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1 A Possibilistic Reliable and Responsive Closed Loop Supply Chain Network Design Model under Uncertainty, Hamidieh, A., & Fazli-Khalaf, M. (2017)

Main Objective

To design a bi-objective, reliable, and responsive multi-echelon closed-loop supply chain network (CLSCN) that minimizes total network costs and total earliness/tardiness of customer deliveries, while considering environmental issues and coping with uncertainties and facility disruptions.

Methodology

A multi-objective linear programming model is proposed. Uncertainty in parameters (e.g., costs, demands) is handled using possibilistic programming (based on triangular fuzzy numbers derived from expert opinions) and converted to an equivalent crisp model. Facility disruptions (specifically at distribution centers) are addressed via a scenario-based approach with associated probabilities. The model is solved using an epsilon-constraint method for the bi-objective nature.

Key Aspects of the Network Design

- **Echelons (Forward):** Suppliers (original and recycled raw materials), Plants (production), Distribution Centers, Customer Zones.
- **Echelons (Reverse):** Customer Zones (return origin), Collection/Inspection Centers, Refurbishing Centers, Recycling Centers, Disposal Centers. Recovered products from refurbishing centers can re-enter the forward flow at distribution centers; recycled raw materials from recycling centers can re-enter at plants.
- **Flows:** Single product flow through forward and reverse channels, including raw materials, finished products, and returned end-of-life products.
- **Decisions:**
  - Facility location and capacity level selection for plants (XJ_{jz}), distribution centers (XL_{lt}), and recycling centers (XO_{oq}).
  - Quantities of materials/products transferred between echelons in each scenario s (e.g., VIJ_{ijs} from supplier i to plant j, VJL_{jls} from plant j to distribution center l).
  - Total earliness ($TEDT_{lks}$) and tardiness ($TTDT_{lks}$) of deliveries.
- **Objectives:**
  1. Minimize total network costs (Z_1): sum of fixed opening costs, variable purchasing, production, processing, holding, and transportation costs, weighted by scenario probabilities.
  2. Minimize total weighted earliness/tardiness (Z_2) of product delivery to customer zones, weighted by scenario probabilities.
- **Uncertainty & Reliability:**

  - Possibilistic programming for uncertain costs and demands.
  - Scenario-based approach for partial/complete disruption of distribution center capacities.
  - Minimum acceptable quality level for raw materials.

- **Constraints:** Demand satisfaction, flow balance across all echelons, facility capacity limits (considering disruptions for distribution centers), quality requirements, binary facility opening decisions, and non-negativity.

Solution Approach

The bi-objective possibilistic programming model is converted to a crisp equivalent. The epsilon-constraint method is used to find non-dominated solutions. CPLEX solver is used for implementation.

Key Findings

- Increasing satisfaction levels (risk-aversion) for uncertain parameters leads to higher total costs.
- The model demonstrates a trade-off between minimizing costs (leading to a more centralized network) and minimizing earliness/tardiness (leading to a more decentralized network with more open facilities).
- Increasing customer demand leads to higher costs and earliness/tardiness, and potentially more open facilities.

Contributions to Reverse Logistics Network Design

- Develops a comprehensive bi-objective CLSCN model integrating forward and reverse flows with considerations for reliability (via disruption scenarios at distribution centers) and responsiveness (earliness/tardiness).
- Employs possibilistic programming to handle parameter uncertainty based on expert opinion, offering an alternative to stochastic programming when historical data is scarce.
- Addresses environmental concerns by explicitly modeling the recovery and recycling of end-of-life products.
- Considers quality levels of raw materials.

Critique from Collaborator (Incorporated/Refined): The model's reliance on subjective expert-based possibility parameters can be a limitation. Its single-period structure doesn't capture dynamic aspects. The responsiveness metric is primarily time-based, and reliability is focused on distribution center disruptions. Variability in returned product quality impacting costs/yields is not deeply explored.

2 Network design for reverse logistics, Srivastava, S. K. (2008)

Main Objective

To develop an integrated, holistic conceptual framework and a corresponding mathematical model for designing a cost-effective and efficient multi-echelon, multi-period reverse logistics (RL) and value recovery network for product returns, specifically within the Indian context, considering Green Supply Chain Management (GrSCM) principles.

Methodology

The study combines descriptive modeling (based on literature and informal interviews with 84 stakeholders) with optimization techniques. A bi-level (hierarchical) optimization approach is used. The first level optimizes collection center locations based on strategic and customer convenience constraints. The second, main optimization model then determines disposition decisions, rework facility locations, capacity additions, and flows to maximize profit. The model is formulated as a Mixed Integer Linear Program (MILP) and solved using GAMS with CPLEX.

Key Aspects of the Network Design

- **Echelons:**
  1. Consumers (origin of returns - 'bring scheme').
  2. Collection Centers (CCs): Initial points for product returns, inspection, sorting, and first disposition (sell directly).
  3. Rework Sites: Two distinct types:
     - Repair and Refurbishing Centers (lower capital, skill-based).
     - Remanufacturing Centers (higher capital, technology-based).
  4. Markets: Primary and secondary markets for reselling reworked goods and recovered modules.
- **Flows:** Multi-product (various categories like electronics, automobiles) returns, considering different grades. Products flow from customers to CCs, then either sold directly or sent to appropriate rework sites. Reworked products/modules are sold in markets.
- **Decisions (Main Model - Post CC Location):**
  - Disposition decisions at CCs (sell directly, send to repair/refurbish, send to remanufacture).
  - Location of rework sites (from candidate CC locations).
  - Capacity additions at rework sites over a multi-period horizon (10 years).
  - Flows of products/modules between CCs and rework sites, and from rework sites to markets.
- **Objective (Main Model):** Maximize profit, defined as {realization from reselling returned products (with/without rework) and recovered modules} - {RL costs (fixed/running facility costs, transportation, processing, inventory) + resolution price paid to customers}.

- **Constraints (Main Model):** Disposition decisions are mutually exclusive; capacity balance at rework sites; goods processed within capacity limits; inventory balance at rework sites.
- **Contextual Factors:** Indian market; data from secondary sources and stakeholder interviews for costs, distances, processing times, recovery rates, etc.

Solution Approach

A hierarchical optimization:

1. Simple optimization model (not detailed in objective/constraints here) to decide CC opening based on strategic and customer convenience (max distance) constraints. This determines product returns at these CCs.
2. Main MILP model then takes these CC locations and return volumes as inputs to optimize disposition, rework facility location/capacity, and flows for profit maximization. Solved with GAMS/CPLEX.

Key Findings

- Remanufacturing is found to be generally not economically viable in the Indian context due to underdeveloped technologies and high capital investment, with refurbishing being the dominant disposition.
- Product returns in most categories are below the 'critical mass' needed for large-scale remanufacturing.
- Customer convenience (distance to CC) and per-unit transportation costs significantly impact network design.
- The model provides insights into optimal facility numbers, locations, and capacities under various scenarios.

Contributions to Reverse Logistics Network Design

- Provides a conceptual framework and a hierarchical MILP model for RL network design tailored to product returns and value recovery in a developing country context (India).
- Considers multiple product categories and distinguishes between repair/refurbishing and remanufacturing facilities.
- Incorporates practical aspects like customer convenience constraints and multi-period capacity decisions for rework sites.
- Highlights the economic challenges of remanufacturing in specific contexts.

Critique from Collaborator (Incorporated/Refined): The hierarchical approach might lead to sub-optimal solutions. Assumptions like unlimited demand for recovered goods and unconstrained storage are simplifications. While uncertainties are mentioned, the core model is deterministic. The operational details distinguishing repair from remanufacturing processes could be further elaborated.

3 Reverse logistics network design with stochastic lead times, Lieckens, K., & Vandaele, N. (2007)

Main Objective

To design an efficient single-product, single-level reverse logistics network by extending traditional MILP models with queueing theory (G/G/1 model) to account for stochastic lead times, inventory positions, and the inherent uncertainty and variability in reverse logistics. The aim is to maximize overall expected yearly profit.

Methodology

The paper starts with a traditional MILP formulation for facility location and allocation in reverse logistics. This is then extended by incorporating queueing relationships (specifically, approximations for G/G/1 queues to model waiting times and inventory) to capture dynamic aspects and variability. This extension transforms the problem into a Mixed Integer Nonlinear Program (MINLP). Due to the complexity, a Genetic Algorithm based on Differential Evolution (DE) is used as the solution method.

Key Aspects of the Network Design

- **Echelons:** A single-level network is considered:
  1. Customer Locations (N): Comprising Disposer Markets (sources of returns, N^{Disp}) and Reuse Markets (sinks for recovered products, N^{Reuse}).
  2. Reprocessing/Recovery Facilities (I): Intermediate nodes where returned products are processed (e.g., disassembly, recycling, remanufacturing). These are candidate locations with predetermined capacity levels (q).
- **Flows:** Single product type.
  - From Disposer Markets ($n \in N^{Disp}$) to Recovery Facilities ($i \in I$).
  - From Recovery Facilities ($i \in I$) to Reuse Markets ($n \in N^{Reuse}$).
  - A fraction of products at recovery facilities can be disposed of ($X_{i,disp}$).
- **Decisions:**
  - Which recovery facilities (i) to open and at which capacity level (q) ($Y_i(q)$).
  - Total product flow reprocessed at facility i at capacity q ($X_i(q)$).
  - Product flow from disposer market n to facility i (X_{ni}).
  - Product flow from facility i to reuse market n (X_{in}).
  - Fraction of demand not satisfied for reuse customer n (u_n).
  - Fraction of returns not collected from disposer customer n (w_n).
- **Objective:** Maximize total expected yearly profit. This includes:
  - Revenue from selling to reuse markets.

- Minus: Fixed costs of opening facilities ($FIX_i(q)$), variable reprocessing costs ($c_i(q)$), transportation costs (c_{ni}), disposal costs ($c_{i,disp}$), penalty costs for unsatisfied demand (c_n^u) or uncollected returns (c_n^w), and inventory holding costs ($c_i(h)E(N_i)$).

- **Stochasticity & Queueing:**
  - Variability in returns and reprocessing is modeled using Squared Coefficient of Variation (SCV) for arrivals ($c_a^2(n)$) and service times ($c_e^2(i)$).
  - Expected waiting time $E(W_{Qi})$ and expected number of products $E(N_i)$ at each facility i are estimated using G/G/1 queue approximations (e.g., Kingman's or Whitt's formula), leading to nonlinear inventory cost terms.
  - Little's Law ($E(N_i) = \lambda_i E(W_i)$) is used to link cycle time to inventory.

- **Constraints:** Flow balance at reprocessing facilities, demand satisfaction at reuse markets, capacity limits of facilities, logical constraints for facility opening, and non-negativity.

Solution Approach

A Genetic Algorithm based on Differential Evolution (DE) is employed to solve the MINLP. The DE uses continuous variables internally, with truncation for binary decisions during evaluation. Different DE schemes and parameter settings are tested.

Key Findings

- Incorporating queueing relationships (and thus inventory costs related to lead times) leads to different network configurations and flow distributions compared to traditional MILP models that ignore these dynamic aspects.

- The MINLP model is relevant when inventory, obsolescence, and lead time costs are significant.

- The DE algorithm finds robust solutions close to the global optimum (when compared to enumeration for smaller cases) within acceptable time limits.

Contributions to Reverse Logistics Network Design

- Extends traditional facility location models for reverse logistics by integrating queueing theory (G/G/1) to explicitly model stochastic lead times and their impact on inventory costs.

- Formulates the problem as an MINLP, capturing the nonlinear relationship between facility utilization, lead times, and inventory.

- Applies a Differential Evolution based genetic algorithm to solve the complex MINLP.

- Highlights the importance of considering operational variabilities and congestion effects in strategic network design for reverse logistics.

Critique from Collaborator (Incorporated/Refined): The model's applicability is limited by its single-product, single-echelon structure and single-period view. Representing facilities as single G/G/1 queues is a simplification. Metaheuristic solutions for MINLPs may not guarantee global optimality. Uncertainty modeling is focused on lead time variability, excluding other sources like return volumes or quality.

4 A robust design for a closed-loop supply chain network under an uncertain environment, Ramezani, M., Bashiri, M., & Tavakkoli-Moghaddam, R. (2013)

Main Objective

To present a robust design for a multi-product, multi-echelon, closed-loop logistic network (CLSCN) under an uncertain environment, where demand and return rates are described by a finite set of possible scenarios. The model aims to determine facility locations, capacity levels, and product flows to maximize total profit using a robust optimization approach (min-max regret).

Methodology

A deterministic mixed-integer linear programming (MILP) model is first presented for the CLSCN. This is then extended to a robust formulation to handle uncertainty in demand and return rates. The robust optimization approach uses the min-max regret criterion. A scenario relaxation algorithm is employed to solve the robust model, aiming for better computation times compared to the extensive form model.

Key Aspects of the Network Design

- **Echelons (Forward):** Suppliers (V), Plants (I), Distribution Centers (J), Customers (C).
- **Echelons (Reverse):** Customers (C, as return origin), Collection Centers (K), Repair Centers (L), Disposal Centers (D). Returned products can also go from collection centers to plants (for remanufacturing) or back to suppliers (for recycling). Repaired products can go from repair centers to distribution centers.
- **Flows:** Multi-product (P) flows through both forward and reverse channels.
- **Decisions (First-stage/Robust):**
  - Location and capacity level ($h \in H$) selection for plants (X_i^h), distribution centers (Y_j^h), collection centers (Z_k^h), and repair centers (W_l^h).
- **Decisions (Second-stage/Scenario-dependent):** Quantities of products shipped between echelons (e.g., QSP_{vip} from supplier v to plant i for product p; QCC_{ckp} from customer c to collection center k).
- **Objective (Deterministic):** Maximize total profit (Total Income - Total Cost). Income from sales. Costs include fixed facility opening, manufacturing, operating, inspection, repairing, remanufacturing, recycling, disposal, and transportation.

- **Objective (Robust):** Minimize the maximum regret (δ) across all scenarios $s \in S$. Regret is $u_s - f_s(Q_s, X_i^h, Y_j^h, Z_k^h, W_l^h)$, where u_s is the optimal profit under scenario s (perfect information) and $f_s(...)$ is the profit of the robust solution under scenario s.
- **Uncertainty:** Demand (D_{cp}) and return rates (RT) are uncertain and modeled via a finite set of scenarios.
- **Constraints:** Flow balance at all nodes, capacity limits for all facilities, maximum number of activated locations for each facility type, and binary/non-negativity restrictions.

Solution Approach

The robust optimization problem (min-max regret) is solved using a scenario relaxation algorithm. This algorithm iteratively solves a relaxed version of the problem with a subset of scenarios and adds "violating" scenarios (those with high regret) until a robust solution is found or infeasibility is detected.

Key Findings

- The robust configuration, while yielding lower profit than the deterministic configuration under ideal conditions, is more reliable as it remains feasible across various demand and return rate scenarios (especially worst-case ones) where the deterministic solution might fail.
- The scenario relaxation algorithm shows superior computational performance compared to solving the extensive form of the robust model, especially as the number of scenarios increases.
- The capacity level and location of the second collection center were identified as key sensitive decisions in the numerical example.

Contributions to Reverse Logistics Network Design

- Develops a multi-product, multi-echelon CLSCN model incorporating both forward and reverse flows.
- Applies a robust optimization approach (min-max regret) to handle uncertainty in demand and return rates, which is crucial for strategic network design.
- Implements an efficient scenario relaxation algorithm to solve the robust model, making it practical for problems with a larger number of scenarios.
- Provides insights into the trade-off between profitability and reliability in network design under uncertainty.

Critique from Collaborator (Incorporated/Refined): The min-max regret criterion can be overly conservative. Uncertainty modeling is limited to demand and return rates. The quality of the robust solution depends on the representativeness of the defined scenarios. Detailed modeling of specific recovery processes (remanufacturing, disassembly) is absent. The model is single-objective (profit-focused).

5 An optimization model for the design of a capacitated multi-product reverse logistics network with uncertainty, Salema, M. I. G., Barbosa-Povoa, A. P., & Novais, A. Q. (2007)

Main Objective

To develop a generalized mixed-integer linear programming (MILP) model for designing a capacitated, multi-product reverse logistics network that considers uncertainty in product demands and returns. The model aims to overcome limitations of case-based models by providing a more generic framework, extending the Recovery Network Model (RNM) by Fleischmann et al. (2001).

Methodology

The paper proposes an MILP formulation. Uncertainty in customer demands and returns is handled using a scenario-based approach, where the objective function minimizes the expected total cost over a finite set of discrete scenarios, each with an associated probability. The model is solved using standard Branch & Bound (B&B) techniques (GAMS/CPLEX).

Key Aspects of the Network Design

- **Echelons (Integrated Forward and Reverse):**
  1. Factories (I): Potential locations for production and receiving returns from disassembly centers. An additional disposal option (I_0) is included.
  2. Warehouses (J): Potential intermediate storage/distribution points in the forward chain.
  3. Customers (K): Sources of demand for new products and origin of used product returns.
  4. Disassembly Centers (L): Potential locations for collecting and disassembling returned products.
- **Flows:** Multi-product ($m \in M$) flows.
  - Forward: Factory → Warehouse → Customer (X^f_{mijks}).
  - Reverse: Customer → Disassembly Center → Factory (for recovery) or Disposal (X^r_{mklis}, X^r_{mkl0s}).
- **Decisions:**
  - Facility location: Which factories (Y^p_i), warehouses (Y^w_j), and disassembly centers (Y^r_l) to open (binary variables, not scenario-dependent).
  - Flow allocation: Fraction of demand/return for each product m and customer k to be routed through the network under each scenario s (e.g., X^f_{mijks}, X^r_{mklis}).
  - Non-satisfied demand (U_{mks}) and non-satisfied return (W_{mks}) fractions under each scenario s.
- **Objective:** Minimize total expected costs across all scenarios. Costs include:

  - Fixed costs for opening factories, warehouses, and disassembly centers.
  - Variable costs for serving demand (transportation, production).
  - Variable costs for handling returns (transportation, reprocessing).
  - Penalty costs for non-satisfied demand and non-satisfied returns.

- **Uncertainty:** Customer demand (d_{mks}) and return volumes (r_{mks}) are scenario-dependent.
- **Constraints:** Demand satisfaction (or penalty for non-satisfaction), return handling (or penalty for non-collection), balance constraint at factories (return volume ≤ demand volume), minimum disposal fraction, capacity limits (min and max) for factories, warehouses, and disassembly centers (for total throughput of all products).

Solution Approach

The MILP model, incorporating multiple scenarios for demand and return, is solved using GAMS/CPLEX.

Key Findings

- The model successfully determines the optimal network configuration (opened facilities and flows) under uncertainty.
- Capacity constraints significantly impact the network structure (e.g., requiring more warehouses compared to an uncapacitated model).
- The multi-product formulation leads to more intricate network structures compared to single-product models, as distribution is managed simultaneously for all products.
- The scenario-based approach allows for evaluating network performance under different future conditions (e.g., pessimistic, optimistic demand/return).

Contributions to Reverse Logistics Network Design

- Extends the generic RNM by incorporating facility capacity limits, multi-product flows, and demand/return uncertainty via a scenario-based stochastic programming approach.
- Provides a more generalized model applicable to a variety of reverse logistics situations beyond specific case studies.
- Demonstrates how to integrate forward and reverse flows in a capacitated, multi-product network under uncertainty.

Critique from Collaborator (Incorporated/Refined): The expected value objective is risk-neutral. The reverse network is simplified (disassembly centers and original factories only). Processing costs, yield uncertainties, and lead times are not explicitly modeled. Defining scenario probabilities is challenging. The model is cost-focused, excluding other performance metrics.

6 The design of reverse distribution networks: Models and solution procedures, Jayaraman, V., Patterson, R. A., & Rolland, E. (2003)

Main Objective

To develop models and efficient solution procedures for designing cost-minimizing reverse distribution networks for product returns.

Methodology

A mixed-integer linear programming (MILP) model ("Model Refurb") is proposed. Due to NP-hard nature, a heuristic solution methodology combining heuristic concentration and heuristic expansion (HE) is also developed.

Key Aspects of the Network Design

- **Echelons:** Origination sites (product returns), optional Collection sites (consolidation, fixed cost), and Refurbishing sites (processing, fixed cost).
- **Flows:** Products from origination sites, potentially via collection sites, to refurbishing sites. Direct shipment from origination to refurbishing is allowed.
- **Decisions:** Which collection and refurbishing sites to open; allocation of product flows through the network.
- **Objective:** Minimize total costs (variable transportation/processing + fixed facility opening costs).
- **Constraints:** Include demand satisfaction, facility capacities, site opening logic, and limits on the number of open facilities.

Solution Approach

Heuristic procedure involving: 1) Random selection of site subsets, 2) Heuristic concentration to identify promising sites, 3) Heuristic Expansion (HE) for greedy improvement. An alternative deterministic heuristic (Procedure CC) is also presented. Subproblems solved using AMPL/CPLEX.

Key Findings

Heuristic procedures, especially with HE, yield high-quality (often near-optimal) solutions much faster than exact methods for large problems. HE significantly improves initial heuristic solutions.

Contributions to Reverse Logistics Network Design

- Provides a comprehensive MILP for multi-echelon reverse network design.

- Develops and validates an effective heuristic (heuristic concentration + HE) for this complex problem.
- Demonstrates practical utility for large-scale reverse logistics network design.

7 Reverse logistics network for municipal solid waste management: The inclusion of waste pickers as a Brazilian legal requirement, Ferri, G.L., Chaves, G.L.D., & Ribeiro, G.M. (2015)

Main Objective

To propose and validate a reverse logistics network model for Municipal Solid Waste (MSW) management in Brazil, maximizing profit while incorporating legal requirements for waste picker inclusion and strategic Material Recovery Facility (MRF) allocation.

Methodology

A mixed-integer linear programming (MIP) model is developed. Validation is performed via scenario analysis using data from São Mateus, Brazil, solved with CPLEX.

Key Aspects of the Network Design

- **Echelons:** MSW Generation locations; Material Recovery Facilities (MRFs for recyclable MSW_R and general MSW_G with varying capacities; waste picker associations considered as potential MRFs); Final Destinations (Sanitary Landfills, Recycling Companies, Recycle Dealers).
- **Flows:** MSW_R and MSW_G from generation points to MRFs; sorted materials from MRFs to recyclers/dealers; refuse from MRFs to landfills.
- **Decisions:** Number, location, and capacity of MRFs to open; quantities of MSW and sorted materials to flow between facilities.
- **Objective:** Maximize total profit (revenue from recyclables sales minus transportation and MRF installation/operation costs).
- **Constraints:** All generated waste processed, MRF capacity limits, flow conservation, facility opening logic.

Solution Approach

MIP model solved with CPLEX. Analysis based on different scenarios (selective collection rates, waste picker inclusion, number of MRFs, population growth).

Key Findings

The model optimizes MRF configuration for maximum profit. Inclusion of MRFs (especially involving waste pickers) reduces transport costs and aids formalization. Higher selective collection rates improve system profitability.

Contributions to Reverse Logistics Network Design

- Applies RL network design to MSW management, integrating legal, social, and economic criteria.
- Offers a planning tool for MSW systems in developing countries with a significant informal sector.
- Highlights MRFs as crucial reverse consolidation points for sorting, value recovery, and waste picker integration.

8 A genetic algorithm approach to developing the multi-echelon reverse logistics network for product returns, Min, H., Ko, H. J., & Ko, C. S. (2006)

Main Objective

To develop a nonlinear mixed-integer programming (NLMIP) model and a Genetic Algorithm (GA) to design a cost-minimizing multi-echelon reverse logistics network for product returns, focusing on the number and location of initial collection points and centralized return centers (CRCs).

Methodology

An NLMIP model is formulated to capture costs associated with product returns. A Genetic Algorithm (GA) is developed as the solution methodology due to the problem's complexity.

Key Aspects of the Network Design

- **Echelons:** Customers (return origin); Initial Collection Points (ICPs, e.g., retail stores, rented space); Centralized Return Centers (CRCs, for inspection, sorting, consolidation); (Implicitly) Manufacturers/Repair facilities (final destination from CRCs).
- **Flows:** Products from customers to ICPs; from ICPs to CRCs.
- **Decisions:**
  - Which ICPs to select/open (Z_j).
  - Which CRCs to establish (G_k).
  - Assignment of customers to ICPs (Y_{ij}).
  - Quantity of products flowing from ICPs to CRCs (X_{jk}).
  - Length of collection/consolidation period at ICPs (T_j).

- **Objective:** Minimize total reverse logistics costs, including: renting costs for ICPs, inventory carrying costs at ICPs, establishment costs for CRCs, and shipping costs from ICPs to CRCs (which is a nonlinear function of volume, distance, and collection period T_j).
- **Constraints:** Customer assignment, flow through open facilities, flow balance at ICPs, CRC capacity, maximum customer-to-ICP distance, minimum number of open ICPs and CRCs.

Solution Approach

A Genetic Algorithm (GA) with specific encoding for facility opening and collection periods, along with cloning, parent selection, crossover, and mutation operators. A fitness function incorporates the objective function and penalties for infeasibility.

Key Findings

The GA effectively solves the NLMIP. Sensitivity analyses indicated that:

- Longer consolidation periods at ICPs reduce total costs due to better freight rates, with stable facility numbers.
- Increased allowable customer-to-ICP distance reduces costs and the number of ICPs.
- Total costs are highly sensitive to unit inventory carrying costs.

Contributions to Reverse Logistics Network Design

- Presents an NLMIP model for product return networks, explicitly considering the trade-off between inventory holding costs (related to consolidation time T_j) and transportation costs.
- Develops a GA tailored for this specific reverse logistics network design problem.
- Provides insights into how operational parameters (consolidation period, service distance) affect network structure and costs.

9 An optimization model for reverse logistics network under stochastic environment by using genetic algorithm, Roghanian, E., & Pazhoheshfar, P. (2014)

Main Objective

To propose a probabilistic mixed-integer linear programming (MILP) model for designing a multi-product, multi-stage reverse logistics network for returned products under uncertainty, aiming to minimize total costs (fixed opening and shipping).

Methodology

A probabilistic MILP model is formulated, where demands at manufacturing and recycling centers are random variables. This model is converted into an equivalent deterministic model using stochastic programming principles (specifically, chance constraints for demand satisfaction). A priority-based Genetic Algorithm (GA) is then proposed to solve the problem.

Key Aspects of the Network Design

- **Echelons:** Returning centers (origin of returned products), Disassembly centers (fixed opening cost CO^C_{jm}), Processing centers (fixed opening cost CO^C_{km}), Manufacturing centers (destination for reusable parts), and Recycling centers (destination for recyclable parts/products).
- **Flows:** Multi-product (p) and multi-part (m) flows. Products from returning centers to disassembly centers (X_{ijp}) or directly to processing centers (X_{ikp}). Parts from disassembly centers to processing centers (X_{jkm}) or directly to recycling centers (X_{jrm}). Processed parts from processing centers to manufacturing centers (X_{kfm}) or recycling centers (X_{krm}).
- **Decisions:** Which disassembly centers to open (Y_{jm}), which processing centers to open (Q_{km}), and the transportation strategy (quantities shipped between echelons).
- **Objective:** Minimize the sum of total shipping costs and fixed opening costs for disassembly and processing centers.
- **Stochasticity:** Demands for parts at manufacturing centers (d_{fm}) and demands for products/parts at recycling centers (d_{rp}, d_{rm}) are stochastic (assumed normally distributed). These are handled via chance constraints, converted to deterministic equivalents using a confidence level (1-α).
- **Constraints:** Capacity of returning centers, disassembly centers, and processing centers; flow balance; demand satisfaction (probabilistic); limits on the number of open disassembly and processing centers.

Solution Approach

A priority-based Genetic Algorithm (GA) is developed. The chromosome consists of six segments representing priorities for flows between different echelons (e.g., returning to disassembly, disassembly to processing). Decoding is done backward, using Algorithm 1 (priority-based decoding for transportation subproblems) for each segment. WMX (Weight Mapping Crossover) and insert mutation are used.

Key Findings

The proposed model and priority-based GA can find feasible solutions for the reverse logistics network design problem under stochastic demand. The numerical example demonstrates the transportation strategy derived by the GA.

Contributions to Reverse Logistics Network Design

- Develops a multi-product, multi-stage reverse logistics network model explicitly incorporating stochastic demands at manufacturing and recycling centers.
- Converts the probabilistic model into a deterministic equivalent for solution.
- Applies a priority-based Genetic Algorithm, which is noted for avoiding complex repair mechanisms, to solve this NP-hard stochastic network design problem.

10 Reverse logistics network design model based on e-commerce, Qian, X.Y., Han, Y., Da, Q., & Stokes, P. (2012)

Main Objective

To study and propose a reverse logistics network design model specifically for e-commerce, aiming to minimize overall logistic costs by determining optimal locations for factories, online retailers, and third-party logistics providers (3PLs). The paper also discusses determining market demands and returns under uncertainty.

Methodology

A 0-1 mixed-integer linear programming (0-1MILP) model is proposed for the e-commerce reverse logistics network. A separate mathematical model is discussed for predicting market demands and returns based on product price and return price, assuming these can be determined when a return policy is set. A case study illustrates the model.

Key Aspects of the Network Design

- **Echelons:**
  1. Factories (I): Potential locations for processing returned products.
  2. Online Retailers (J): Potential locations for handling returns or reselling.
  3. Third-Party Logistics Providers (3PLs) (K): Potential locations for collecting, centralizing, and routing returned products.
  4. Consuming Markets (L): Fixed locations where demand and returns originate.
- **Flows:**
  - Forward: Products from factories/3PLs via online retailers to markets.
  - Reverse: Returns from markets collected by 3PLs, then delivered to factories or online retailers.
- **Decisions:**
  - Which factories (Y_i), online retailers (Y_j), and 3PLs (Y_k) to open/use.
  - Fraction of market (l) demand served from factory i and online retailer j (X_{ijl}).

- Fraction of market (l) demand served from 3PL k and online retailer j (X_{kjl}).
- Fraction of returns from market l collected by 3PL k and delivered to factory i (X_{lki}).
- Fraction of returns from market l collected by 3PL k and delivered to online retailer j (X_{lkj}).

- **Objective:** Minimize total logistical costs, including fixed opening costs for factories, online retailers, and 3PLs, plus transportation costs for both forward and reverse flows.

- **Constraints:** Ensure returned products to online retailers meet market demand, balance flows at online retailers, ensure all returns are delivered to factories or online retailers, ensure products from factories/3PLs meet market demand, balance flows at factories, facility opening logic (Y_i, Y_j, Y_k), capacity limits (M_i, N_j, Q_k), and a minimum portion (η) of returns delivered to factories.

Solution Approach

The 0-1MILP model is formulated. The paper mentions using Lingo9.0 for solving the numerical example. The demand and return quantities (d_l, r_l) are determined by a separate optimal return policy model.

Key Findings

The model identifies optimal locations and flows for the e-commerce reverse logistics network. The case study demonstrates that returned products are centralized at the 3PL, which then routes them to online retailers (for resale) or back to factories (for processing), based on cost and policy (e.g., minimum return to factory).

Contributions to Reverse Logistics Network Design

- Proposes a specific 0-1MILP model for designing a three-echelon (factories, online retailers, 3PLs) reverse logistics network tailored to the e-commerce context, where 3PLs play a central role in collecting returns.

- Integrates the concept of an optimal return policy (determining demand and return quantities) as an input to the network design model.

- Highlights the role of 3PLs in managing e-commerce returns and the trade-offs in routing these returns to either online retailers or factories.