Série dos Seminários de Acompanhamento à Pesquisa

DEI
DEPARTAMENTO DE ENGENHARIA INDUSTRIAL

Número 34 | 12 2021

Planejamento de infraestruturas de reabastecimento em redes de veículos elétricos: novas abordagens utilizando modelos de otimização Location-Routing

Autor:

Luiz Eduardo Cotta Monteiro

PUC RIO

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Autor:

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CRÉDITOS:

SISTEMA MAXWELL / LAMBDA
https://www.maxwell.vrac.puc-rio.br/

Organizadores: Fernanda Baião / Soraida Aguilar

Layout da Capa: Aline Magalhães dos Santos

Formação e trajetória acadêmica

- Graduação em Engenharia de Produção (PUC-Rio / UVA): 2015

“Otimização da Produção em uma Fábrica de Cerveja de Pequeno Porte” (SPOLM + ENEGEP)

- Mestrado em Engenharia de Produção (DEI - PUC-Rio): 2016-2018

“Modelos de simulação e de programação matemática aplicados na análise e otimização do transporte de passageiros na Linha 4 do sistema metroviário do Rio de Janeiro” (ANPET + SBPO)

- Projeto de P&D - Desenvolvimento de rede móvel de armazenamento de energia (PUC-Rio ; Enel; ANEEL; E2Go): 2018-2020

“Optmization of a Mobile Energy Storage Network” (em processo de submissão)

- Doutorando em Engenharia de Produção (DEI - PUC-Rio): 2019/2 - atual

Contexto da Pesquisa

Global EV Outlook 2021

Accelerating ambitions despite the pandemic

iea

EV30@30 and the Drive to Zero campaigns support EV deployment

EV30@30 Campaign

The EV30@30 Campaign was launched at the CEM meeting in 2017 to spur the deployment of EVs. It sets a collective aspirational goal for EVs (excluding two/three-wheelers) to reach 30% sales share by 2030 across all signatory countries. This is the benchmark against which progress is to be measured for the EVI members. Fourteen countries endorsed the campaign: Canada; Chile; China; Finland; France; Germany; India; Japan; Mexico; Netherlands; Norway; Portugal; Sweden and United Kingdom. In addition, 30 companies and organisations support the campaign, including: C40; FIA Foundation; Global Fuel Economy Initiative; Hewlett Foundation; Natural Resources Defence Council; REN21; SLoCaT; The Climate Group; UN Environment Programme; UN Habitat; World Resources Institute; ZEV Alliance; ChargePoint; Energias de Portugal; Enel X; E.ON; Fortum; Iberdrola; Renault-Nissan-Mitsubishi Alliance; Schneider Electric; TEPCO; Vattenfall and ChargeUp Europe.

Coordinated by the IEA, the campaign includes five implementing actions to help achieve the goal in accordance with the priorities and programmes of each EVI member country.

These include:

- Support and track the deployment of EV chargers.
- Galvanise public and private sector commitments to incorporate EVs in company and supplier fleets.
- Scale up policy research and information exchanges.
- Support governments through training and capacity building.
- Establish the Global EV Pilot City Programme to achieve 100 EV-Friendly Cities over five years.

Drive to Zero Campaign

The Global Commercial Vehicle Drive to Zero Campaign was launched at the 2020 CEM meeting and operates as part of the EVI. The campaign, administered by CALSTART, a clean transport non-profit organisation, aims to bring governments and leading industry stakeholders together to collaboratively develop policies, programmes and actions that can support the rapid manufacture and deployment of zero-emission commercial vehicles. Drive to Zero counts more than 100 pledge partners, including nine national governments (as of April 2020) and leading state, provincial and regional governments and agencies from across the world.

Global EV Outlook 2021

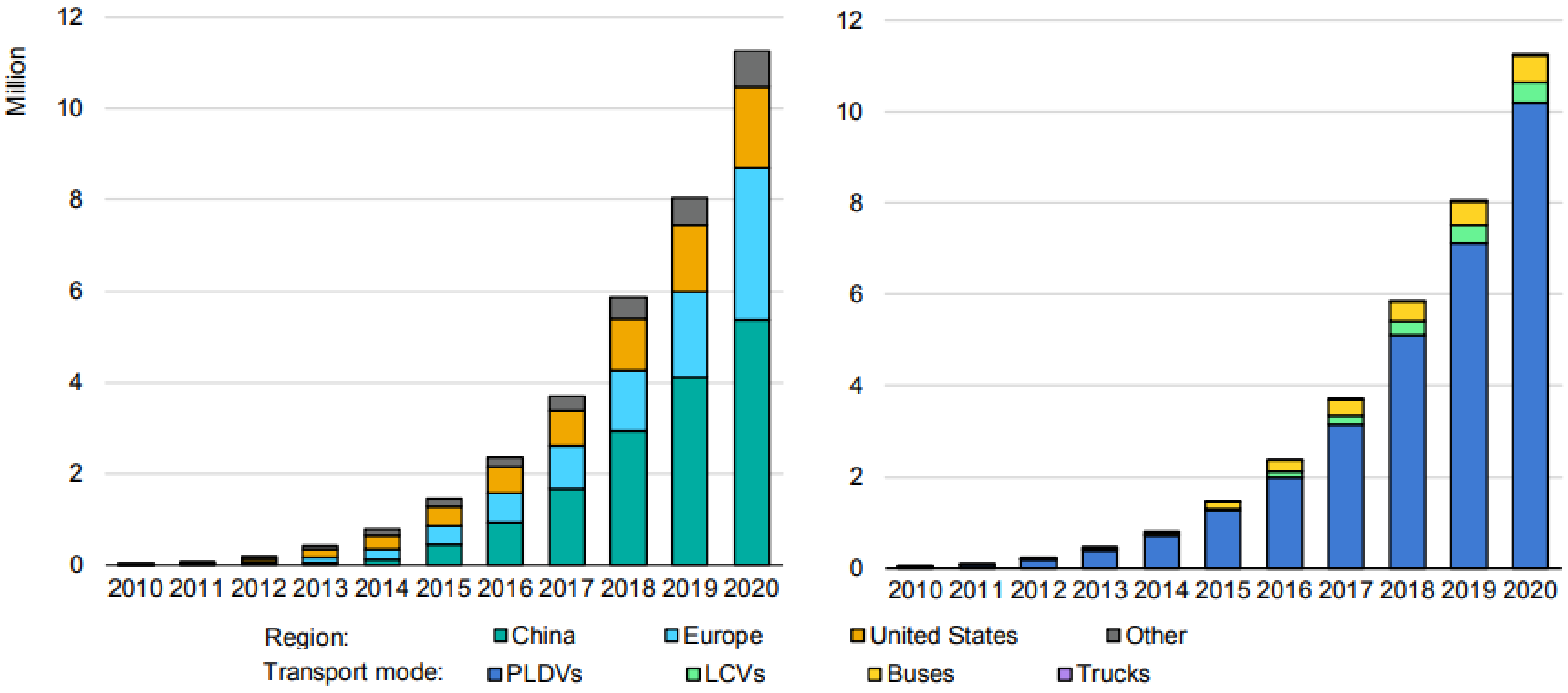
Accelerating ambitions despite the pandemic

Electric vehicles across all transport modes had steady growth over the last decade

Global electric vehicle stock by region (left) and transport mode (right), 2010-2020

Region

Mode



Notes: PLDVs = passenger light-duty vehicles, LCVs = light-commercial vehicles. Electric vehicles include battery electric and plug-in hybrid electric vehicles. Europe includes EU27, Norway, Iceland, Switzerland and United Kingdom. Other includes Australia, Brazil, Canada, Chile, India, Japan, Korea, Malaysia, Mexico, New Zealand, South Africa and Thailand.

Sources: IEA analysis based on country submissions, complemented by ACEA (2021); CAAM (2021); EAFO (2021); EV Volumes (2021) and Marklines (2021).

Global EV Outlook 2021

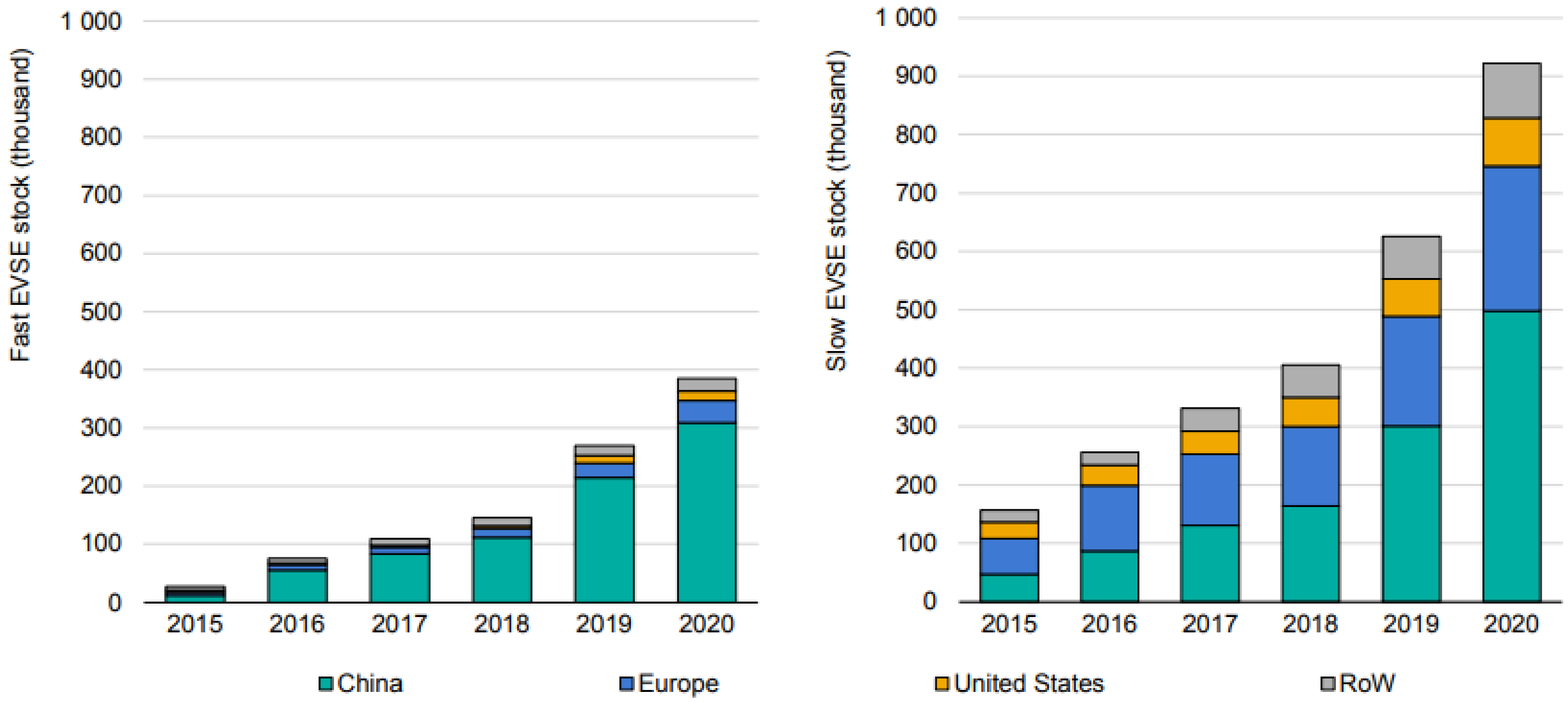
Accelerating ambitions despite the pandemic

Publicly accessible slow and fast chargers increased to 1.3 million in 2020

Stock of fast and slow publicly accessible chargers for electric light-duty vehicles, 2015-2020

Fast

Slow



Notes: EVSE = electric vehicle supply equipment. RoW = rest of the world. Slow chargers have a charging power below 22 kW, while fast chargers provide more than 22 kW. For additional details about charger classification by rated power refer to Global EV Outlook 2019. Regional slow and fast publicly accessible charger data can be interactively explored via the Global EV Data Explorer.

Sources: IEA analysis based on country submissions, complemented by AFDC (2021) and EAFO (2021).

Perguntas de pesquisa

- Como planejar infraestruturas de reabastecimento em redes de veículos elétricos?
- Quais os fatores críticos para viabilizar a implementação de uma rede de veículos elétricos? ("Chicken and egg problem"; custo e vida útil de baterias; autonomia dos veículos; etc...)
- Como viabilizar o investimento em frotas e infraestruturas de reabastecimento de veículos elétricos?

➢ **Novas abordagens utilizando modelos de otimização Location-Routing**

Location-routing problem

- Location and routing **decisions are interdependent** and studies have shown that the overall system cost may be excessive if they are tackled separately.
- **Watson-Gandy and Dohrn (1973)** were probably the first authors to clearly consider customer visits while locating depots.
- The potential benefits brought by including vehicle routing decisions while locating depots were **quantified** for the first time by **Salhi and Rand (1989).**

* C. Prodhon, C. Prins. (2014). A survey of recent research on location-routing problems. European Journal of Operational Research 238, 1–17.

Location-routing problem

- **Decision Variables**

$$y_i = 1 \; if \; depot \; i \; is \; opened$$

$$x_{ij} = 1 \; if \; edge \; (i,j) \; is \; trasversed \; from \; i \; to \; j \; by \; a \; vehicle.$$

- **Objective Function**

The objective function, to be minimized, can be formulated as the sum of three terms:
(i) the cost of open depots / Charge Stations;
(ii) fixed costs of vehicles used;
(iii) cost of the routes

$$\text{Minimize Z} =$$

$$\sum_{i \in J} \mathrm{O}_i \, \mathrm{y}_i \;\; + F \sum_{i \in I} \; \sum_{j \in J} \mathrm{x}_{ij} \;\; + \sum_{i \in V} \; \sum_{j \in V} \mathrm{c}_{ij} \, \mathrm{x}_{ij}$$

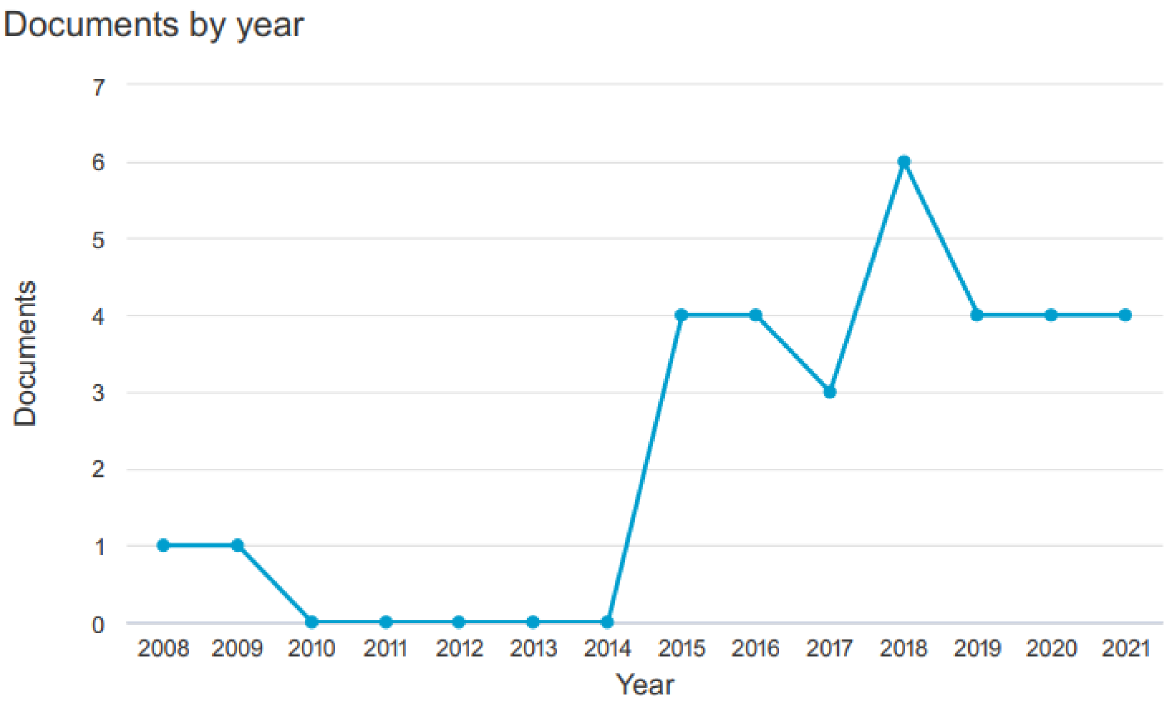
Revisão da Literatura: location-routing AND Electric AND vehicle

TITLE-ABS-KEY (location-routing AND electric AND vehicle)

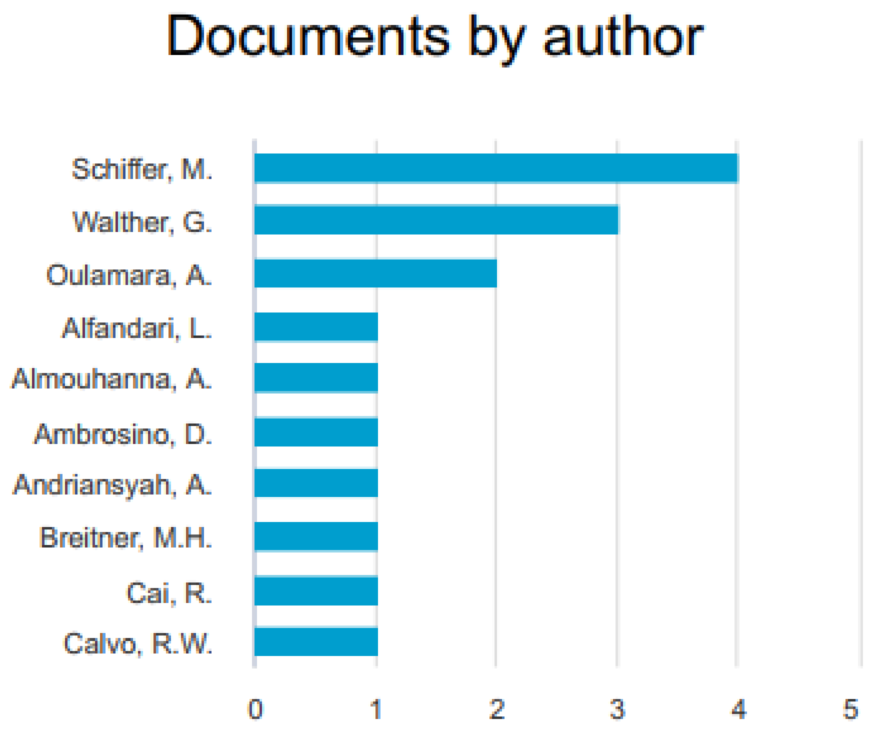
31 document results

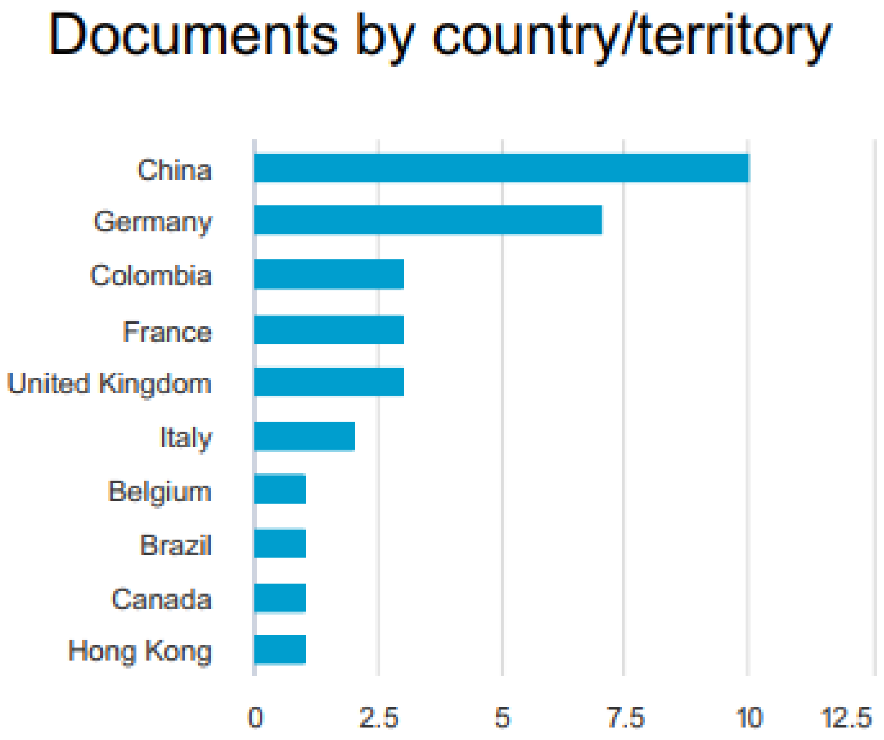
Select year range to analyze: 2008 to 2021 Analyze

Year ↓	Documents ↑
2021	4
2020	4
2019	4
2018	6
2017	3
2016	4
2015	4
2014	0



Revisão da Literatura: location-routing AND Electric AND vehicle





10 artigos identificados com aderência à pesquisa

Year	Authors	Title	Problem Type	Model Characteristics	Model Decisions	Objective Function	Math Model Type	Solve Method
2015	Yang J., Sun H.,	Battery swap station location-routing problem with capacitated electric vehicles	Electric Vehicles Battery Swap Stations Location Routing Problem (BSS-EV-LRP)	Delivery Problem 1 depot Locate BSS on network Homogeneus fleet Vehicles Load capacity constraint Distance contraint (battery power) BSS have no capacity constraints	Define: (a) The location of the BSS (b) the tours from depot to serve all customers with BSS service. * Including the allocation of customers to EVs; and the allocation of EVs to BSS	Minimize total cost: somatory of BSS opening costs and EV's routing costs	MIP	* Solver CPLEX * Four Fase Heuristic (SIGALNS) * 2 phase Tabu-Search, modified clarke and Wright heuristic (TS-MCWS)
2015	Li-Ying W., Yuan-Bin S.,	Multiple charging station location-routing problem with time window of electric vehicle	**Multiple charging station** location-routing problem with time window of electric vehicle (EV-MCS-LRPTW)	Delivery Problem Only one depot Homogeneus fleet	Determinate: (a) number, type and location of recharging station (4 different types) (b) number of vehicles and their routes of operation	Minimize total cost (station cost + electricity cost + driver wage)	MIP	*CPLEX 12.2 (only small instances) *Hibrid Heuristic: AVNS + TS (Adaptative Variable Neighborhood search + Tabu Search). Algorithm implemented in Java
2017	Schiffer M., Walther G.,	The electric location routing problem with time windows and partial recharging	Electric location routing problem with time windows and partial recharging (ELRP-TWPR)	Delivery Problem Only one depot Homogeneus fleet Propose 3 models considering different types of Recharging Station: Convencional Recharge, Battery Swap and both of them.	Determinate: (a) number and location of recharging station. (b) number of vehicles and their routes of operation	4 different objectives: (i) Minimize total traveled distance (ii)Minimize number of vehicles for a given number os charging stations (iii) Minimize number of Stations for a given number of vehicles (iv) Minimize total costs	MIP	Solver Gurobi 6.0.5 with Python 2.7.8 Envirenment (up to 2 hours)
2018	Paz J.C., Granada-Echeverri M., Escobar J.W.,	The multi-depot electric vehicle location routing problem with time windows	Multi-depot electric vehicle location routing problem with time windows (MDVLRP-TW)	Delivery problem Multiple depots Homogeneus fleet Propose 3 models considering different types of Recharging Station: Convencional Recharge, Battery Swap and both of them.	Determinate: (a) number and location of recharging station. (b) number and location of depots (c) number of vehicles and their routes of operation	Minimize total distance	MIP	Solver CPLEX 12.5 (up to 8 hours) Implemented in C++
2018	Schiffer M., Walther G.,	Strategic planning of electric logistics fleet networks: A robust location-routing approach	Robust Electric LRP with Time Windows and Partial Recharging (RELRPTWPR)	One homogeneus fleet for all scenarios	Decision variables: (i) non-adjustable variable: Location decision for Stations (Yi) (ii) adjustable variable: vehicle routing (Xij)	Minimize Total Costs (driving costs; fixed costs for installing charging stations; fixed cost of vehicle acquisition)	Robust MIP	Hybrid of Adaptative Large Neighbourhood Serach (ALNS) and Dynamic Programming (DP)
2018	Schiffer M., Walthera G.,	An adaptive large neighborhood search for the location-routing problem with intra-route facilities	Similar to Electric LRP with time windows and partial recharging (ELRP-TWPR) *Inclui a localização de depósitos intermediários para recargas (fretes)	*Similar ao ELRP-TWPR (Schiffer) *Any vertex can sit Refueling Facilities *Loading Facilities cannot be sitted on costumer vertices *Fuel decreases in linear relation to consumption rate and arc distance	Determinate: (a) number and location of recharging station. (b) number of vehicles and their routes of operation (c) number and location of Loading facility	Minimize Total Costs (driving costs; fixed costs for installing charging stations; fixed cost of vehicle acquisition; fixed costs for installing Loading facility)	MIP	Adptative Large Neighborhood serarch enhanced by local search and dynamic programming components
2019	Zhang S., Chen M., Zhang W.,	A novel location-routing problem in electric vehicle transportation with stochastic demands		Only Battery Swap Station Stochastic demands				
2021	Li L., Lo H.K., Huang W., Xiao F.,	Mixed bus fleet location-routing-scheduling under range uncertainty	Bus location-routing-scheduling	Drive range uncertainty				
2021	Schiffer M., Klein P.S., Laporte G., Walther G.,	Integrated planning for electric commercial vehicle fleets: A case study for retail mid-haul logistics networks	Mid-haul logistics Network - modelling aproach combined with a TCO objective function to represent tge economic impact of the fleet transformation.	First LRPIF that accounts for multiple planning periods, mixed fleets (ICV and EV), battery degradation, EV limitations, and specific characteristics of the logistics network like customer time windows and multiple driver shifts	(a) number and location of recharging station. (b) number and types of vehicles over time (when to replace ICV by a EV) (c) Routes of vehicles	Minimize: Investment Costs (EV + ICV + Stations) + Operational Cost (distance- based + driver shifts) Obs: In time t=1 all vehicles are ICV	MIP	Metaheuristic + branch and prune algorithm to make all investment decisions
2021	Çalık H., Oulamara A., Prodhon C., Salhi S.,	The electric location-routing problem with heterogeneous fleet: Formulation and Benders decomposition approach		Heterogeneous fleet Benders decomposition				

Modelo E-LRP selecionado para implementação

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

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Production, Manufacturing and Logistics

The electric location routing problem with time windows and partial recharging

CrossMark

Maximilian Schiffer*, Grit Walther

RWTH Aachen University, School of Business and Economics, Chair of Operations Management, Kackertstraße 7, Aachen 52072, Germany

*** Consider different types of Recharging Station: Convencional Recharge (fast) and Battery Swap.**

“Gaps” na Literatura e estratégias propostas

- Novas extensões do Modelo LRP:
  Non-Linear Charging Function
  Battery State of Charge and Deppreciation Cost
  Hybrid Fleet
- Novas propostas de modelagem buscando maior eficiência.
- Modelo estocástico considerando a incerteza na demanda.
- Métodos de solução com melhor desempenho (métodos exatos e metaheurísticos) para atingir novos ***benchmarks*** na literatura.
- Análise atualizada sobre a viabilidade e o investimento em frotas e infraestruturas de reabastecimento de veículos elétricos.

Fase da pesquisa / Próximos passos

- **Fase Atual:**

  Implementação de Modelo EVRP with Non-Linear Charging Function

- **Próximos passos:**

  Implementação do modelo E-LRP-PR-TW (Schiffer and Walther)

  Incluir extensões no modelo E-LRP-PR-TW **(Non-Linear Charging Function; Battery State of Charge and Deppreciation Cost)**

  Métodos de solução exatos e metaheurísticos

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