

Milk Distribution Network Optimization: A Literature-Based Analytical Study

Abir Rara¹, Adit Agarwal², Aditya Kasera³, Aditya Sachdev⁴, Aksh Patel⁵

Anil Surendra Modi School of Commerce, NMIMS Deemed-to-be University, Mumbai, India

B.Sc. Finance, Semester III | Operations Research

¹⁻⁵ Author email and ORCID: to be supplied by authors



<https://doi.org/10.55041/ijssmt.v2i9.026>

Cite this Article: Rara, A., Agarwal, A., Kasera, A., Sachdev, A. & Patel, A. (2026). Milk Distribution Network Optimization: A Literature-Based Analytical Study. *International Journal of Science, Strategic Management and Technology*, 02(9), 1-9. <https://doi.org/10.55041/ijssmt.v2i9.026>

License:  This article is published under the Creative Commons Attribution 4.0 International License (CC BY 4.0), permitting use, distribution, and reproduction in any medium, provided the original author(s) and source are properly credited.

Abstract

This literature-based analytical study examines milk distribution network optimization as an application of operations research, with particular attention to the Milk Collection Problem and its relationship to classical transportation and vehicle-routing models. Two peer-reviewed studies published in 2022 are comparatively examined. The first investigates a Milk Collection Centre–Vehicle Routing Problem for a dairy operation in southern Chile, integrating facility-location decisions with vehicle routing and separate milk-quality constraints. The second develops a Milk Collection Problem model for a real dairy company in Turkey, incorporating heterogeneous vehicle capacities, time windows, vehicle-access restrictions, milk-quality incompatibility, tank loading requirements, and fuel-consumption effects. The study compares the modelling structures, constraints, solution methodologies, practical findings, limitations, and possible extensions of the two studies. Both papers formulate realistic operational decisions using mixed-integer linear programming and employ heuristic or metaheuristic approaches for larger instances. The Chilean study reports transportation-cost reductions of up to 10% from introducing milk collection centres, while the Turkish study demonstrates the computational usefulness of a Variable Neighbourhood Search framework for realistic constrained instances. The comparison shows how the classical transportation model can be extended through facility location, routing, capacity, incompatibility, loading, and time-window constraints to represent real dairy logistics. The analysis also identifies uncertainty, seasonality, spoilage risk, and data requirements as areas for further model development.

Keywords: Operations Research; Milk Collection; Transportation Problem; Vehicle Routing; Mixed-Integer Linear Programming; Logistics

1. INTRODUCTION

Operations Research (OR) is the discipline of applying quantitative and analytical methods — mathematical modelling, statistics, and optimization algorithms — to help decision-makers arrive at the best possible course of action when resources are limited and objectives are measurable. Classical OR techniques such as Linear Programming (LP), the Transportation Problem, the Assignment Problem, and network models (shortest path, minimum spanning tree, maximum flow) were originally developed for logistics and military planning, and today underpin decision-making across manufacturing, healthcare, finance, and agriculture.

This study focuses on Milk Distribution Network Optimization, a real-world application that falls under the broad umbrella of Transportation and Network-Flow Problems. In its simplest classical form, distributing a perishable product such as milk from a set of supply points (farms or collection centres) to a set of demand points (processing plants or distribution centres) is a textbook Transportation Problem: minimize the total cost of moving a homogeneous product from multiple sources to multiple destinations, subject to supply and demand constraints. In practice, however, milk distribution networks are considerably richer than the textbook model — they involve vehicle capacities, multiple product qualities that cannot be mixed, time-sensitive collection windows, and the choice of vehicle routes and not just quantities to ship. The published literature therefore generalizes the classical Transportation Problem into Vehicle Routing Problems (VRP) and Mixed-Integer Linear Programming (MILP) network-design models.

The objective of this review is to examine how classical transportation logic is extended in realistic milk-collection networks and to compare the modelling assumptions, constraints, solution methods, findings, limitations, and possible extensions reported in two selected studies.

2. LITERATURE REVIEW

2.1 Paper 1 — A Milk Transportation Problem with Milk Collection Centers and Vehicle Routing

Paredes-Belmar, G., Montero, E., & Leonardini, O. (2022). *ISA Transactions*, 122, 294–311.

The paper is inspired by an actual raw-milk collection operation of a dairy company in southern Chile. Milk is produced by hundreds of farms scattered across a large rural area and of two distinct qualities that legally cannot be blended together. The company must collect the entire daily production and bring it to a single processing plant. The authors study whether introducing intermediate Milk Collection Centres (MCCs) — smaller depots served by small trucks that in turn feed larger plant trucks — can reduce total transportation cost.

The authors formulate a Milk Collection Centre–Vehicle Routing Problem (MCC-VRP), combining the strategic decision of where to locate MCCs with operational vehicle-routing decisions. The model is a Mixed-Integer Linear Programming (MILP) location-routing problem. Its network contains candidate MCC sites, farms, a processing plant, two truck fleets, and separate milk-quality categories.

The objective minimizes the fixed cost of opening MCCs together with the travel costs of small- and big-truck routes. Constraints govern farm visitation, vehicle capacities by milk quality, MCC storage capacity, route structures, and assignment of farms only to opened MCCs. The study considers exact MILP solution for small instances, a Three-Stage heuristic, and an Iterated Local Search (ILS) metaheuristic for larger instances.

The approaches were validated on a real instance involving 472 farms in southern Chile and on smaller test cases. Introducing milk collection centres reduced total transportation costs by up to 10% in the real-world 472-farm instance compared with a pure door-to-door collection strategy.

2.2 Paper 2 — Modelling and Solving the Milk Collection Problem with Realistic Constraints

Polat, O., Kalaycı, C. B., & Topaloğlu, D. (2022). *Computers & Operations Research*, 142, 105759.

This paper studies the Milk Collection Problem for a real dairy company in Turkey with 87 farms and milk collection centres served by 11 specialized tanker trucks. The authors emphasize realistic constraints that are often simplified in earlier models, including heterogeneous vehicle fleets, minimum and maximum tank-loading ratios, restrictions on vehicle access, and incompatibility between milk qualities.

The model integrates tanker assignment and tanker routing as a realistically constrained Capacitated Vehicle Routing Problem. The network is represented as a directed graph, with decision variables assigning milk types and tanks to stops and determining the arcs travelled by each tanker.

The constraints are grouped into routing, incompatibility, and loading categories. Routing constraints include vehicle capacities, available tanker types, collection time windows, maximum route duration, and divisible demand. Incompatibility constraints include vehicle-access restrictions, multiple separated tanks, and milk-quality separation. Loading constraints include tank-fill ratios and fuel consumption linked to distance and load.

Small instances were solved to near-optimality using CPLEX, while a Variable Neighbourhood Search (VNS) metaheuristic was developed for realistic larger instances. The model and VNS framework were tested on the real 87-farm, 11-tanker case across five operating scenarios.

3. METHODOLOGY

This study adopts a literature-based analytical and comparative research design. It does not collect primary survey data or conduct a new field experiment. Instead, it examines two peer-reviewed research articles addressing the Milk Collection Problem and compares their operational contexts, mathematical formulations, constraints, solution methodologies, findings, limitations, and opportunities for extension.

The two articles were selected because both directly address milk collection as an operations-research problem and both extend classical transportation logic through vehicle-routing and capacity-related constraints. The first study examines a two-tier milk collection network involving collection centres and vehicle routing in southern Chile. The second examines an integrated tanker assignment and routing problem with realistic constraints in Turkey.

The analytical framework used in this review consists of five dimensions: (1) real-world operating context; (2) problem formulation and decision variables; (3) operational constraints and assumptions; (4) exact, heuristic, or metaheuristic solution methods; and (5) practical findings, limitations, and potential extensions. This framework is used to identify common features and meaningful differences between the two studies.

The mathematical expressions discussed in this paper are simplified, illustrative restatements of the objectives and constraints described in the selected studies; they are not presented as verbatim reproductions of the authors' complete formulations.

4. RESULTS AND DISCUSSION

Both studies demonstrate that a classical Transportation Problem is often insufficient to represent real milk logistics. Milk is perishable, production is geographically dispersed, vehicles have finite and sometimes heterogeneous capacities, and different milk qualities may need to remain separated. Consequently, the basic transportation objective of minimizing movement cost is extended through routing, facility-location, time-window, incompatibility, and loading constraints.

Paper 1 introduces a facility-location layer through Milk Collection Centres. Its main operational insight is that a two-tier network can reduce transportation costs when farms are geographically dispersed. The reported reduction of up to 10% in the real 472-farm instance provides a clear quantitative illustration of the potential value of redesigning the collection network.

Paper 2 places greater emphasis on operational realism within the tanker fleet. Its routing, incompatibility, and loading constraints capture details such as vehicle access, tank separation, collection windows, tank-fill ratios, and fuel consumption. The use of VNS enables the integrated model to be handled for realistic larger instances where exact optimization becomes computationally difficult.

Comparatively, the two studies address different layers of the same broader logistics problem. Paper 1 emphasizes strategic network structure through MCC location and the interaction between small- and large-truck routes. Paper 2 emphasizes detailed operational planning of tanker assignment, loading, and routing. Both combine exact optimization for smaller instances with heuristic or metaheuristic approaches for larger instances.

The comparison also identifies common limitations. Both models assume substantial knowledge of farm locations, production volumes, distances, and operating conditions. Both are primarily single-period formulations and therefore do not fully capture seasonal changes in milk production. In addition, heuristic solutions for NP-hard problems are not guaranteed to be globally optimal for large instances.

Further research could incorporate stochastic or robust optimization for uncertain travel times and milk yields, multi-period planning for seasonal production changes, explicit spoilage or quality-decay costs linked to route duration, and



an integrated model combining Paper 1's facility-location layer with Paper 2's detailed routing, incompatibility, and loading constraints.

5. CONCLUSION

Both selected studies confirm that Milk Distribution (Collection) Network Optimization, while rooted in the classical Transportation Problem's logic of minimizing the cost of moving a product from sources to destinations under supply and capacity constraints, requires meaningful extensions once real operational detail is introduced. Facility-location decisions, vehicle routing, multiple non-mixable product qualities, time windows, and vehicle-specific loading limits materially change the modelling problem. Mixed-Integer Linear Programming provides the mathematical backbone for both studies, while metaheuristics such as Iterated Local Search and Variable Neighbourhood Search make larger real-world instances more tractable. The comparative analysis indicates that applied OR models generally preserve the core objective-and-constraints structure of classical transportation models while adding operational detail to improve real-world representation. Future work can build on these models by incorporating uncertainty, seasonality, spoilage risk, and more integrated network-design decisions.

REFERENCES

- Paredes-Belmar, G., Montero, E., & Leonardini, O. (2022). A milk transportation problem with milk collection centers and vehicle routing. **ISA Transactions*, 122*, 294–311. <https://doi.org/10.1016/j.isatra.2021.04.020>
- Polat, O., Kalaycı, C. B., & Topaloğlu, D. (2022). Modelling and solving the milk collection problem with realistic constraints. **Computers & Operations Research*, 142*, 105759. <https://doi.org/10.1016/j.cor.2022.105759>