# ****Abstract****

In modern supply chain management, optimizing the distribution network is essential to minimize costs while maintaining efficiency and reliability. A critical decision in supply chain design is determining the optimal configuration of distribution centers, including whether to rent new Direct Distribution Centers (Direct DCs) or utilize existing ones, as well as how to allocate resources such as vehicles and containers effectively. The complexity of this decision-making process increases with multiple customer locations, variable transportation costs, and the diverse requirements for vehicle or container types.

This study addresses the challenge of determining the most cost-effective distribution strategy through a Mixed-Integer Linear Programming (MILP) model. The primary goal is to optimize the supply source for each customer and allocate resources for demand distribution, minimizing overall distribution costs. The model incorporates various factors, such as operational distribution costs, fuel costs, vehicle rental fees, and distribution time, all of which are crucial in the decision-making process. Additionally, constraints are established to ensure customer demand is met, vehicles and containers are efficiently utilized, and logistical and budgetary requirements are satisfied.

While the MILP model developed in this study provides a solid foundation for optimizing the distribution network, future extensions will incorporate reinforcement learning to adaptively adjust the number of warehouses based on changing demands and costs. This hybrid approach will enhance decision-making, further improving the distribution process in dynamic environments. By integrating operational costs, resource allocation, and flexibility, this research contributes to enhancing the overall efficiency of distribution networks in supply chain management.

# ****Model component****

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| **Notation** | **Definition** |
| Objective Function | Determining the capacity, and network to supply and distribute products (e.g., cartons) while minimizing total supply chain costs. |
| Performance Measure | Total supply chain cost, which consists of:   * Capital expenses (e.g., vehicle rental, storage, and container costs) * Operational expenses (e.g., staff costs, fuel costs, vehicle rent costs) |
| Decision Variables | * Quantities of products supplied from supply points to customers. |
|  | * Selection of transportation modes and their fraction of the total demand fulfilled. |
|  | * Allocation of supply routes |
| Parameters | * **Supply Costs**: Costs related to sourcing goods from supply points to distribution centers. |
|  | * **Transportation Costs**: Costs associated with vehicle and container usage, including fuel and rent |
|  | * **Distance Metrics**: Relevant distances for all transportation routes |
|  | * **Warehouse and Vehicle Capacity**: Constraints and limits on storage and transportation |
|  | * **Fuel and Utilization**: Metrics related to fuel usage and vehicle utilization * **Staff and Labor**: Cost and capacity related to warehouse and driver staff |
|  | * **Demand and Supply**: Parameters related to customer demands and supply chain needs |
|  | * **Other Costs**: Additional costs related to supply chain and facility operations |
| Constraints | * Constraints focus on ensuring that the demand of customers is met by the available supply from direct DCs and depots. |
|  | * Constraints ensure that depots are properly assigned and resources (containers, vehicles) are allocated efficiently. |
|  | * Constraints ensure that the fraction of resource utilization (vehicles and containers) remains within valid limits. |
|  | * Constraints ensure that variables for demand and supply are non-negative, and the assignment decisions are binary. |

# Mathematical model notation

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| **Notation** | **Definition** | **Value** |
| **Objective Function** | |  |
|  | Total Monthly Supply and Distribution Cost | IDR/Month |
| **Sets** |  |  |
|  | Sets of Direct DC units |  |
|  | Sets of Depo units |  |
|  | Sets of Customer points |  |
|  | Sets of Container types |  |
|  | Sets of Vehicle modes |  |
| **Indices** |  |  |
|  | Direct DC unit; |  |
|  | Depo unit; |  |
|  | Customer points; |  |
|  | Container types; |  |
|  | Vehicle modes; |  |
| **Parameters** |  |  |
|  | Supply cost to supply carton from SDC to Direct DC *i* | IDR/month |
|  | Operational Distribution Cost to distribute carton for direct DC | IDR/month |
|  | Operational Distribution Cost to distribute carton from depo | IDR/month |
|  | Fuel Cost for all vehicle to distribute from direct DC to customers | IDR/month |
|  | Fuel Cost for all vehicle to distribute from depo to customers | IDR/month |
|  | Fuel Cost for all vehicle to distribute from direct DC to depo | IDR/month |
|  | Vehicle Rent Cost for direct DC to distribute Customer’s demand for all vehicle | IDR/month |
|  | Vehicle Rent Cost for depo to distribute Customer’s demand for all vehicle | IDR/month |
|  | Vehicle Rent Cost for direct DC to supply Depo’s supply for all vehicle | IDR/month |
|  | Total Direct DC warehouse staff’s cost | IDR/month |
|  | Total Depo warehouse staff’s cost | IDR/month |
|  | Total Direct DC driver’s cost | IDR/month |
|  | Total Depo driver’s cost | IDR/month |
|  | Customer's Demand supplied by Vehicle from Direct DC to all Customer | Carton/month |
|  | Customer's Demand supplied by Vehicle from Depo to all Customer | Carton/month |
|  | Customer's Demand supplied by Vehicle from Direct DC to Depo | Carton/month |
|  | Monthly demand supply from direct DC | Carton/month |
|  | Distance from direct DC to depo | Km |
|  | Distance from direct DC to customer | Km |
|  | Distance from depo to customer | Km |
|  | Weighted Distance from direct DC to all Direct DC’s Customer | Km |
|  | Weighted Distance from Depo to Depo’s Customer | Km |
|  | Fuel Usage for all vehicle to distribute from direct DC to customers | Liter |
|  | Fuel Usage for all vehicle to distribute from depo to customers | Liter |
|  | Fuel Usage for all vehicle to distribute from direct DC to depo | Liter |
|  | Capacity of vehicle | Carton/unit |
|  | Capacity of Container | Carton/unit |
|  | Capacity of warehouse staff to handle carton | Carton/person |
|  | Capacity of driver to handle trips | Trip-unit/person |
|  | Total Depo’s Distribution Time for direct DC to distribute all customers for vehicle | Hour |
|  | Total Depo’s Distribution Time for depo to distribute all customers for vehicle | Hour |
|  | Total Depo’s Distribution Time for direct DC to Depo for vehicle | Hour |
|  | Time loading cartons | Hour |
|  | Time unloading cartons | Hour |
|  | Time Vehicle Utilization | Hour/Month |
|  | Round trip hour from direct DC to all customer | Hour |
|  | Round trip hour from Depo to all customer | Hour |
|  | Round trip hour from direct DC to Depo | Hour |
|  | Number of Depo's Vehicle in direct DC to distribute all customer for vehicle mode | Unit/month |
|  | Number of Depo's Vehicle in depo to distribute all customer for vehicle mode | Unit/month |
|  | Number of Depo's Vehicle in direct DC to supply depo for vehicle mode | Unit/month |
|  | Total number of Driver for Direct DC | Person/month |
|  | Total number of Driver for Depo | Person/month |
|  | Total number of warehouse staff for Direct DC | Person/month |
|  | Total number of warehouse staff for Depo | Person/month |
|  | Total number of containers to supply from SDC to Direct DC *i* | Unit/month |
|  | Vehicle Velocity | Km/hour |
|  | Rate of vehicle rent cost per month | Rp/unit-month |
|  | Rate of warehouse staff’s cost at direct DC | IDR/person |
|  | Rate of warehouse staff’s cost at depo | IDR/person |
|  | Container’s Rate per Trips for container to supply from SDC to direct DC | IDR/unit |
|  | Rate of driver’s cost at direct DC | IDR/person |
|  | Rate of driver’s cost at depo | IDR/person |
|  | Vehicle Consumption’s Rate (km/liter) | Km/liter |
|  | Total trips from Direct DC to Customer for vehicle | Trip |
|  | Total trips from Depo to Customer for vehicle | Trip |
|  | Total trips from Direct DC to Depo for vehicle | Trip |
|  | Fuel price | IDR/liter |
| **Decision Variable** |  |  |
|  | Customer's Demand Carton served by Direct DC to customer | Carton/month |
|  | Customer's Demand Carton served by Depo to customer | Carton/month |
|  | Binary Decision for Depo to be supplied from Direct DC | - |
|  | Binary Decision for Customer to be supplied from Direct DC | - |
|  | Binary Decision for Customer to be supplied from Depo | - |
|  | Fraction of Customer's Demand supplied by Vehicle from Direct DC | - |
|  | Fraction of Customer's Demand supplied by Vehicle from Depo | - |
|  | Fraction of T&W supply distributed by container to direct DC | - |
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# Mathematical Equation

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# Model Verification

## **Conceptual model verification**

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| **Notation** | **Definition** | **Mathematical Model** |
| **Objective Function** | Determining the capacity, and network to supply and distribute products (e.g., cartons) while minimizing total supply chain costs. | ( 1) |
| **Decision Variables** | * Quantities of products supplied from supply points to customers. |  |
|  | * Selection of transportation modes and their fraction of the total demand fulfilled. |  |
|  | * Allocation of supply routes |  |
| **Parameters** | * **Supply Costs**: Costs related to sourcing goods from supply points to distribution centers. |  |
|  | * **Transportation Costs**: Costs associated with vehicle and container usage, including fuel and rent: | ,  , |
|  | * **Distance Metrics**: Relevant distances for all transportation routes |  |
|  | * **Warehouse and Vehicle Capacity**: Constraints and limits on storage and transportation | , *,* |
|  | * **Fuel and Utilization**: Metrics related to fuel usage and vehicle utilization | ,  *,* |
|  | * **Staff and Labor**: Cost and capacity related to warehouse and driver staff | ,  *,* |
|  | * **Demand and Supply**: Parameters related to customer demands and supply chain needs |  |
|  | * **Other Costs**: Additional costs related to supply chain and facility operations |  |
| **Constraints** | * Constraints focus on ensuring that the demand of customers is met by the available supply from direct DCs and depots. |  |
|  | * Constraints ensure that depots are properly assigned and resources (containers, vehicles) are allocated efficiently. |  |
|  | * Constraints ensure that the fraction of resource utilization (vehicles and containers) remains within valid limits. |  |
|  | * Constraints ensure that variables for demand and supply are non-negative, and the assignment decisions are binary. |  |

## 

APPENDIX

(Unorganized)

Contain my train of thoughts and logic behind the design

1. Total Distribution Cost for distribution from SDC to all warehouse

I: Sets of direct DC unit

i: Direct DC unit indices;

J: Sets of depo unit

j: Depo unit indices;

1. Supply cost to supply carton from SDC to Direct DC *i*

A: Sets of Container type

a: Container type indices;

: Container’s Rate per Trips for container to supply from SDC to direct DC (Rp/Trip)

1. Container’s Quantity used for selected Container to supply from SDC to Direct DC *i*

: Fraction of T&W supply distributed by container

: Container capacity of container (Carton)

1. Monthly demand supply that need to be supplied to direct DC

K: Sets of Customer unit

k: Customer indices;

: Decision whether the Depo supplied by Direct DC or not

1. Operational Distribution Cost to distribute carton from depo
2. Fuel Cost for depo to distribute customer demand

: Fuel Price (Rp/km)

1. Fuel Usage for depo to distribute customer demand

: Fraction of Customer's Demand supplied by selected Vehicle from Depo to Customer

: Vehicle Consumption’s Rate (km/liter)

1. Weighted Distance from Depo to Depo’s Customer

: distance from Depo to Customer (km)

1. Vehicle Rent Cost for depo

: rate of vehicle’s rate (Rp/unit-month)

1. Amount of Depo's Vehicle in depo for vehicle mode

: time Vehicle Utilization (Hour/month)

1. Total Depo’s Distribution Time for depo for vehicle

: capacity of vehicle

1. Customer's Demand supplied by Vehicle from Depo to Customer
2. Round trip Hour
3. Operational Distribution Cost to distribute carton from direct DC
4. Fuel Cost for direct DC

: Fuel Price (Rp/km)

1. Fuel Usage for direct DC to depo

: Fraction of Customer's Demand supplied by selected Vehicle from direct DC to Depo

: Vehicle Consumption’s Rate (km/liter)

1. Weighted Distance from direct DC to Direct’s Customer

: distance from Depo to Customer (km)

1. Vehicle Rent Cost for direct DC

: rate of vehicle’s rate (Rp/unit-month)

1. Amount of Depo's Vehicle in direct DC for vehicle mode

: time Vehicle Utilization (Hour/month)

1. Total Depo’s Distribution Time for direct DC for vehicle

: capacity of vehicle

1. Customer's Demand supplied by Vehicle from direct DC to Customer
2. Round trip Hour for overall vehicle in direct DC
3. Fuel Cost for direct DC to Depo

: Fuel Price (Rp/km)

1. Fuel Usage for direct DC to Depo (rawan)

: Fraction of Customer's Demand supplied by selected Vehicle from direct DC to Depo

: Vehicle Consumption’s Rate (km/liter)

: distance from direct DC to Depo (km)

1. Vehicle Rent Cost for direct DC to Depo

: rate of vehicle’s rate (Rp/unit-month)

1. Amount of Depo's Vehicle in direct DC to Depo for vehicle mode

: time Vehicle Utilization (Hour/month)

1. Total Depo’s Distribution Time for direct DC to Depo for vehicle

: capacity of vehicle

1. Customer's Demand supplied by Vehicle from direct DC to Depo
2. Round trip Hour for each direct DC to Depo
3. Total Depo to Customer Trips for vehicle b
4. Total number of Driver for Direct DC
5. Total Depo driver’s cost
6. Total Direct DC to Customer Trips for vehicle b
7. Total Direct DC to Depo Trips for vehicle b
8. Total number of Driver for Direct DC
9. Total Direct DC driver’s cost
10. Total number of warehouse staff in Depo
11. Total Depo warehouse staff’s cost
12. Total number of warehouse staff in Direct DC
13. Total Direct DC warehouse staff’s cost