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EUFAL - Electric Urban Freight and Logistics

Deliverable 1.31: Tools set

Document Control Sheet

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Short Summary:

In deliverable 1.31 a set of tools for implementation of electric freight vehicles (EFV) in city logistics is presented. In total, six tools have been established and prepared for the development on the platform (e.g. DynaTOP). These tools are described in detail focussing on the objectives, functionalities and methodological procedure of each tool. We also show the benefits for the users. Finally, we discuss the requirements for the successful implementation on the EUFAL platform of exchange and potential barriers for implementation.

1 Introduction

The development of electric freight vehicles (EFV) in city logistics is one of the most important challenges for present business stakeholders. The efficiency of this process needs the appropriate approach and tools. However, nowadays there is a lack of enough efficient tools supported EFV development. The ambition of EUFAL project is to fulfil this gap by the implementation of dedicated tools set on the web-based platform.

The major objective of the deliverable 1.31 is to describe a set of tools for implementation of EFV in city logistics and to derive general assumptions and requirements for developing the tools on the web platform. In the framework of task 1.31, the following six tools have been established and prepared for the development on the platform.

- DynaTOP
- An optimization algorithm for a two echelon vehicle routing problem (TEVRP) with delivery bots
- Adaptive Large Neighbourhood Search (ALNS) algorithm for a mixed fleet of electric vehicles (EVs) and internal combustion engine vehicles (ICEVs) with temperature dependent energy consumption
- Stochastic Fleet Mix Optimizer
- Assessment framework
- VECEPT Fleet Optimization Tool

These tools are related to many activities focussing on the implementation, development and utilization of EFV, e.g. vehicle procurement, fleet mix development, vehicle deployment, total cost of ownership (TCO) calculators, route optimization considering the charging infrastructure, optimization and planning of charging stations infrastructure and logistics structure (see Table 1).

Table 1. Type of actions supported by the tools

Type of actions	DynaTOP	An optimization algorithm for a two echelon vehicle routing problem with delivery bots	Adaptive Large Neighbourhood Search algorithm for a mixed fleet of EVs and ICEVs with temperature dependent energy consumption	Stochastic Fleet Mix Optimizer	Assessment framework	VECEPT Fleet Optimization Tool
Vehicle procurement					1	
Fleet mix development	1			1	1	
Vehicle deployment		1	1		1	
TCO calculators				1	1	1
Route optimization considering the charging infrastructure	1	1	1			1
Optimization and planning of charging stations infrastructure	1				1	1
Logistics structure	1	1				

The tools set will support very different groups of city logistics stakeholders, including public authorities, freight carriers, shippers and companies, research entities, city users and business stakeholders for fleet management (see Table 2).

Table 2. User categories

	DynaTOP	An optimization algorithm for a two echelon vehicle routing problem with delivery bots	Adaptive Large Neighbourhood Search algorithm for a mixed fleet of EVs and ICEVs with temperature dependent energy consumption	Stochastic Fleet Mix Optimizer	Assessment framework	VECEPT Fleet Optimization Tool
Public authorities		1	1	1	1	
Freight carriers	1	1	1	1	1	
Shippers and companies	1	1	1	1	1	
Research entities	1					1
City users	1					
Business stakeholders for fleet management		1	1	1		

2 DynaTOP - Metaheuristics and tools for transportation optimization problems

Keywords

- Metaheuristic transport optimization
- Fleet mix optimization
- Route planning and optimization

Description of the tool

The aim of DynaTOP is to provide a set of concepts and implementations to model and solve a large set of transportation problems using metaheuristics in a fast and concise way. Furthermore, such transportation problems will often be derived from real world applications, leading to the requirement of including custom constraints and calculations as well. Therefore, a general system is necessary, as well as performance and usability (and maintainability). As there is always a trade-off between those three goals in designing a piece of software, a special focus was put on decoupling general concepts from their implementation. It resolves around the concept of a central solution, decoupling general metaheuristic(s) algorithms from problem-specific information. A solution implements a set of traits (methods defined in an interface) required by the optimization to ensure a certain structure and assess the value of a change as well as apply it. The metaheuristics module contains improvement techniques based on neighbourhood search, resolving around the concept of moves. The problem represents the interface with the problem itself, i.e. providing the data needed generating and evaluating solutions. Traits are used to define this interface, which can be accessed by a problem-specific implementation of a solution, or by the evaluation module in case of vehicle routing problems. Route uses evaluation to provide data structures for efficient move evaluation usable in the solution implementation. Utils provides several utility methods for the solution.

Objectives

The purpose of DynaTOP is to provide a framework to solve optimization problems, especially vehicle routing problems (VRP), using heuristics. The focus lies on neighbourhood based local search techniques, whereas other techniques (e.g. insertion, crossover, path relinking) are possible, but not necessarily implemented at the moment. As such, the code is distributed among the following packages in order to decouple general techniques from VRP-specific ones.

- DynaTOP (core) implements the core features, especially the move and metaheuristic interfaces, as well as the default implementations of standard local search based metaheuristics (e.g. hill climbing, vnd, vns)
- dynatop.vrp: Vehicle routing problem (VRP) specific implementations and abstractions, e.g. common neighbourhood generators and insertion heuristics. As a sub package, .tresp encapsulates the implementation of an efficient sequence evaluation approach based on the literature (see Irnich et al., Vidal et al.)

- dynatop.examples.vrp: Example implementations for several vehicle routing problems using DynaTOP.

Benefits for users

DynaTOP is a framework for optimization problems. Due to this, it uses sub tools which are defined for special issues of a customer or stakeholder. All these sub tools are part of a library that offers a growing number of metaheuristics and can be offered to any interest group.

Requirements for the successful implementation on the platform

DynaTOP is an expert framework running on servers at AIT and will be offered on the EUFAL platform via User Interface (UI) where some functions can be used. The whole system will run on AIT`s servers and will be connected to the EUFAL platform via a link.

Potential implementation barriers

DynaTOP runs only on AIT server (calculation time optimized) and will be connected to EUFAL platform via a link operated by a UI.

3 An optimization algorithm for a two echelon vehicle routing problem with delivery bots

Keywords

- Two-echelon
- Vehicle routing problem
- Urban logistics
- Optimization
- Metaheuristic

Description of the tool

The optimization algorithm determines the deployment of the first and second echelon vehicles to facilitate timely meetings at the satellite locations where transfer of goods, dispatch of delivery bots, and battery swapping of delivery bots take place. Delivery requests are characterized by locations, time windows, and demand quantities. The algorithm minimizes the total routing costs. This tool is applicable primarily for freight transport in urban areas since the bots have limited range.

Objectives

The purpose of this tool is to obtain routes that minimize the routing costs of first echelon vehicles and that of delivery bots for freight distribution in the city.

Requirements for the successful implementation on the platform

Relevant data of high quality.

Potential implementation barriers

- Insufficient understanding and documentation of how the tool must be operated
- Insufficient data availability

4 Adaptive Large Neighbourhood Search algorithm for a mixed fleet of EVs and ICEVs with temperature dependent energy consumption

Keywords

- Adaptive Large Neighbourhood Search algorithm
- Vehicle routing problem
- Urban logistics
- Optimization
- Energy consumption function

Description of the tool

The optimization algorithm determines the deployment of the available fleet of electric and conventional vehicles to specific tasks characterized by various locations, time windows, demand quantities, service time durations, and compatibility with drivers. The algorithm minimizes the sum of routing costs (energy and maintenance) and vehicle usage costs. This tool is applicable primarily for freight transport in urban areas since the electric vehicles may be recharged at most once during the day. This tool ensures a better accounting for the vehicle power consumption by including cabin climate control power in addition to mechanical power. Thus, this tool eliminates to a large extent the mismatch in planned driving range and realized driving range, which has been a major concern to early adopters.

Objectives

The purpose of this tool is to obtain routes that minimize the costs of energy used by electric vehicles (through recharging costs) and conventional vehicles (through fuel costs) in the available fleet.

Requirements for the successful implementation on the platform

Relevant data of high quality.

Potential implementation barriers

- Insufficient understanding and documentation of how the tool must be operated
- Insufficient data availability

5 Stochastic Fleet Mix Optimizer

Keywords

- Total cost of ownership (TCO)
- Fleet size and mix problem
- Vehicle routing problem
- Urban logistics
- Optimization
- Sample average approximation

Description of the tool

The framework determines the optimal fleet mix of electric and conventional vehicles that may operate on specific tasks characterized by various locations, time windows, demand quantities, service time durations, and compatibility with drivers. The framework minimizes the total cost of ownership (TCO) over a 10.6 year horizon with the vehicles operating on 227 days per year. The TCO is calculated here as the sum of operational costs (routing, maintenance, insurance, driver wages, etc) and acquisition costs (with tax).

Objectives

The purpose of the tool is to enable assessment of mixed electric fleet ownership from a TCO perspective.

Requirements for the successful implementation on the platform

Relevant data of high quality.

Potential implementation barriers

- Insufficient understanding and documentation of how the tool must be operated
- Insufficient data availability
- Confidentiality issues with data

6 Assessment framework

Keywords

- Assessment framework
- TCO
- Multi-criteria Decision Analysis (MCDA)
- Mixed fleet composition

Description of the tool

The tool addresses the identification and development of a set of key performance indicators (KPIs) based on user needs for urban mobility and the aim to promote more sustainable transport solutions. Moreover, the tool presents a framework for assessing the impacts of replacing conventional vehicles with electric vehicles. In this context, MCDA techniques along with TCO calculations are applied for the assessment process.

Objectives

In collaboration with a Danish company it will be tested whether an electronic convenience vehicle (ECV) solution can meet the requirements of the commercial sector. In terms of sustainability, this will promote the use of electric vehicles in urban areas resulting in cleaner air, less noise and improved quality of life.

Benefits for users

This will highly depend on the degree of implementation in vehicle fleets and a trustworthy estimation cannot be given until the test period will be finished.

Requirements for the successful implementation on the platform

None specific

Potential implementation barriers

The tool will be provided in form of a framework description which easily can be implemented by interested groups.

7 VECEPT Fleet Optimization Tool

Keywords

- Fleet management tool
- Optimization algorithm
- Novel mobility concepts

Description of the tool

The VECEPT fleet management tool can be applied to determine optimized strategies for the gradual introduction of plug-in hybrid vehicles and battery electric vehicles into existing (conventional) fleets. Incorporating basic data on the existing vehicle fleet and respecting the daily mobility requirements of the users, optimized solutions with respect to costs and CO_2 emissions are computed. Fleet optimization relies on information on the fleet's daily operations including the required number and type of vehicles, the expected number and length of trips, and opportunities to recharge a vehicle's batteries between trips. This information can be extracted from vehicle logbooks and GPS loggers, if available, in order to alleviate the burden on the fleet operator, who would otherwise have to provide this information manually. Summarizing the characteristics of a fleet's daily trips by a manageable number of prototypes, their frequency of occurrence and their variabilities, significantly reduces complexity and makes optimization feasible. Via the generation of scenarios, users can specify their assumptions of future developments, e.g. regarding demand, energy or fuel costs. This feature also allows users to determine requirements for charging infrastructure. Estimation on the number of charging stations can be introduced as scenario input. According to the coverage of charging infrastructure, the proposed fleet composition will vary with respect to the percentage of conventional, electric and plugin-hybrid vehicles. Since the fleet management tool allows users to interact instantaneously, different potential coverage values can be assumed and their effects on the fleet composition can be evaluated.

The fleet management tool graphically presents a set of comparable solutions, enabling users to choose the fleet composition which best fits their preferences for costs and CO_2 emissions. For each solution detailed buy- and sell-decisions for vehicles are given over a defined time horizon.

The VECEPT fleet management software aims at supporting decision makers with regard to their fleet configuration.

The core of the software is an algorithm which generates potentially Pareto-optimal solutions with respect to costs and CO_2 emissions. Over a predefined time horizon, e.g. four years, the method determines the vehicles to be purchased and sold. Since two objectives are considered, the method does not only generate one optimal solution, but also a whole set of potentially Pareto-optimal solutions. Decision makers can then choose the solution which best fits their preferences of this whole set. This means that no priorities for one or the other objective need to be specified beforehand, but fleet compositions and detailed solutions can be compared visually and in detail.

Objectives

The strategy change from personally dedicated vehicles to vehicle pooling in commercial fleets will be a major step to reduce environmental effects of commercially initiated mobility and transport.

Benefits for users

The first scenario represents a virtual example of a company whose trips mainly occur in the corridor between Vienna and Graz, where the recharging of electricity is only possible in Vienna and Graz. The demand data of this company contains shorter trips starting in Vienna and heading towards Graz, as well as longer trips going from Vienna to Graz and back. The aim of the fleet management software is to optimize the vehicle fleet over a given time horizon (4 years in this example), starting from an initial vehicle fleet. Obviously, if recharging electricity is only possible in Vienna and Graz, a battery range of more than 200km would be required. In the first scenario, the recommended fleet at the end of the time horizon contains three plug-in hybrid vehicles and six conventional vehicles. Given the long distance which needs to be traversed until charging is possible, the plug-in hybrid vehicle is very well suited. The second scenario again represents a virtual example of a company whose trips mainly occur in the corridor between Vienna and Graz. However, now the charging infrastructure along the corridor between Vienna and Graz has been expanded, such that there are several possibilities to recharge the vehicle battery along the way between Vienna and Graz. The recommendation for the vehicle fleet in the second scenario contains only electric vehicles, which leads to very low CO_2 emissions.

Requirements for the successful implementation on the platform

None specific

Potential implementation barriers

None specific