Multidepot Distribution Planning at Logistics Service Provider Nabuurs B.V

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1. Introduction

- Nabuurs B.V. (Nabuurs) is a Dutch, family owned, logistics firm
- Warehousing and Logistics are Nabuurs’ main operations
- Founded in 1962 with only 1 truck, it now has over 20 brands and 1000 employees
- Turnover is approximately 100 million Euros
- Nabuurs has a 2025 goal to significantly reduce CO2 emissions and find sustainable alternatives

1. Introduction

- Nabuurs deals with frozen, refrigerated and ambient fast-moving consumer goods (FMCGs)
- Ambient: Food that can be stored at room temperature
- The paper focuses of the transportation of Ambient FMCGs, which contribute the most to the firm’s revenues
- Logistics industry requires high investments for low profit-margins

Multi Depot System

OPTIMIZE BY COMBINING

We optimize our customers' logistics processes by combining separate networks, services and goods flows into a unique supply chain concept. We do this on 3 levels:

1. **Combining the different networks.** We have a multi-depot network for FMCG distribution, but also a network of regional distribution centers with which we are close to major cities throughout the Netherlands.

2. **Bundling the goods flows of different shippers.** We position ourselves as an independent chain director.

3. **Combining warehousing and distribution with integrated co-packing.** Mechanized co-packing, for example, within the logistics chain.

Operations

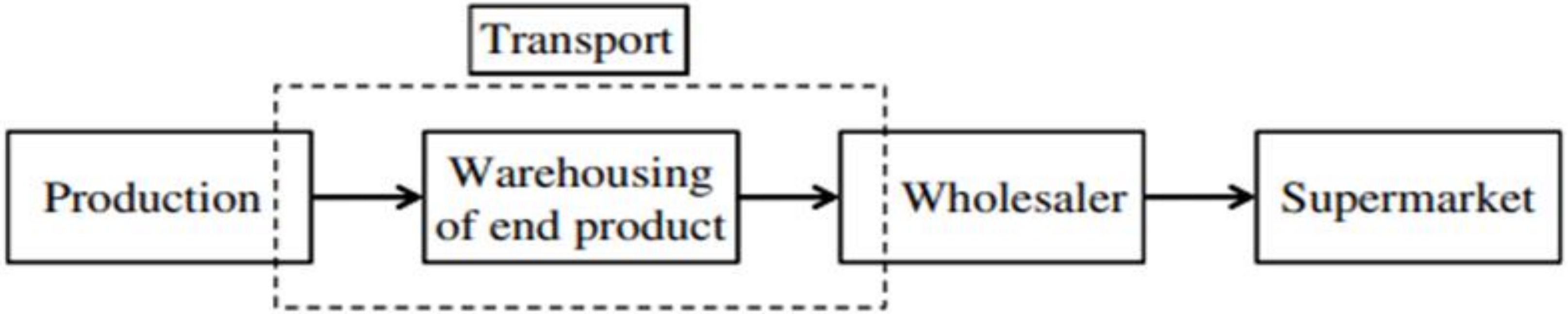

Figure 1: Transportation activities in which Nabuurs is involved are depicted in the supply chain network for refrigerated, frozen, and ambient products—its three market segments.

2. Problem Definition

- Nabuurs changed from a Single Depot (SD) to a Multi Depot (MD) system; however MD planning is done manually, which takes hours
- Scarcity of literature that compares MD planning with SD planning
- Planning is done reactively rather than proactively due to lack of timely available information
- Current system (OTD) does not have enough relevant informatrion
- All these constitute to Nabuur’s high costs

2. Problem Definition

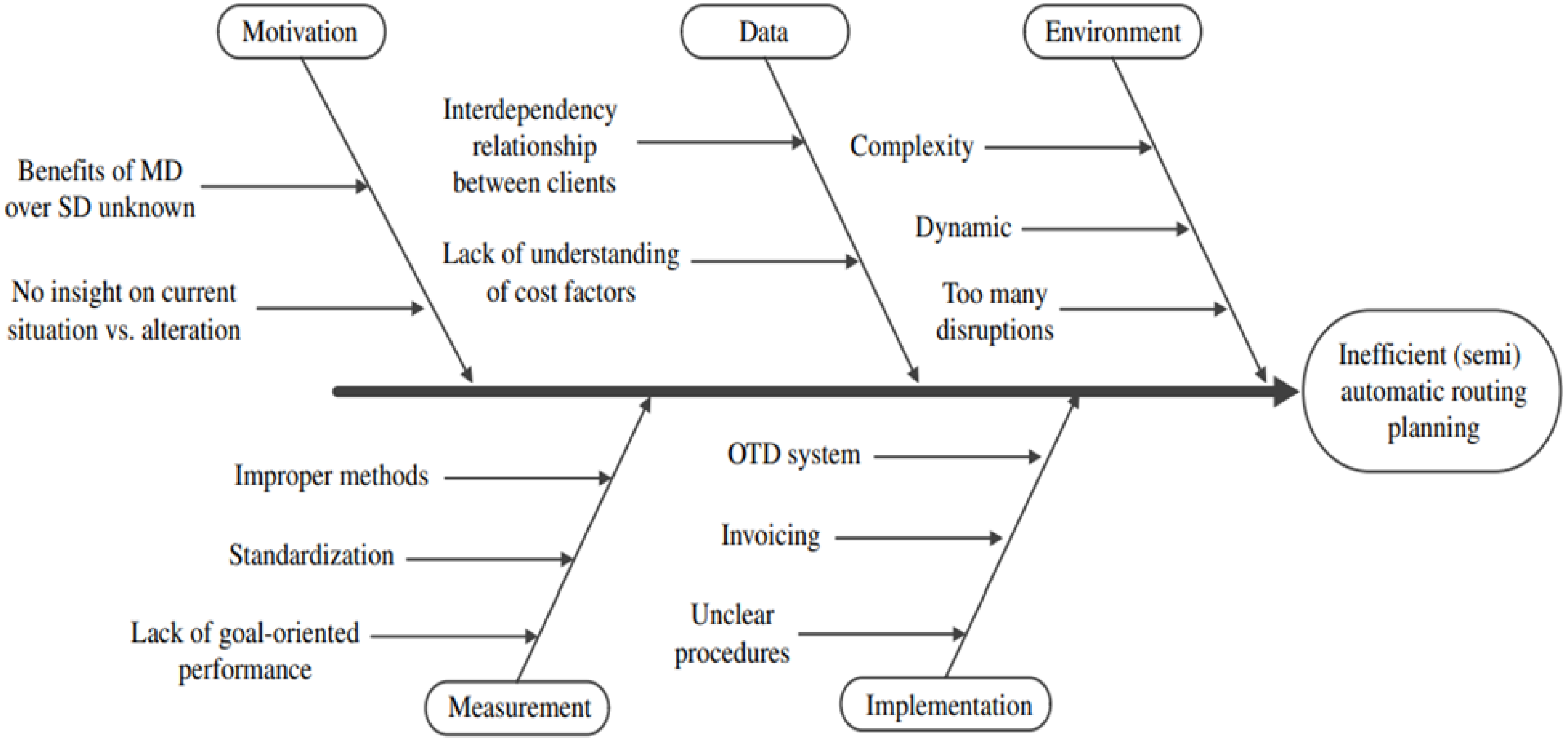

Figure 3: The cause-and-effect diagram shows an inefficient, semiautomatic route-planning process.

3. Objectives of the study

- Verification of MD planning’s superiority over SD planning
- Studying the benefits of proposed automated MD planning compare to current manual MD planning
- Reactive and proactive planning comparison
- Conducting various sensitivity analyses (i.e. adding/removing clients, significantly increasing/decreasing orders etc.)

4. Methodology

- Phase 1: The Performance Evaluation Model (PEM)

Calculating empty/full truck's travelled distance ratio. Allowing the user to visualize output,

- Phase 2: SHORTREC (A tool of ORTEC) based simulation Model

SHORTREC was a simulation model that minimized overall costs. Solution method starts with a basic solution and tries to improve. Many possibilities exist hence it takes time.

4. Methodology: Phase 1 Results

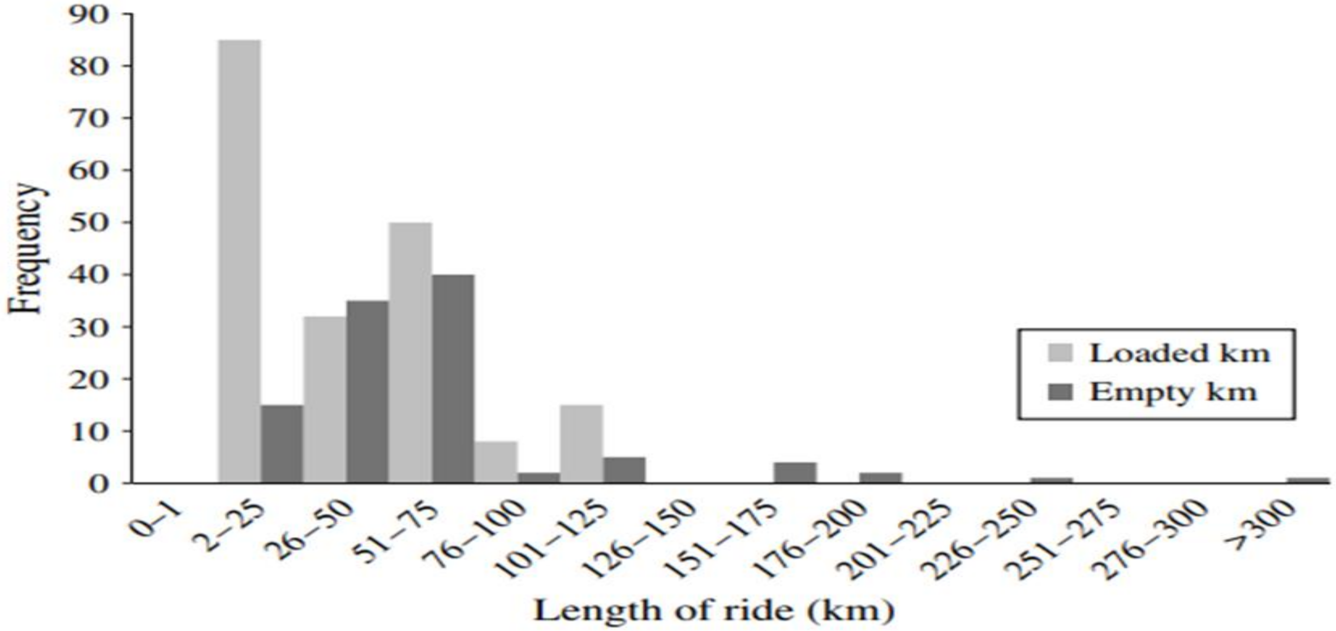

Figure 5: For postcode 34, this figure illustrates the number of kilometers traveled by fully loaded vehicles ("Loaded km") and the number of KMs traveled by empty trucks ("Empty km").

4. Methodology: Phase 2 Heuristics

Construction algorithms	Improvement algorithms
Sequential insertion algorithm	Optimization algorithms
Savings algorithm	Cyclic transfer algorithm
Priority-based parallel insertion algorithm	Tabu search algorithm
Cluster-based insertion algorithm	
Multidepot insertion algorithm	
Group-based insertion algorithm	
Pickup-and-delivery insertion algorithm	

Table 1: The table categorizes the two types of algorithms—construction and improvement—used by SHORTREC, and lists the algorithms in each category.

5. Results

1. Scenario 1: MD planning vs. SD planning
2. Scenario 2: Automated MD Planning vs. Manual MD Planning
3. Scenario 3: Proactive vs. Reactive Planning

5. Results: MD vs. SD

Scenario 1				Performance comparison							
Setting	No. of orders	Smallest or largest volume orders deleted	No. of available preloaded vehicles	Cost (€)	Distance (km)	No. of vehicles	No. of trips	Working time (min.)	Driving time (min.)	Stopping time (min.)	Waiting time (min.)
SD	174	0	25	27,693	21,803	57	116	34,392	18,932	14,280	1,339
MD	174	0	25	25,267	19,287	54	119	31,836	17,117	14,280	199
Difference (%)				−8.76	−11.54	−5.26	2.96	−7.43	−9.69	0.00	−85.14
SD	100	−74 large	25	11,292	8,856	34	49	13,838	7,887	5,880	71
MD	100	−74 large	25	11,229	8,595	30	50	13,842	7,690	5,880	212
Difference (%)				−0.56	−2.95	−11.76	2.04	0.03	−2.50	1.02	198.59
SD	100	−74 large	10	12,853	9,919	30	48	15,576	8,657	6,720	199
MD	100	−74 large	10	12,802	9,868	28	50	15,643	8,623	6,840	180
Difference (%)				−0.40	−0.51	−6.67	4.17	0.43	−0.39	1.79	−9.55
SD	100	−74 small	25	19,183	15,206	46	96	24,096	13,237	10,140	719
MD	100	−74 small	25	18,404	14,465	41	96	23,075	12,697	10,140	238
Difference (%)				−4.06	−4.87	−10.87	0.00	−4.24	−4.08	0.00	−66.90
SD	100	−74 small	10	21,252	17,173	47	96	25,883	14,763	11,040	80
MD	100	−74 small	10	19,892	15,563	43	96	25,081	13,567	11,100	414
Difference (%)				−6.40	−9.38	−8.51	0.00	−3.10	−8.10	0.54	417.50

Table 2: The table presents an overview of the tests we did to compare SD and MD planning.

5. Results: Automated vs. Manual

Scenario 2	Cost (€)	Distance (km)	No. of vehicles	No. of rides	No. of orders	Working time (min.)	Driving time (min.)	Stopping time (min.)	Waiting time (min.)
Manual	5,643	5,083	10	32	32	7,945	N/A	N/A	N/A
SHORTREC	5,191	4,451	11	32	32	6,567	3,933	2,445	189
Difference (%)	–8.01	–12.43	10.00	0.00	0.00	–17.34			

Table 3: The table shows a comparison of the KPIs in the MD manual and automated scenarios (SHORTREC).

5. Results: Proactive vs Reactive Planning

Scenario 3				Performance and comparison							
Horizon: 48 hours	Option for night's rest	Option for free end location	Option for free start location	Cost (€)	Distance (km)	No. of vehicles	No. of rides	Working time (min.)	Driving time (min.)	Stopping time (min.)	Waiting time (minutes)
Reactive planning: 48 hours (2 × 24)	No	Yes	Yes	23,989	17,155	62	133	29,752	15,317	13,005	1,430
Proactive planning: 48 hours	Yes	Yes	Yes	20,447	13,399	56	130	26,897	11,827	17,040	2,350
			Difference (%)	−14.77	−21.89	−9.68	−2.26	−9.60	−22.79	31.03	64.34

Table 4: The table provides detailed results of the reactive and proactive MD ambient planning scenarios.

Solutions	Option for one-night rest in vehicle	Option for free end location	Option for free start location	Cost (€)	Distance (km)	No. of vehicles	No. of rides	Working time (min.)	Driving time (min.)	Stopping time (min.)	Waiting time (min.)
Upper-bound	No	No	No	31,589	25,063	66	131	37,226	21,972	13,680	1,574
Lower-bound	No	Yes	Yes	20,349	13,442	55	128	26,412	11,868	12,720	1,824

Table 5: The table shows upper- and lower-bound solutions for reactive planning.

6. Mathematical Model

Indices

- $\mathcal{P}$: Set of pickup nodes, $\mathcal{P} = \{1, \ldots, n\}$.
- $\mathcal{D}$: Set of delivery nodes, $\mathcal{D} = \{n+1, \ldots, 2n\}$.
- $\mathcal{N}$: Set of pickup and delivery nodes, $\mathcal{N} = (P \cup D)$.
- $\mathcal{K}$: Set of all vehicles, $\mathcal{K} = \{1, \ldots, k\}$.
- $\mathcal{M}$: Set of start terminals of vehicles, $\mathcal{M} = \{m_1, \ldots, m_k\}$.
- $\mathcal{M}'$: Set of end terminals of vehicles, $\mathcal{M}' = \{m'_1, \ldots, m'_k\}$.
- $\mathcal{V}$: Set of all locations, $\mathcal{V} = (N \cup M \cup M')$.

- $\mathcal{A}$: Set of ordered pairs of nodes (i.e., arcs) $\mathcal{A} = \{(i, j): i, j \in \mathcal{V}, i \neq j\}$.
- $\mathcal{G}$: A complete undirected graph, $\mathcal{G} = (\mathcal{V}, \mathcal{A})$.
- $\mathcal{P}_k$: Set of pickup nodes that can be served by vehicle k, $\mathcal{P}_k = \{1, \ldots, n_1\}$ and $n_1 \leq n$.
- $\mathcal{D}_k$: Set of delivery nodes that can be served by vehicle k, $\mathcal{D}_k = \{n+1, \ldots, n+n_1\}$ and $n_1 \leq n$.
- $\mathcal{N}_k$: Set of pickup and delivery nodes $\mathcal{N}_k = (P_k \cup D_k)$.
- $\mathcal{K}_i$: Set of vehicles that can serve request i $\mathcal{K}_i = \{1, \ldots, k_1\}$ and $k_1 \leq k$.
- $\mathcal{V}_k$: Set of all nodes that can be visited by vehicle k $\mathcal{V}_k = (N_k \cup M_k \cup M'_k)$.
- $\mathcal{A}_k$: Set of ordered pairs of nodes for vehicle k $\mathcal{A}_k = \{(i, j): i, j \in \mathcal{V}_k, i \neq j\}$.
- $\mathcal{G}_k$: A complete undirected subgraph $\mathcal{G}_k = (\mathcal{V}_k, \mathcal{A}_k)$.

6. Mathematical Model

Parameters

- Q_k: Capacity of vehicle k $(k \in K)$.
- $\mathcal{T}_1$: Maximum driving time on any arc (i, j) (in seconds).
- $\mathcal{T}_2$: Maximum route time (in seconds).
- $\bar{v}^r$: R nondecreasing speed levels $(r = 1, 2, \ldots, R)$.
- c_r: Fuel cost at a speed level r per kilometer $(r \in \mathcal{R})$.
- c_{ij}^k: Other travel-related costs between nodes i and j using vehicle k $(k \in \mathcal{K}, (i, j) \in \mathcal{A})$.
- d_{ij}: Distance between nodes i and j $(i, j \in \mathcal{A})$.
- l_{ij}: Minimum speed level between nodes i and j $(i, j \in \mathcal{A})$.
- a_i: A lower bound on the time window of customer i $(i \in \mathcal{V})$.
- b_i: An upper bound on the time window of customer i $(i \in \mathcal{V})$.
- t_i: Service time of customer i $(i \in \mathcal{P} \cup D)$.
- q_i: A nonnegative demand for every i $(i \in \mathcal{P})$.

Variables

- x_{ij}^k: A binary variable equal to 1 if arc (i, j) is used by vehicle k and 0 otherwise $(k \in \mathcal{K}, (i, j) \in \mathcal{A})$.
- S_j^k: The time at which service starts at node j with vehicle k $(k \in \mathcal{K}, j \in \mathcal{V})$.
- O_j^k: The time spent on a route that has a node j as last visited before returning to the depot with vehicle k $(k \in \mathcal{K}, j \in \mathcal{V})$.
- L_j^k: Amount of load at node j on vehicle k $(k \in \mathcal{K}, j \in \mathcal{V})$.
- w_{ij}^r: A binary variable equal to 1 if arc (i, j) is traversed at a speed level r and 0 otherwise $((i, j) \in \mathcal{A}, r \in \mathcal{R})$.

6. Mathematical Model

$$\text{minimize} \quad \left\{ \sum_{r\in\mathcal{R}} c_r \sum_{i,\,j\in\mathcal{A}_k} d_{ij} w_{ij}^r \right. \tag{1}$$

$$\left. + \sum_{k\in\mathcal{K}} \sum_{i,\,j\in\mathcal{A}_k} c_{ij}^k x_{ij}^k \right\} \tag{2}$$

subject to

$$\sum_{k\in\mathcal{K}_i} \sum_{j\in\mathcal{N}_k} x_{ij}^k = 1 \quad \forall i \in \mathcal{P}, \tag{3}$$

$$\sum_{j\in\mathcal{N}_k} x_{ij}^k - \sum_{j\in\mathcal{N}_k} x_{j,\,n+i}^k = 0 \quad \forall k \in \mathcal{K},\ \forall i \in \mathcal{P}_k, \tag{4}$$

$$\sum_{j\in\mathcal{N}_k} x_{m_k,\,j}^k = 1 \quad \forall k \in \mathcal{K}, \tag{5}$$

$$\sum_{i\in\mathcal{N}_k} x_{i,\,m'_k}^k = 1 \quad \forall k \in \mathcal{K}, \tag{6}$$

$$\sum_{i\in\mathcal{V}_k} x_{ij}^k - \sum_{i\in\mathcal{V}_k} x_{ji}^k = 0 \quad \forall k \in \mathcal{K},\ \forall j \in \mathcal{N}_k, \tag{7}$$

$$S_i^k + t_i + \sum_{r\in\mathcal{R}} d_{ij} w_{ij}^r/\bar{v}^r + M_{ij}^k(1 - x_{ij}^k) \le S_j^k \quad \forall k \in \mathcal{K},\ \forall (i,j) \in \mathcal{A}_k, \tag{8}$$

$$a_i \le S_i^k \le b_i \quad \forall k \in \mathcal{K},\ \forall i \in \mathcal{V}_k, \tag{9}$$

$$S_i^k \le S_{n+i}^k \quad \forall k \in \mathcal{K},\ \forall i \in \mathcal{P}_k, \tag{10}$$

$$S_j^k + t_j + \sum_{r\in\mathcal{R}} d_{j0} w_{j0}^r/\bar{v}^r - F(1 - x_{j0}^k) \le O_j^k \quad \forall k \in \mathcal{K},\ \forall j \in \mathcal{A}_k, \tag{11}$$

$$L_i^k + q_i + W_{ij}^k(1 - x_{ij}^k) \le L_j^k \quad \forall k \in \mathcal{K},\ \forall (i,j) \in \mathcal{A}_k, \tag{12}$$

$$L_i^k \le Q_k \quad \forall k \in \mathcal{K},\ \forall i \in \mathcal{V}_k, \tag{13}$$

$$\sum_{r\in\mathcal{R}} d_{ij} w_{ij}^r/\bar{v}^r \le \mathcal{T}_1 \quad \forall (i,j) \in \mathcal{A}, \tag{14}$$

$$O_j^k \le \mathcal{T}_2 \quad \forall k \in \mathcal{K},\ \forall j \in (\mathcal{N}_k), \tag{15}$$

$$x_{ij}^k \in \{0,1\} \quad \forall k \in \mathcal{K},\ \forall (i,j) \in \mathcal{A}_k, \tag{16}$$

$$w_{ij}^r \in \{0,1\} \quad \forall (i,j) \in \mathcal{A},\ r = 1,\ldots,R, \tag{17}$$

$$S_i^k;\ L_i^k;\ O_i^k \ge 0 \quad \forall k \in \mathcal{K},\ \forall i \in \mathcal{V}_k. \tag{18}$$

6. Mathematical Model

$$L_i^k + q_i + W_{ij}^k(1 - x_{ij}^k) \le L_j^k$$

$$\forall k \in \mathcal{K}, \forall (i, j) \in \mathcal{A}_k, \qquad (12)$$

$$L_i^k \le Q_k \quad \forall k \in \mathcal{K}, \forall i \in \mathcal{V}_k, \qquad (13)$$

where $W_{ij}^k = \min\{Q_k, Q_k + q_i\}$.

7. Conclusion and Recommendations

1) MD planning saves more money than SD planning especially as order volume increases.

2) making depots, drivers and orders more interchangeable in the second scenario shifted the system from manual to automated. This saved costs or did it? Manual planning allows small changes, but automatic planning takes minutes not hours.

3) Proactive planning saves more money as compared to reactive planning.

4) SHORTREC is a great tool for planning on a tactical level rather than an operational level. Proposed planning system allows rapid route combination generation along with different what-if analysis.

8. Contemporary Examples in The Republic of Turkey

The leading logistics firms in Turkey using autonomous multi-depot systems:

1. Borusan Lojistik
2. Netlog Lojistik
3. Oman Lojistik
4. Ekol Lojistik

THANK YOU FOR YOUR ATTENTION