Vehicle routing optimization with pickups and deliveries for nonprofit applications

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Outline

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Problem statement

Vehicle routing problems (VRPs)

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Vehicle routing problems (VRPs)

Commercial and profitable sectors

Nonprofit operations

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Vehicle routing problems (VRPs)

Commercial and profitable sectors

Nonprofit operations

Nonprofit operations

Disaster management	Public transportation	Health care logistics

Equity and fairness

Problem statement

Vehicle routing problems with pickups and deliveries

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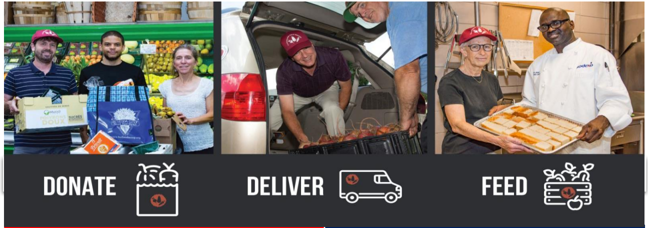
Vehicle routing problems with pickups and deliveries



Food rescue and delivery

Handicapped people transportation

Equity and fairness

Taken from: https://www.montgomerycountymd.gov/HHS/FoodRescueMiniGrants.html

Problem statement

Vehicle routing problems with pickups and deliveries

Food rescue and delivery

Handicapped people transportation

Equity and fairness

Outline

Justification

Practical issues

- In commercial sectors: routing costs vary from 19% to 37% of the total logistic cost [Ghiani et al., 2004].
- In nonprofit contexts: people (e.g., users, citizens, patients) are directly considered.

Theoretical issues

VRP and PDVRP are $\mathcal{NP}$-Hard problems [Toth and Vigo, 2014].

Algorithmic issues

- Robust, efficient and low complexity algorithms
- Several features and conditions from the problem should be included
- Computational resources availability
- Large and complex problems

Outline

Theoretical framework

Mixed-integer linear programming (MILP) model for the CVRP – [Toth and Vigo, 2014]

Sets:

- $\mathcal{N}$: set of nodes
- $\mathcal{K}$: set of vehicles
- $\mathcal{S}$: subset of nodes ($\mathcal{S} \subseteq \mathcal{N}$)

Parameters:

- c_{ij}: cost of traveling from node i to node j
- $r(\mathcal{S})$: number of vehicles required to serve all the nodes in $\mathcal{S}$

Decision variables:

- $x_{ij} = \begin{cases} 1 & \text{if arc } (i,j) \text{ is used in the solution} \\ 0 & \text{otherwise} \end{cases}$

$$\min f = \sum_{i \in \mathcal{N}} \sum_{j \in \mathcal{N}} c_{ij} \cdot x_{ij} \tag{1}$$

subject to,

$$\sum_{j \in \mathcal{N}} x_{ij} = 1 \qquad \forall\ i \in \mathcal{N} \setminus \{0\} \tag{2}$$

$$\sum_{i \in \mathcal{N}} x_{ij} = 1 \qquad \forall\ j \in \mathcal{N} \setminus \{0\} \tag{3}$$

$$\sum_{i \in \mathcal{N}} x_{i0} = |\mathcal{K}| \tag{4}$$

$$\sum_{j \in \mathcal{N}} x_{0j} = |\mathcal{K}| \tag{5}$$

$$\sum_{i \notin \mathcal{S}} \sum_{j \in \mathcal{S}} x_{ij} \geq r(\mathcal{S}) \qquad \forall\ \mathcal{S} \subseteq \mathcal{N} \setminus \{0\}, \mathcal{S} \neq \emptyset \tag{6}$$

$$x_{ij} \in \{0, 1\} \qquad \forall\ i \in \mathcal{N}, j \in \mathcal{N} \tag{7}$$

Theoretical framework

Most often addressed VRP attributes [Braekers et al., 2016]:

- Capacitated vehicles
- Heterogeneous vehicles
- Time windows
- Backhauls
- Multiple depots
- Multi-period time horizon
- Precedence and coupling constraints
- Split deliveries*
- Stochastic demands
- Time-dependent travel times
- Stochastic travel times
- Dynamic requests

Sets:

- $\mathcal{N}$: set of nodes
- $\mathcal{K}$: set of vehicles
- $\mathcal{S}$: subset of nodes ($\mathcal{S} \subseteq \mathcal{N}$)

Parameters:

- c_{ij}: cost of traveling from node i to node j
- Q: vehicle capacity
- d_i: demand (units to pickup or delivery) at node i

Decision variables:

- $x_{ijk} = \begin{cases} 1 & \text{if vehicle k goes from node } i \text{ to node } j \text{ in the solution} \\ 0 & \text{otherwise} \end{cases}$
- f_{ij}: load of the vehicle when going from i to j

$$\min f = \sum_{i \in \mathcal{N}} \sum_{j \in \mathcal{N}} \sum_{k \in \mathcal{K}} c_{ij} \cdot x_{ijk} \qquad (8)$$

subject to,

$$\sum_{j \in \mathcal{N}} \sum_{k \in \mathcal{K}} x_{ijk} = 1 \qquad \forall\ i \in \mathcal{N} \backslash \{0\} \qquad (9)$$

$$\sum_{j \in \mathcal{N}} x_{ijk} - \sum_{j \in \mathcal{N}} x_{jik} = 0 \qquad \forall\ i \in \mathcal{N}, k \in \mathcal{K} \qquad (10)$$

$$0 \leq f_{ij} \leq Q \cdot \sum_{k \in \mathcal{K}} x_{ijk} \qquad \forall\ i, j \in \mathcal{N} \qquad (11)$$

$$\sum_{j \in \mathcal{N}} f_{ji} - \sum_{j \in \mathcal{N}} f_{ij} = d_i \qquad \forall\ i \in \mathcal{N} \backslash \{0\} \qquad (12)$$

$$\sum_{i \in \mathcal{S}} \sum_{j \in \mathcal{S}} x_{ijk} \leq |\mathcal{S}| - 1 \qquad \forall\ \mathcal{S} \subseteq \mathcal{N} \backslash \{0\}, \mathcal{S} \neq \emptyset, k \in \mathcal{K} \qquad (13)$$

$$x_{ijk} \in \{0, 1\} \qquad \forall\ i, j \in \mathcal{N}, k \in \mathcal{K} \qquad (14)$$

Theoretical framework

Vehicle routing problems

- Exact approaches
- **Heuristics**
- Metaheuristics
- Matheuristics

Constructive heuristics

- Clarke and Wright algorithm
- Nearest neighbor algorithm
- Best insertion algorithm
- Sweep algorithm

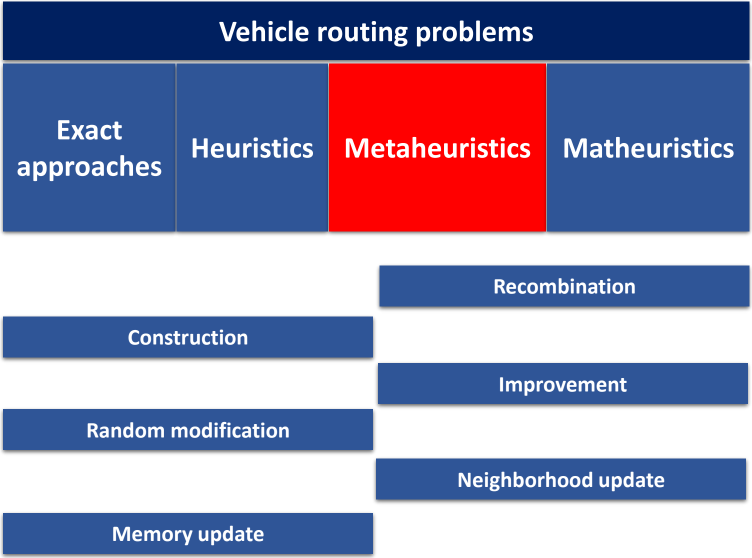
Split algorithm

Improvement heuristics

- k-Opt heuristics
- λ-interchange heuristic

Theoretical framework

Components of metaheuristic algorithms - [Gendreau and Potvin, 2005]



Theoretical framework

A general scheme for metaheuristic algorithms [Zäpfel et al., 2010]

Create one or several start solutions (e.g., via specific heuristic)
while *termination criterion not satisfied* **do**
  if *intensify* **then**
    Create new solution by intensification step
  else
    Create new solution by diversification step
  end if
  Update best found solution (if necessary)
end while
return *Best found solution*

Outline

State of the art

Problem	Author(s)	Exact	Metaheuristic	Matheuristic
1-PDVRP & 1-PDTSP	[Hernández-Pérez and Salazar-González, 2004a]	✓		
	[Hernández-Pérez and Salazar-González, 2004b]		✓	
	[Hernández-Pérez et al., 2009]		✓	
	[Zhao et al., 2009]		✓	
	[Mladenović et al., 2012]		✓	
	[Hernández-Pérez et al., 2018]		✓	
m-PDVRP & m-PDTSP	[Rodríguez-Martín and Salazar-González, 2012]			✓
	[Hernández-Pérez and Salazar-González, 2014]	✓		
DARP	[Parragh et al., 2010]		✓	
	[Muelas et al., 2013]		✓	
	[Parragh and Schmid, 2013]			✓
	[Liu et al., 2015]	✓		
	[Braekers and Kovacs, 2016]	✓		
	[Masmoudi et al., 2017]		✓	

State of the art

- Bicycle repositioning problems

	Author(s)	Sol. strategy	Key features on problem and sol. strategy
Exact	[Raviv et al., 2013]	MILPs	Min. Cost and user dissatisfaction
	[Chemla et al., 2013]	B&C and TS	Multiple visits
	[Dell'Amico et al., 2014]	B&C	Multiple vehicles
	[Erdoğan et al., 2015]	Bender's dec.	Multiple visits
	[Alvarez-Valdes et al., 2016]	MILPs	Total dissatisfaction + balance route durations
Heuristics and hybrids	[Ho and Szeto, 2014]	TS	Min. User dissatisfaction
	[Forma et al., 2015]	Matheuristic	Clustering + Routing + Repositioning
	[Kadri et al., 2016]	GA + LR	Min. Waiting times on stations
	[Dell'Amico et al., 2016]	D&R + VND	Balance route durations
	[Cruz et al., 2017]	ILS + VND	Multiple visits
	[Ho and Szeto, 2017]	HLNS	Min. Cost and user dissatisfaction

B&C: branch-and-cut • TS: tabu search • GA: genetic algorithm
LR: lagrangian relaxation • D&R: destroy and repair
VND: variable neighborhood descent
ILS: iterative local search • HLNS: hybrid large neighborhood search

- Home and health care logistics

Author(s)	Sol. strategy	Key features on problem and sol. Strategy
[Melachrinoudis et al., 2007]	TS and MILPs	Min. Early/late pickups and deliveries
[Liu et al., 2013]	GA and TS	Four commodities; time windows
[Fikar and Hirsch, 2015]	Matheuristic	DRP + walking routes
[Zhang et al., 2015]	MA	Multi-trip
[Lim et al., 2016]	ILS + VND	Multi-trip and time windows
[Detti et al., 2017]	TS and VNS	Multi-depot and heterogeneous fleet
[Shi et al., 2018]	GA, BA, FA and MILP	Stochastic travel times
[Osaba et al., 2019]	BA	Rich VRP

DRP: dial-a-ride problem
BA: bat algorithm
FA: firefly algorithm
MA: memetic algorithm

State of the art

- Disaster relief

Author(s)	Sol. strategy	Key features on problem and sol. strategy
[Yi and Kumar, 2007]	ACO and MILP	Split demand; min. Unsatisfied injured people and demand
[Jotshi et al., 2009]	MILPs	Patient pickup and patient delivery problem
[Wohlgemuth et al., 2012]	TS and MILP	Time-dependent; time windows

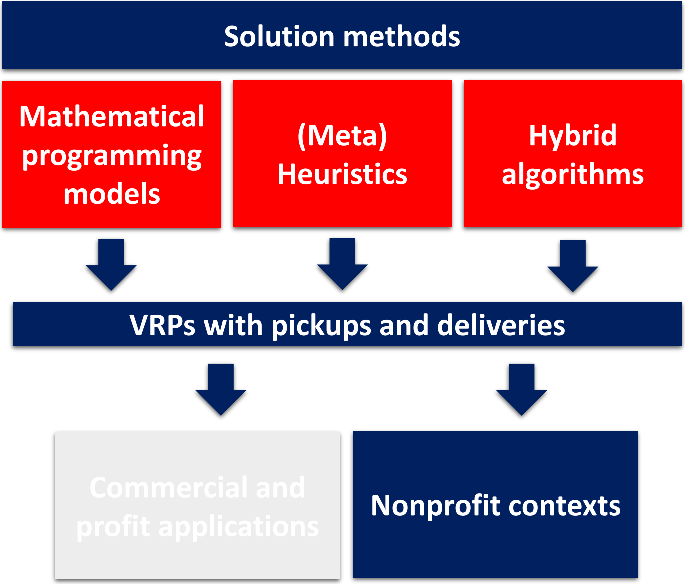
- Food rescue and delivery problem

Author(s)	Sol. strategy	Key features on problem and sol. strategy
[Rey et al., 2018]	MILP	Bender's decomposition
[Nair et al., 2018]	MILPs and TS	Periodic; LS as post-optimization for TS

ACO: ant colony optimization
LS: local search

Outline

Objectives


Solution methods
Mathematical programming models
(Meta) Heuristics
Hybrid algorithms
VRPs with pickups and deliveries
Commercial and profit applications
Nonprofit contexts

Objectives

VRPs with pickups and deliveries for nonprofit contexts

Identify

Research opportunities and novel insights

Design

Mathematical programming models for PDVRPs

Heuristic-based solution strategies (metaheuristics and hybrid algorithms)

Exact and heuristic-based solution strategies for PDVRPs with additional features

Outline

Methodology

Phase I

Literature review: variants, models, solution strategies and nonprofit applications

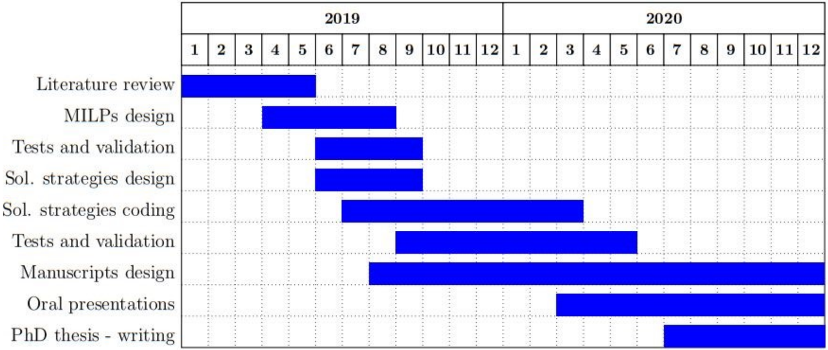
Phase II

Mathematical models and solution strategies: design, implementation and validation

Phase III

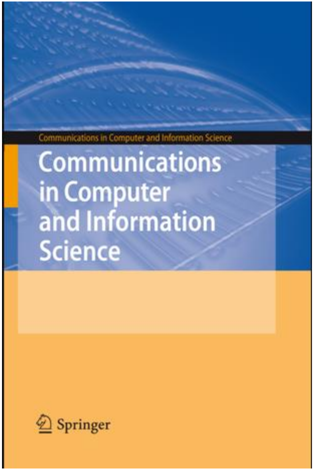
Doctoral thesis document and cientific publications: writing and oral presentations

Methodology



Outline

Contributions



Mixed-Integer Linear Programming Models for One-Commodity Pickup and Delivery Traveling Salesman Problems

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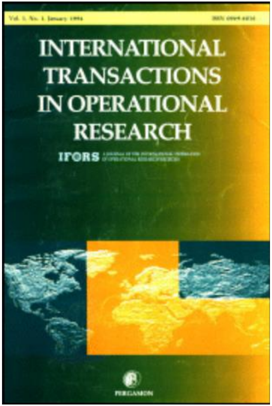
Abstract. This article addresses two different pickup and delivery routing problems. In the first one, called the one-commodity pickup and delivery traveling salesman problem, a known amount of a single product is supplied or demanded by a set of two different types of locations (pickup or delivery nodes). Therefore, a capacitated vehicle must visit each location once at a minimum cost. We also deal with the relaxed case where locations can be visited several times. In the last problem, the pickup or delivery operation can be split into several smaller pickups or deliveries, and also locations can be used as temporal storage points with the aim of reducing the cost of the route. To solve these problems, we present two mixed-integer linear programming models and we solve them via commercial solver. We analyze how several visits to a single location may improve solution quality and we also show that our simple strategy has a good performance for instances with up to 60 locations.

Keywords: Pickup and delivery · Traveling salesman problem · Mixed-integer linear programming · Split delivery

Accepted for publication

Contributions



Intl. Trans. in Op. Res. xx (2019) 1–14

The one-commodity pickup and delivery vehicle routing problem: A mixed-integer linear programming approach

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Abstract

In this paper we study the one-commodity pickup and delivery vehicle routing problem. It aims to design a set of routes able to pick up or delivery a known amount of a single product supplied or demanded by two different types of locations (pickup or delivery nodes). To do so, a capacitated fleet of homogeneous vehicles is available to meet the demand while the total traveling cost is minimized. However, when several vehicles are available, optimal routes for the problem are not typically cost-balanced. Therefore, we propose a mixed-integer linear program to model the one-commodity pickup and delivery vehicle routing problem with length route constraints and we compare the performance and balance for different length parameters. To solve this mathematical model, we use a commercial solver, we test instances with up to 40 nodes and different target values for balancing routes. Finally, we provide some insights about how the number of nodes, number of vehicles and vehicle capacity affect imbalance throughout the route costs.

Keywords: Pickup and Delivery; Mixed-integer linear programming; Vehicle routing problem

Manuscript submitted: september 3^{rd}, 2019

Contributions

Annals of Operations Research manuscript No.
(will be inserted by the editor)

A multi-start evolutionary local search for the bicycle repositioning problem

Juan D. Palacio · Juan Carlos Rivera

Received: date / Accepted: date

Abstract Bicycle sharing systems (BSS) are known around the world as an alternative and economical way for individual transportation when short distance trips are required. BSS arise from a lack of efficient and sustainable transportation systems in urban areas where mobility, environmental aspects and public health are main government concerns. When providing an efficient BSS operation, an adequate availability of bicycles and parking slots is required throughout the system. To do so, one vehicle must serve a set of stations and pick up or deliver bicycles according to a previous demand estimation and a fixed number of available bicycles. In this paper, we address the BBS vehicle operation as a bicycle repositioning problem and we propose a hybrid metaheuristic based on multi-start evolutionary local search and variable neighborhood descend to solve it. To test the performance of our algorithm, we solve instances with up to 500 stations available in the literature and we demonstrate that our approach is able to provide competitive results when comparing to other existing strategies. Finally, we also use our metaheuristic algorithm to solve a set of a real case instances based on Encicla, a public BSS within the Aburrá Valley, in Antioquia, Colombia.

Keywords Bicycle repositioning problem · Sustainable transportation · Pickup and delivery traveling salesman problem · Evolutionary local search · Variable neighborhood descend

Manuscript submitted: july 1^{st}, 2019

Contributions

WORKSHOP on ENGINEERING APPLICATIONS WEA

Mixed-Integer linear programming models for one-commodity pickup and delivery traveling salesman problems

ICCL 2019
10th - International Conference on Computational Logistics

The one-commodity pickup and delivery vehicle routing problem: A mixed-integer linear programming approach

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ASOCIO 2019
III Congreso Colombiano de Investigación de Operaciones

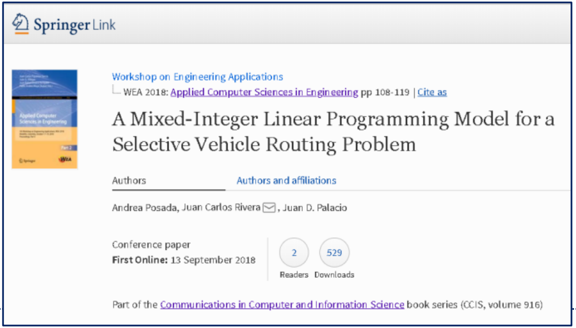
Modelos de programación lineal entera mixta para el problema de reposicionamiento de bicicletas

Multi-vehicle | Split | Case of study: EnCicla

Diseño de rutas para la distribución de bicicletas compartidas: estrategias exactas y heurísticas

Single-vehicle | GRASP

Contributions



Springer Link

Workshop on Engineering Applications
WEA 2018: Applied Computer Sciences in Engineering pp 108-119 | Cite as

A Mixed-Integer Linear Programming Model for a Selective Vehicle Routing Problem

Authors | Authors and affiliations

Andrea Posada, Juan Carlos Rivera, Juan D. Palacio

Conference paper
First Online: 13 September 2018

2 Readers | 529 Downloads

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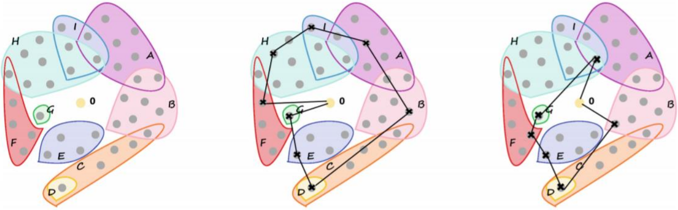

(a) (b) (c)

Selective Vehicle Routing Problem: A Metaheuristic Approach *

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Abstract. In this paper we deal with a selective vehicle routing problem (SVRP), which was proposed in [18]. In this problem each node belongs to one or several clusters. Contrary to classical vehicle routing problems, here it is not necessary to visit all nodes, but to visit appropriate nodes in such a way that all clusters are visited exactly once. A genetic algorithm (GA) based on random key representation is proposed to solve this SVRP variant. The proposed algorithm is a hybrid metaheuristic which integrates randomized constructive solutions, a variable neighborhood search procedure, an order-first cluster-second operator, and a mixed-integer linear model to repair unfeasible solutions. The metaheuristic is tested by using instances with up to 63 nodes adapted from the generalized vehicle routing problem (GVRP). The GVRP is a special case of this SVRP where each node belongs to exactly one cluster. The results allow to evaluate the impact of different clusters configuration on the instance complexity, the impact of each algorithm's component on the metaheuristic performance, and the efficiency of the method by a comparison with a mixed-integer linear program.

Accepted for publication

Work in process

For the Ph.D. thesis project:

- Matheuristic algorithms for the 1–PDTSP
  - MILPs as neighborhood within a ELS+VND procedure: destroy and repair strategy
  - MILP as post-optimization procedure
- Latency on PDVRPs
  - MILPs with maximum latency constraints
  - Minimum lantency 1–PDVRP
  - Number of vehicles and latency: lexicographic strategy
- Selective-based strategies for the 1–PDTSP
- 1–PDVRP with synchronization constraints

For undergraduate research projects:

- Optimization models to improve repositioning logistic operations in a bike sharing system
- Multi-objective optimization approaches for the repositioning logistic operation in bike sharing systems

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Vehicle routing optimization with pickups and deliveries for nonprofit applications

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