism facilitates route consolidation by reassigning customers to fewer active vendors or shorter routes. The algorithm thus maintains routing efficiency even when overall procurement volume declines, whereas non-cooperative configurations result in underutilised vehicles travelling fixed routes regardless of demand levels, leading to proportionally higher distance per unit demand.

Furthermore, the proximity-based customer reallocation logic of the CWSA inherently adapts to changing demand distributions such that if demand shifts spatially (e.g, increased demand in certain neighbourhoods during festivals), the algorithm reassigns customers based on updated vendor-customer proximity, thereby preserving routing efficiency without requiring manual intervention. However, it is important to acknowledge that extreme demand fluctuations, such as demand exceeding cumulative vendor capacity or demand concentrated in geographically isolated areas, may challenge the algorithm's performance, and in such cases, the cooperative advantage may diminish if capacity constraints prevent effective customer reassignment or if spatial clustering limits proximity-based optimisation.

These findings contribute to the existing literature on logistics distribution and market relocation by demonstrating that spatial and adaptive savings calculations are critical for optimising routing efficiency and reducing redundancies. The results imply that urban planners and local authorities should consider wider impacts on the informal sector particularly vendor accessibility in their relocation strategies, rather than solely focusing on decongesting city centres. The improved network efficiency observed through cooperative routing underscores the potential for creating more resilient and sustainable urban distribution systems.

Nevertheless, several limitations of this study should be acknowledged for consideration in future research. The Clarke and Wright Savings Algorithm (CWSA) employed in this study is a heuristic algorithm and therefore cannot guarantee a truly global optimal solution. Although multiple strategies and scenarios have been tested, some residual inaccuracies or suboptimal routing combinations may persist.

In addition, the use of Euclidean distance in this study represents a simplified geometric approximation of vendor travel, used primarily to capture relative spatial relationships rather than exact road network distances. While this approach provides a consistent and computationally efficient basis for evaluating routing efficiency across multiple scenarios, it does not account for real world travel constraints such as one-way systems, congestion or accessibility barriers.

Despite this simplification, the model demonstrates strong algorithmic robustness and consistent cooperative advantages across twelve market location scenarios. Future research should therefore extend this work by integrating network-based distance measures derived from GIS or OpenStreetMap data, as well as real-time route tracking, to reflect more realistic travel patterns. In addition, systematically varying vehicle capacities and daily demand levels would allow a more detailed sensitivity analysis, providing insights into how efficiently and stably the model performs under more complex and dynamic operational conditions. Such extensions would enhance both the empirical precision and policy relevance of the model for urban logistics planning in informal settings.

6. Concluding remarks

Wholesale market relocations critically influence urban logistics and the operational efficiency of mobile vendors. As cities expand and congestion concerns intensify, strategic market placement becomes essential to maintain accessibility and service continuity. This study has developed a method for a comprehensive assessment of how different relocation strategies affect the mobile vendors operating in the informal sector. It has developed an adaptation of the Clarke and Wright Savings Algorithm (CWSA) and assesses the market relocation performance in Samarinda, Indonesia.

The key conclusions of this research are summarised as follows:

- Strategic market relocation is crucial for urban logistics efficiency. Poorly planned market relocations can threaten the livelihood of mobile vendors by imposing additional travel on them eroding into their low margin operations. Whilst relocation to NWM2 empirically yields the highest potential gains, the analytical framework developed in this study enables the systematic evaluation of alternative sites, allowing planners to align market placement with future development plans.
- Cooperative behaviour generates substantial savings over the non-cooperative behaviour. This can help the vendors to offset the disbenefits caused by market relocations. In case of NWM2, cooperative behaviour reduces vendor travel distance by 5.27 % (to 481.05 km) in the inclusive scenario and by 34.91 % (to 330.52 km) in the selective scenario. Whilst the system efficiency improves in general, the impact per vendor could vary significantly, with some seeing great reductions (e.g. vendor V31) while others face the prospect of increased travel (e.g. vendor V15). This can be addressed by rotating the routes, for instance, among vendors at an agreed interval such as a week.
- Cooperative behaviour may result in an unserved demand which can be addressed by additional travel though leading to a sub-optimal solution. Fulfilling the residual unserved demand in Samarinda increases the total vendor travel distance by 1.46 % in the inclusive scenario and 2.93 % by the selective scenario if the market were to be relocated to NWM2. This confirms that the cooperative routing remains highly efficient even after completely serving all customer demand at the new market location.

These findings highlight the importance of integrating vendor cooperation behaviour into urban logistics planning. To foster resilient and equitable distribution systems, policymakers should promote cooperative routing frameworks by encouraging information sharing and joint trip planning among mobile vendors to minimise redundant travel. Integrating the proposed CWSA model adaptations into local planning tools allows urban authorities to simulate relocation impacts and test alternative sites before implementation. Strengthening vendor coordination through digital platforms or community-based clusters will facilitate collective decision making and operational coordination. Coordination also facilitates providing targeted support such as logistical training, financial assistance or infrastructure improvements to vendors adversely affected by increased travel distances and incorporate adaptive routing and demand responsive systems into future urban logistics planning to enhance flexibility in dynamic environments.

Future research should extend this framework to develop more responsive optimisation models. Addressing these considerations will ensure that wholesale market relocations benefit not only large-scale distributors but also informal vendors, contributing to more resilient, equitable, and sustainable urban economies.

CRediT authorship contribution statement

Triana Sharly Permaisuri Arifin: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chandra Balijepalli:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Anthony Whiteing:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX A. Difference in distance travelled by vendors due to the market relocation from WM to NWMs (Non-cooperative behaviour)

V	New Wholesale Market (NWM)											
	1	2	3	4	5	6	7	8	9	10	11	12
V1	4.53	−1.69	−2.18	−2.16	6.22	3.9	12.76	8.66	4.52	0.68	7.87	16.28
V2	3.24	−0.77	−0.75	−0.56	4.81	2.66	7.39	4.33	2.04	0.03	7.81	16.29
V3	6.63	0.14	0.69	1.06	7.94	6.18	16.15	11.83	7.57	−1.36	3.46	11.48
V4	6.64	0.16	−0.24	0.06	7.82	6.23	16.28	12	7.79	−1.57	1.31	9.84
V5	−2.71	−0.05	2.9	3.57	−1.69	−2.91	2.94	−1.39	−2.93	2.09	10.68	19.48
V6	3.06	−2.46	−2.38	−1.6	4.96	2.32	10.46	6.22	2.22	1.2	9.26	17.94
V7	−5.35	−0.93	1.2	1.77	−3.9	−5.77	−2.25	−6.57	−7.71	2.24	11.08	19.95
V8	4.61	0.63	3.06	3.73	5.76	4.29	15.13	10.75	6.41	0.26	6.72	15.35
V9	6.64	0.16	0.95	1.48	7.82	6.23	16.59	12.2	7.84	−1.57	1.31	9.84
V10	4.39	−1.46	−1.47	−1.42	6.05	3.78	12.44	8.33	4.46	0.93	8.44	16.89
V11	4.69	1.64	4.19	4.82	4.85	4.71	15.94	11.67	7.5	−1.23	0.14	8.12
V12	−0.36	−2.42	−5.28	−5.68	1.62	−1.16	−2.5	−4.18	−4.34	1.3	8.64	16.74
V13	−3.4	−1.51	−1.65	−1.59	−1.72	−3.96	−3.19	−5.02	−5.93	1.76	9.6	17.84
V14	6.54	−0.36	−1.12	−0.91	7.92	6.04	15.64	11.36	7.15	−1.53	1.35	9.16
V15	−2.95	−1.86	−2.73	−2.78	−1.34	−3.55	−6.46	−8.33	−7.06	1.72	9.6	17.85
V16	4.42	−0.12	2.15	2.98	5.9	3.92	13.66	9.33	5.12	1.65	10.06	18.83
V17	2.5	2.46	6.7	7.54	1.88	2.86	14.54	10.42	6.48	−0.26	3.04	10.52
V18	6.67	1.26	3.38	4.01	7.55	6.39	17.43	13	8.59	−2.02	2.58	11.33
V19	6.56	0.9	2.59	3.19	7.55	6.24	17	12.6	8.22	−1.79	3.22	11.87
V20	6.41	−0.55	−1.09	−0.79	7.85	5.89	15.43	11.15	6.94	−1.21	2.66	10.54
V21	4.72	0.99	3.85	4.55	5.76	4.44	15.56	11.15	6.78	0.03	6.08	14.81
V22	6.64	1.35	3.67	4.33	7.55	6.36	17.4	12.98	8.58	−1.81	3.36	12.11
V23	6.7	1.47	4.06	4.82	7.94	6.32	16.96	12.57	8.2	1.19	8.73	17.45
V24	3.06	−2.46	−2.38	−1.6	4.96	2.32	10.46	6.22	2.22	1.2	9.26	17.94
V25	4.48	0.44	3.09	3.85	5.69	4.14	14.92	10.54	6.2	0.58	8.03	16.73
V26	3.06	−2.46	−2.38	−1.6	4.96	2.32	10.46	6.22	2.22	1.2	9.26	17.94
V27	−1.24	−1.56	0.6	1.28	0.82	−2.06	6	1.6	−2.68	2.08	10.9	19.76
V28	1.52	−0.55	−0.55	−0.5	2.82	1.16	10.23	6.18	2.46	1.19	8.49	16.87
V29	0.48	2.3	6.8	7.68	−0.64	1.02	12.16	8.3	4.76	0.38	4.54	11.88
V30	3.24	−0.77	−0.75	−0.56	4.81	2.66	7.39	4.33	2.04	0.03	7.81	16.29
V31	1.35	−2.44	−3.83	−3.64	3.29	0.58	3.98	1.02	−1.06	1.25	8.95	17.34
V32	1.52	−0.55	−0.55	−0.5	2.82	1.16	10.23	6.18	2.46	1.19	8.49	16.87
V33	0.62	−0.51	3.45	4.29	1.1	0.55	11.53	7.33	3.28	1.84	10.63	19.5
V34	2.49	0.75	5.16	6.04	2.74	2.51	13.43	9.23	5.23	1.27	8.87	17.39
V35	−0.36	−2.42	−5.28	−5.68	1.62	−1.16	−2.5	−4.18	−4.34	1.3	8.64	16.74
V36	−0.36	−2.42	−5.28	−5.68	1.62	−1.16	−2.5	−4.18	−4.34	1.3	8.64	16.74
V37	5.78	2.22	6.68	7.56	6.84	5.52	16.86	12.44	8.02	2.1	10.86	19.72
V38	4.53	−1.69	−0.43	0.37	6.22	3.9	13.01	8.69	4.52	0.68	8.7	17.43
V39	1.6	−2.35	−6.03	−6.62	3.56	0.81	3.28	0.54	−1.2	0.85	7.67	15.74
V40	2.68	−1.44	−0.75	−0.51	4.38	2.04	6.63	3.58	1.29	1.35	9.38	17.86
V41	−4.9	−1.28	0.12	0.58	−3.52	−5.36	−5.52	**−9.88**	−8.84	2.2	11.08	**19.96**
V42	6.56	0.9	2.59	3.19	7.55	6.24	17	12.6	8.22	−1.79	3.22	11.87
V43	2.67	−2.42	−1.83	−1.06	4.58	1.92	10.11	5.85	1.81	1.36	9.57	18.29
V44	3.06	−2.46	−2.38	−1.6	4.96	2.32	10.46	6.22	2.22	1.2	9.26	17.94
V45	6.44	−0.01	2.07	2.79	7.69	6.01	16.47	12.05	7.68	−1	5.2	13.99
V46	−0.74	−1.49	−1.08	−0.88	1.19	−1.47	3.18	0.13	−2.16	1.79	9.89	18.38
V47	4.78	−1.6	−6.93	−2.61	6.49	4.13	12.31	8.21	4.38	0.28	7.42	15.83
V48	4.64	−1.37	−1.5	−1.45	6.32	4.01	12.41	8.3	4.43	0.9	8.41	16.86
V49	−0.74	−1.49	−1.08	−0.88	1.19	−1.47	3.18	0.13	−2.16	1.79	9.89	18.38
V50	−0.74	−1.49	−1.08	−0.88	1.19	−1.47	0.43	−2.59	−2.15	1.79	9.89	18.38

APPENDIX B. Difference in distance travelled by vendors due to the market relocation from WM to NWMs (Cooperative behaviour in Inclusive Scenario)

V	New Wholesale Market (NWM)											
	1	2	3	4	5	6	7	8	9	10	11	12
V1	6.01	−0.91	1.52	2.35	7.48	5.49	15.56	11.16	6.82	0.17	8.15	16.91
V2	−0.38	−2.43	−5.28	−5.69	1.6	−1.17	−2.51	−4.2	−4.34	1.29	8.63	16.74
V3	6.31	2.73	5.44	6.04	7.41	5.98	17.06	12.63	8.21	−0.15	6.8	15.65
V4	4.67	0.34	1.06	1.67	5.87	4.28	14.93	10.53	6.36	0.74	5.48	13.25
V5	−4.9	−1.29	0.12	0.58	−3.51	−5.36	−5.52	**−9.88**	−8.84	2.21	9.66	19.96
V6	3.05	−2.47	−2.39	−1.6	4.94	2.3	10.45	6.2	2.2	1.2	9.25	17.92
V7	−4.9	−1.29	0.12	0.58	−3.51	−5.36	−1.8	−9.88	−8.84	2.21	9.66	19.96
V8	5.22	0.35	−0.23	−0.01	6.21	4.9	16.08	11.18	6.81	−1.89	1.88	10.05
V9	4.68	0.44	2.46	3.15	5.71	4.13	14.91	10.53	6.2	0.58	5.34	13.09
V10	5.72	−0.47	3.78	4.66	7.14	5.24	15.76	11.34	6.92	1.39	10.13	18.99
V11	2.5	2.45	6.69	7.54	1.89	2.85	14.54	10.41	6.48	−0.25	3.03	10.52
V12	−0.38	−2.43	−5.28	−5.69	1.6	−1.17	−2.51	−4.2	−4.34	1.29	8.63	16.74

(continued on next page)

(*continued*)

V	New Wholesale Market (NWM)											
	1	2	3	4	5	6	7	8	9	10	11	12
V13	2.78	0.06	0.41	0.58	4.17	1.15	4.81	2.91	1.46	−0.38	7.17	15.23
V14	5.72	0.53	0.92	1.36	6.23	5.57	16.53	11.25	6.88	−1.89	1.88	10.05
V15	0.05	−0.78	−2.18	−1.28	1.22	−0.37	2.41	0.58	−1.47	0.01	7.56	12.8
V16	3.05	−2.47	−2.39	−1.6	4.94	2.3	10.45	6.2	2.2	1.2	9.25	17.92
V17	0.92	1.82	6.19	7.05	0.15	1.2	12.86	8.8	4.73	0.49	4.04	13.19
V18	6.88	2.03	4.94	6.57	7.93	6.53	17.25	12.83	8.42	−2.1	1.48	10.04
V19	5.89	0.14	0.53	0.97	6.31	5.99	16.14	10.91	7.08	−1.58	1.85	9.66
V20	4.68	0.44	2.46	3.15	5.74	4.45	14.91	10.53	6.2	0.58	7.48	14.25
V21	6.66	1.25	5.17	5.88	7.55	6.39	17.43	12.99	8.58	−2.03	0.7	9.26
V22	6.66	2.04	5.17	5.88	7.55	6.39	17.43	12.99	8.58	−2.03	1.1	9.81
V23	3.84	−0.61	1.41	2.1	4.69	3.98	13.86	9.48	5.45	0.43	6.97	14.31
V24	3.05	−2.47	−2.39	−1.6	4.94	2.3	10.45	6.2	2.2	1.2	9.25	17.92
V25	3.97	−1.19	1.36	2.12	5.29	3.88	13.62	9.29	5.08	−0.25	6.29	14.85
V26	3.05	−2.47	−2.39	−1.6	4.94	2.3	10.45	6.2	2.2	1.2	9.25	17.92
V27	−1.22	−1.55	0.62	1.3	0.82	−2.05	6.01	1.62	−2.66	2.1	10.92	19.78
V28	3.56	−2.29	−6.78	−7.57	5.51	2.78	9.06	5.25	1.93	0.4	6.7	14.75
V29	0.47	2.3	6.79	7.67	−0.65	1.01	12.15	8.28	4.76	0.36	6.68	11.87
V30	−0.38	−2.43	−5.28	−5.69	1.6	−1.17	−2.51	−4.2	−4.34	1.29	8.63	16.74
V31	3.05	−2.47	−2.39	−1.6	4.94	2.3	10.45	6.2	2.2	1.2	9.25	17.92
V32	3.56	−2.29	−4.28	−7.57	5.51	2.78	9.06	5.25	1.93	0.4	6.7	14.75
V33	−1.12	−0.57	3.1	3.92	0.74	−1.8	8.85	4.43	0.01	2.26	11.13	**20.00**
V34	5.54	0.87	3.25	4.13	6.75	4.71	15.26	10.87	6.39	1.75	10.49	19.35
V35	−2.36	−1.58	−2.31	−2.88	−0.68	−2.99	−5.56	−6.77	−6.32	0	7.88	16.27
V36	−0.39	−1.51	−1.5	−2.28	1.62	−1.21	3.77	−3.73	2.22	0.96	8.77	16.37
V37	5.78	2.2	6.67	7.55	6.83	5.5	16.85	12.43	8.01	2.09	10.84	19.71
V38	6.2	−0.69	4.52	3.99	7.31	5.84	15.77	11.25	7.71	0.78	9.14	17.95
V39	4.2	−1.78	−1.77	−1.63	6.28	1.66	−5.34	4.85	2.74	0.69	9.59	16.92
V40	3.02	−3.12	−2.61	−3.18	4.73	2.35	2.66	3.3	1.19	−0.86	8.04	15.37
V41	−5.03	−1.42	0.37	0.94	−3.57	−5.45	−1.93	−6.25	−7.39	2.16	9.58	19.87
V42	5.88	−0.36	0.14	2.29	6.87	5.49	15.64	11.36	7.16	−1.52	1.35	9.63
V43	3.05	−2.47	−2.39	−1.6	4.94	2.3	10.45	6.2	2.2	1.2	9.25	17.92
V44	3.11	−2.01	−1.43	2.32	4.94	2.4	10.45	6.2	2.24	1.2	9.25	18.69
V45	4.29	−0.84	2.61	3.46	5.53	3.93	14.71	9.42	5.93	−0.35	8.01	16.83
V46	3.02	−0.94	−2.31	−2.07	4.73	2.35	6.78	4.38	2.1	−0.03	8.31	16.52
V47	1.56	−1.42	−3.82	−4.23	2.72	0.98	6.97	4.08	0.19	0.42	5.85	15.71
V48	1.26	−0.95	−4.37	−4.78	2.74	1.37	9.83	5.77	1.13	0.03	6.73	15.16
V49	2.96	−0.77	−2.36	−2.13	4.8	2.29	7.38	4.65	2.74	−0.09	8.25	16.46
V50	2.49	−0.24	−0.11	−1.55	4.72	1.71	7.43	4.37	2.1	−0.61	7.5	15.99

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