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Analysing the Feasibility of a Simulated Zero-Emission Vehicle Fleet in Logistics

A Scenario-Based Case Study

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Abstract

As logistics providers strive to reduce their operational emissions with increasing urgency, the feasibility and costs associated with transitioning to zero-emission vehicle fleets is of growing concern. Meanwhile, vehicle routing problems, a staple in the field of operational research, struggle to capture the wide range of real-world complexities known to impact the operation of electric commercial vehicles to problems similar in size to those faced by commercial enterprises. The purpose of this thesis is to demonstrate how a pragmatic formulation of a Capacitated Electric Vehicle Routing Problem with Time Windows can constitute a viable decision-making tool for logistics providers seeking to eliminate operational emissions. Our two-stage solution contributes to the existing literature by enabling the incorporation of a wide range of real-world factors to large problem instances, while maintaining relatively low computational complexity.

The viability of our method is demonstrated using a Norwegian logistics provider, Bring Home Delivery, as a case study. Using historical order data to generate problem instances, we examine the feasibility and operational costs of fulfilling different levels of demand using an electric vehicle fleet. To enable comparative analyses to the case study subject's current operations, the same problem set is solved as a conventional routing problem using a diesel vehicle fleet. By first optimizing routes for minimal operational cost and incorporating the necessary use of charging infrastructure in a subsequent step, the model is successfully applied to problem instances containing up to 648 customer nodes and 731 charging locations.

Based on our findings, we conclude that an electric vehicle fleet is a viable alternative to diesel vehicles in all scenarios, incurring operational costs similar to, or below, the costs of a diesel vehicle fleet. However, deliveries to remote areas of the largest customer network are deemed infeasible due to a combination of limited vehicle range, unavailability of charging infrastructure, and long charging times. Furthermore, the feasibility and operational costs of the solutions using electric vehicles are far more sensitive to changes in variables such as ambient temperatures or customer density than those of their diesel counterparts.

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Table of contents

List of figures

List of tables

Abbreviations

API Application Programming Interface

AT Ambient Temperature

BEV Battery Electric Vehicle

BHD Bring Home Delivery

CAR Climate Action Regulation

C-EVRPTW Capacitated Electric Vehicle Routing Problem with Time Windows

CVN Cumulative Number of Vehicles

C-VRP Capacitated Vehicle Routing Problem

C-VRPTW Capacitated Vehicle Routing Problem with Time Windows

DCV Diesel Commercial Vehicle

DVRC Daily Vehicle Routing Cost

ECV Electric Commercial Vehicle

EEA European Economic Area

EU European Union

EV Electric Vehicle

EVRP Electric Vehicle Routing Problem

GDP Gross Domestic Product

GHG Greenhouse Gas

G-VRP Green Vehicles Routing Problem

MIP Mixed-Integer Programming

OC Operational Cost

PRP Pollution-Routing Problem

RVRP Recharging Vehicle Routing Problem

SoC State of Charge

TSP Travelling Salesperson Problem

VRP Vehicle Routing Problem

VRPTW Vehicle Routing Problem with Time Windows

1 Introduction

The following chapter describes the empirical background of this thesis. Furthermore, its purpose and subsequent research questions are presented, followed by a brief description of the thesis' structure.

1.1 Empirical background

As the world's population steadily rises and economies become increasingly globalized, our reliance on transportation and logistics networks to provide continued social and economic progress grows larger. In the European Union (EU) alone, approximately 10 million people are employed in the transportation industry, and households spend an average of 13.2 % of their disposable income on the moving of goods and services (European Union, 2019). However, the increased mobility of goods and people is not without consequences; more than 24 % of global CO_2 emissions from fuel combustion stem from the transportation sector (International Energy Agency, 2020). In 2015, the associated air pollution caused an estimated 385,000 premature deaths and USD 1 trillion in health damages (Anenberg et al., 2019).

Due to the nature of greenhouse gas emissions (GHGs), their negative impacts are not geographically limited to any city or country. Consequently, a vast range of intergovernmental initiatives, such as the Paris Agreement, the 2030 Agenda for Sustainable Development, and the EU's Climate Action Regulation (CAR), aim to regulate and reduce the consumption of fossil fuels. The primary source of this pollution, both globally and locally, is road transportation, of which freight constitutes 29.4 % of emissions (International Energy Agency, 2019). While a decarbonization of the road transportation sector would reduce global GHG emissions by an estimated 11.9 %, it is instead progressing negatively faster than any other sector (Wang & Ge, 2019).

Among the measures available to curb emissions are: reducing the demand for transportation, improving energy efficiency through technological advancements, or adopting transportation modes that are inherently "greener". A rising global GDP, increased adaptation of logistics-intensive e-commerce and a projected global doubling in personal vehicles on roads by 2040, makes reducing demand for transportation challenging (International Energy Agency, 2020). Furthermore, improvements to the energy efficiency of combustion engines have stagnated at a level where less than half of the fuel consumed propels the vehicle forward (Albatayneh et al., 2020). Consequently, efforts are primarily focused on the latter alternative – transitioning to modes of transportation that are more energy-efficient, and thereby less harmful to the environment.

To meet the obligations ratified in the Paris Agreement and conform to the decreasing carbon budgets imposed by CAR, national governments are increasingly promoting electric vehicles (EVs) as a preferred mode of transport. For instance, Norway, a Paris Agreement signatory and European Economic Area (EEA) member, has become the country with the highest proportion of EVs in the world, largely due to their exemption from a high sales tax and toll fees (Nikel, 2019). The Norwegian Government has announced that by 2025, all new passenger cars and light vans shall be zero-emission vehicles, with heavy-duty trucks to follow suit by 2030 (Norwegian Ministry of Transport and Communications, 2017). Several other countries, including Denmark, Sweden, Iceland and Ireland, have made similar commitments with corresponding incentive structures (Wappelhorst & Cui, 2020).

This constitutes a monumental challenge to commercial operators of logistics networks. As the demand for goods rises, companies must simultaneously adopt alternative modes of transport to adhere to increasingly strict regulations and growing demand from stakeholders for greener delivery modes (Velázquez-Martínez & Cottrill, 2020). Furthermore, due to the relative infancy and high acquisition cost of electric commercial vehicles (ECVs), this transition requires significant investments into technologies with which companies have limited experience. The considerably lower ranges of ECVs compared to conventional diesel vans and trucks, longer charging times, often limited availability of charging infrastructure, and high sensitivity to factors such as load weight, ambient temperatures, route elevation and more, means that there is considerable uncertainty associated with the transition to a zero-emission vehicle fleet.

1.2 Purpose and research questions

Operations research has long been concerned with the Vehicle Routing Problem (VRP), a combinatorial optimization and linear programming problem which, in its most basic form, is concerned with how a fleet of vehicles can visit a set of customers exactly once, while minimizing the total distance travelled. Since first introduced by Dantzig and Ramser (1959), the complexity of VRPs has grown considerably, as new sub-problems incorporate an increasingly wide range of real-world dynamics to solve for intricate objectives in large customer networks.

The purpose of this thesis is to contribute to existing VRP literature by proposing a pragmatic approach to a Capacitated Electric Vehicle Routing Problem with Time Windows (C-EVRPTW). By employing a two-stage approach to the C-EVRPTW, we maintain relatively low computational complexity, enabling both the solving of large problem instances and the inclusion of a high number of real-world variables. Using Bring Home Delivery (BHD), a Norwegian logistics provider, as a case study, we demonstrate how this method can be utilized as a decision-making tool for commercial enterprises faced with the challenge of transitioning to zero-emission vehicle fleets.

The case study uses historical order data from BHD to generate problem instances that reflect real-world dynamics. It is exclusively concerned with last-mile deliveries, meaning goods transported to the end-consumer from BHDs terminal located in Haugenstua, Oslo. The unique characteristics of this part of the logistics providers' value chain warrants consideration independent of the preceding elements for multiple reasons: Firstly, last-mile deliveries consist of dynamic networks of customers that are subject to considerable changes from day to day, both in the level of demand and the location of customers. Furthermore, deliveries are generally made using fleets of smaller vehicles, such as vans or light trucks, which travel shorter distances to multiple locations in predominantly urban environments. As governments impose increasingly stringent regulations to combat the adverse impact vehicles have on air quality in populated areas (Hovi et al., 2019), the feasibility of last-mile deliveries using combustion engine vehicles is rapidly diminishing. Furthermore, alongside personal vehicles, the vans and light trucks used for last-mile deliveries are subject to a more rapid phasing out than heavy-duty vehicles, meaning the transition to zero-emission alternatives is more urgent (Norwegian Ministry of Transport and Communications, 2017).

Meanwhile, the preceding inter-depot transportation consists of routes that are more homogenous by nature, where the origin and possible destinations constitute a static network of relatively few nodes, with changes only to the level of demand between depots. The routes are generally travelled by heavy-duty trucks, across greater distances and at highway speeds. As such, the primary challenge of inter-depot transportation is not the routing of vehicles, but the loading, size, and allocation of a vehicle fleet. Furthermore, the elimination of operational emissions from inter-depot transportation may rely on the adoption of entirely different modes of transport, such as hydrogen vehicles that are less constrained by limited ranges and long refuelling times. However, such a transition would require significant investments in infrastructure, as, at time of writing, there are only three operational hydrogen refuelling stations in Norway (Norwegian Hydrogen Association, 2021). As such, while emissions from inter-depot transportation should be addressed, its feasibility appears less contingent on route optimization and analysis, than on technological progress and infrastructure investments.

To reflect that the demand for goods fluctuates significantly over time, the order data is divided into different scenarios, representing occasions where BHD must satisfy high, medium, and low levels of demand. Each scenario then constitutes a problem instance, which is solved as a C-EVRPTW. Furthermore, as the performance of an electrified vehicle fleet is best examined relative to an alternative, the same problem instances are solved by formulating a Capacitated Vehicle Routing Problem with Time Windows (C-VRPTW) using a conventional diesel vehicle fleet. In doing so, this thesis seeks to answer the following research questions:

RQ1: *Can Bring Home Delivery transition to zero-emission last-mile deliveries from their Oslo terminal, without compromising on their delivery times, using only electric vehicles?*

RQ2: *How would doing so impact their operational costs?*

By answering *RQ1*, we determine whether a zero-emission vehicle fleet is at all capable of satisfying the demand of BHDs customers in problem instances known to have already been solved by a conventional diesel fleet. Furthermore, as BHD exclusively transports goods in excess of 35 kg, deliveries are made in predetermined time windows so that customers can ensure that they are present to take receipt of the goods. An important measure of the quality of service is therefore BHD’s ability to ensure that deliveries are made within the agreed-upon time window.

Lastly, while satisfying the demand in a given scenario may be feasible, the incurred costs of doing so are crucial to the decision-making process of any commercial enterprise. Although Norwegian consumers exhibit some degree of willingness to pay for the consideration of ethical concerns (Schjøll & Thorjussen, 2019), the elasticity of demand for zero-emission transportation relative to conventional delivery is unknown.

While the historical order data provided by BHD contains a wide range of characteristics for each order, it is not possible to ascertain the routes driven by vehicles, nor the order in which customers were visited. Instead, the operational costs in each scenario are estimated for both the C-EVRPTW and C-VRPTW. Consequently, *RQ2* provides important context to the results of *RQ1* by estimating BHD's operational costs using an ECV fleet relative to those of a DCV fleet.

For simplicity, as the names of the two simulation models are hard to distinguish, please note that the C-EVRPTW is referred to as S_{Electric} in subsequent chapters. Similarly, the C-VRPTW is referred to as S_{Diesel} to improve readability.

1.3 Thesis structure

The subsequent sections are structured as follows: Chapter 2 briefly describes the theoretical background and general characteristics of routing problems, including its most common sub-problems. A comprehensive literature review with emphasis on research pertaining to environmental considerations in routing problems is then provided, with the objective of describing the field's current state-of-the-art. Furthermore, the contribution of this thesis to the existing literature is described. Chapter 3 details the thesis' underlying methodology, including model formulation, the generation of problem instances, descriptions of how real-world data were collected and analysed, and how the final model's performance was validated and benchmarked. In Chapter 4, the problem instances are solved using S_{Electric} and S_{Diesel}, followed by comparative analyses of the results. Finally, Chapter 5 discusses the findings in relation to the research questions and their implications to practice and theory, followed by a brief conclusion and recommendations for future research in Chapter 6 and 7, respectively.

2 Literature review

The following chapter contains a description of the key concepts and literature on which this thesis is based. Section 2.1 provides a brief narrative of the origins and structure common to all routing problems, as well as examples of its most common sub-problems. Section 2.2 contains a thorough, while not exhaustive, review of literature relevant to the work presented in this thesis. For comprehensive reviews of the field in general, see Eksioglu et al. (2009), Toth and Vigo (2014), Braekers et al. (2016) or Gayialis et al. (2019). While the significant diversity and overlap between routing problem types makes it challenging to categorize the literature systematically, an attempt has been made to discuss relevant contributions in their appropriate context, ordered chronologically except where doing so is not expedient. Critical observations are made alongside the review of each paper with the intention of identifying areas of potential progress. Lastly, Section 2.3 describes where the field of Electric Vehicle Routing Problems (EVRPs) appears to be headed, and how this thesis contributes to the current state-of-the-art.

2.1 The Vehicle Routing Problem (VRP)

The model presented in this thesis is a sub-problem of the Vehicle Routing Problem (VRP), itself a generalization of the Traveling Salesperson Problem (TSP) which seeks to determine the route through a given set of points that minimizes the total distance travelled.

Dantzig and Ramser (1959) first formulated what they labelled the Truck Dispatching Problem, by modelling a homogenous fleet of trucks tasked with delivering fuel to a network of gas depots, solved as a linear optimization problem. This differed from earlier problems by demanding that routes were constructed so that all vehicles departed from, and returned to, a central hub after visiting their designated customer set. The model also allowed for unique levels of demand for each customer and considered the limited loading capacities of each vehicle, today known as a Capacitated Vehicle Routing Problem (C-VRP). Based on this, Clarke and Wright (1964) generalized a linear optimization problem that seeks to determine how a set of customers can be served from a central hub by vehicles with dissimilar loading capacities at minimal total travelling distance, today known as a Vehicle Routing Problem (VRP).

In general, a VRP is modelled as a weighted directed graph where nodes represent individual customers. The arcs between nodes constitute the paths taken by vehicles, and each arc's weight signifies the cost of that path, as seen in Figure 2.1.

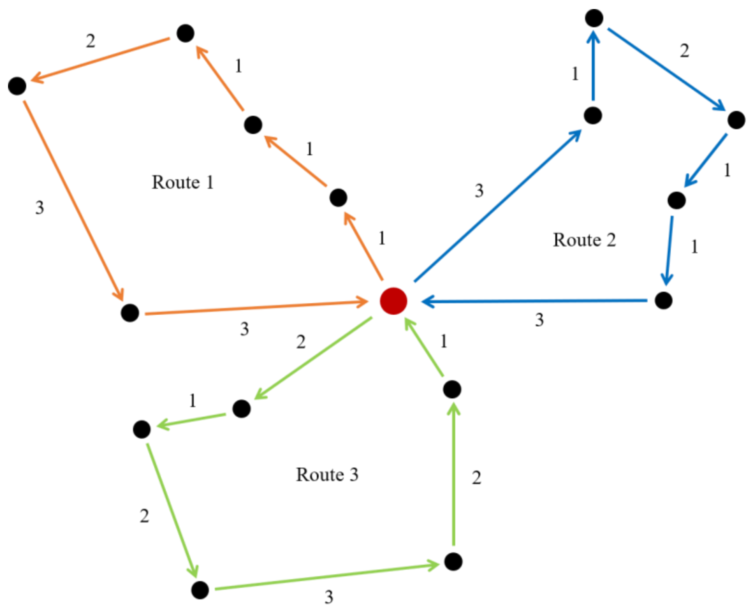


Figure 2.1: Example of three vehicle routes covering a set of customers from a terminal, with the weight of arcs denoting the distance between nodes

Subject to constraints, such as loading capacities, vehicle range, prearranged delivery times or vehicle fleet size, the routing problem is solved to keep an objective function, in early iterations a measure of travel distance or vehicle fleet size, at a minimum. As nearly all VRPs constitute NP-hard problems, further discussed in Section 3.2, most applications involve the use of heuristic algorithms to provide near-optimal solutions (Lenstra & Kan, 1981). While the aforementioned iterations of the VRP contain objective functions which simply measures the distance between nodes or the number of vehicles used, more recent work aims to minimize total travel time, operational cost, or more comprehensive, multi-objective measures described in greater detail in Section 2.2.

The Vehicle Routing Problem with Time Windows (VRPTW) is perhaps the most common generalization of the original VRP, due to its relevance to the operation of real-world logistics networks (Desaulniers et al., 2014). First introduced by Pullen and Webb (1967), the problem adds complexity by requiring the servicing of customers to occur within a predetermined time interval, constituting a time window. In cases where the violation of a time window is possible but incurs a penalty cost, the time window is considered soft. This allows for the incorporation of compromises similar to those of real-world operations, where the size of a vehicle fleet may be kept lower in exchange for an inability to deliver all goods on time in certain problem instances. However, this type of soft constraint requires a weighting of the penalty incurred if violated, which can then be balanced against the benefit of upholding it. If a time window is hard, the model is restricted so that arrival or departure outside the specified time interval is prohibited. Consequently, the problem solution must ensure conformity by making changes to route arcs, fleet sizes or other variables which may incur additional costs. While time windows most commonly impose restrictions on when a vehicle may arrive at a customer node, they may also concern the availability of the depot, drivers or the roads available for routing (Braekers et al., 2016).

The performance of heuristics used to solve VRPs is most commonly benchmarked using problem instances first introduced in Solomon (1987), containing six problem sets with a total of 56 problem instances. Each instance consists of 100 customers with unique demand in weight and a time window for delivery. Vehicles are capacitated by a maximum load weight, and the problem is originally multi-objective by aiming to minimize the number of vehicles used, route duration, travel distance, and waiting times. Several adaptations and extensions of the original problem sets have since been published alongside entirely new benchmarks, to improve their applicability to a broader range of VRPs, primarily containing changes to the sizes and density of customer networks.. A recent review of these and their best-known solutions can be found in (Meira et al., 2017).

2.2 The Electric Vehicle Routing Problem (EVRP)

Multiple approaches to the inclusion of environmental considerations in routing problems have been proposed. Sbihi and Eglese (2010) and Maden et al. (2010) demonstrate that the minimization of travel distance and avoidance of traffic congestion commonly emphasized in conventional VRPs concerning fossil-fuelled vehicles indirectly reduces GHG emissions.

More targeted approaches include the Emissions Vehicle Routing Problem formulated by Figliozzi (2010), in which the minimization of GHG emissions and fuel consumption is addressed directly through incorporation in the objective function itself, either as the primary objective or as a component of a cost function. By including departure times and vehicle speed as decision variables, travel in congested traffic is avoided as drivers can make adjustments to when they depart from each node, subject to meeting hard time window constraints, thereby allowing the fleet to operate at speeds where emissions are lower. Similarly, Bektaş and Laporte (2011) formulate the Pollution-Routing Problem (PRP) containing a more comprehensive emissions model which, in addition to permitting varying vehicle speeds, accounts for the impact of changes in vehicle load from one arc to another. Their collective findings suggest that changes to parameters such as departure times, vehicle speed and the number of vehicles utilized can result in moderate reductions in both emissions and total operational costs relative to conventional VRPs. However, neither attempts to eliminate operational emissions through the use of alternative transport modes.

An different approach is the use of inherently cleaner modes of transportation to solve regular cost optimization problems, thereby addressing environmental concerns directly. Gonçalves et al. (2011) construct a pick-up and delivery VRP containing both conventional diesel vehicles and ECVs. However, while the time required to recharge an ECV is derived from a function of distance travelled and maximum vehicle range, the availability and location of charging infrastructure is not incorporated in their model. Conrad and Figliozzi (2011) formulate the Recharging Vehicle Routing Problem (RVRP) in which a fully electric vehicle fleet is used to service a set of 40 customers, with experimental instances derived from adaptations of the Solomon problem sets (Gambardella, 1999). Their model permits charging en route at a selection of customer locations, thereby extending the potential distance covered by a single vehicle. One finding of particular interest is that even when the primary objective is the minimization of routes or vehicles employed, the imposition of hard time windows significantly increases the necessary fleet size and total distance travelled. Meanwhile, recharging at customer locations becomes less feasible when subjected to time constraints. However, the estimated time required to recharge a vehicle is fixed and does not account for a vehicles' state of charge (SoC), and, as in Gonçalves et al. (2011), the energy consumption function does not reflect factors known to have a significant impact on the range of ECVs, such as operating temperatures, differences in elevation between arcs, and vehicle load (Basso et al., 2019).

Similarly, Schneider et al. (2014) propose a hybrid heuristic that efficiently solves an Electric Vehicle Routing Problem with Time Windows (E-VRPTW) for constructed problem instances of up to 100 customers. However, as customer locations are derived from Solomon instances and charging locations are subsequently randomly generated to ensure coverage of the customer network, the challenges posed by the absence or dispersion of charging infrastructure in real-world networks is not addressed. Furthermore, energy consumption is a function of travel distance, neglecting the impact of factors such vehicle load and elevation, all of which limits their routing model's applicability to real-world problems, particularly with regards to the transportation of heavy goods where load weight significantly impacts vehicle range. This may reflect the relative infancy of EVRPs compared to traditional routing problems, in which considerations of range constraints and refuelling times are scarcely made due to the ubiquity of gas stations and the longer ranges of diesel trucks. Examples include Kek et al. (2008) and Laporte et al. (1985), where range constraints are imposed on fleets of gasoline trucks as part of a routing problem, and Ichimori et al. (1983), who propose a model to minimize travel distance and ensure vehicles do not run out of fuel using a polynomial algorithm. More recently, Erdoğan and Miller-Hooks (2012) proposed the Green Vehicle Routing Problem (G-VRP) to enable the servicing of larger customer networks with alternative-fuel vehicles, such as ECVs or hydrogen trucks, by incorporating fuel monitoring and replenishment in their model formulation, and including optional refuelling nodes in their problem set.

Another essential aspect in determining the commercial viability of ECVs is their profitability relative to conventional vehicles. In response to environments increasingly conducive to operating with low- or zero-emission vehicle fleets, Davis and Figliozzi (2013) propose a method of evaluating the competitiveness of ECVs in different scenarios. By accounting for acquisition costs, depreciation, maintenance, battery replacements, tax incentives and energy costs of ECVs, the authors estimate a total cost-of-ownership relative to a fleet comprised of a commonly used diesel truck. Their findings show that the high acquisition cost of ECVs must be compensated for by maintaining low operational costs, and that ECVs are not competitive once the necessary fleet size exceeds that of a conventional vehicle fleet. Consequently, long travel distances close to the maximum range of each ECV, maintenance of low vehicle speeds and loads, frequent customer stops and predictability in customer demand levels are crucial to efficient resource utilization, and thereby the commercial viability of ECVs. Similarly, Feng and Figliozzi (2013) emphasize that while current ECVs are approximately three times more expensive than comparable diesel trucks to acquire, their energy cost on a per-mile basis is nearly one-quarter of their counterparts (studies from other markets estimate the difference in energy cost to be as high as 1:10, see Xiao et al. (2019)). In their most favourable scenario, where the acquisition cost of an ECV is 9-23 % lower than 2013 US market prices, vehicle fleets become competitive when each vehicle is driven more than 19,000 kilometres per year. Seen in conjunction with the findings of Gambardella (1999), where the imposition of hard time window constraints significantly increases the number of vehicles required, this appears in conflict with the need to maintain ECV fleet sizes that do not exceed the number of conventional vehicles used to service the same customer set.

More recently, Lin et al. (2016) address several of the shortcomings above, as the first to consider the impact of vehicle load on ECV battery consumption as part of a comprehensive energy cost function derived from Barth and Boriboonsomsin (2009); Barth et al. (2005) and Bektaş and Laporte (2011). Using a real-world case study network from Ruan et al. (2012), their model provides an optimal solution to an EVRP with 13 customers, two charging stations and a heterogenous vehicle fleet, where the objective function minimizes total operational cost. Their findings indicate that ECVs can cover distances in time comparable to that of diesel trucks, but will incur significant labour cost and time penalties once en-route charging is required. However, their formulation does not impose time windows, nor does it account for differences in elevation between nodes or ambient temperatures. Lastly, while able to provide an exact solution for a small customer network, they are unable to solve larger problem instances more similar to real-world dynamics. Keskin et al. (2019) demonstrate that waiting times at public charging locations may impact routing decisions if the objective is cost minimization, or if hard time-window constraints are present. In other words, if the demand for public chargers is higher than the available supply in a region, driving to an area where demand is lower may be preferable to waiting, even if the total travel distance is increased. More recently, Keskin et al. (2021) demonstrates that when waiting times at charging locations are unexpectedly high, taking recourse action may result in lower total costs. For instance, by skipping a sub-set of customers following a charging stop to uphold subsequent time windows, and dispatching an additional ECV to service the skipped sub-set, the total cost incurred by time-windows violations may be reduced. However, while applicable to scenarios where vehicle fleets supply homogenous goods, this approach appears infeasible in networks where demand is unique to each customer, as the goods to be delivered are already loaded onto a vehicle by the time the need for such recourse action can be determined.

Basso et al. (2019) demonstrate that the accuracy of the energy cost function can significantly impact routing, fleet size, and the utilization of charging infrastructure. First, they employ a conventional EVRP model derived from Bektaş and Laporte (2011) and Goeke and Schneider (2015) to solve 18 problem instances of various sizes. By comparing the solutions with that of their revised model, which accounts for vehicle acceleration, load weight, topography and more, the conventional EVRP is found to propose infeasible solutions in all but four of the 18 cases. While the authors’ approach is not feasible for large scale instance with heterogenous vehicle fleets, nor accounts for operational costs or the impact of constraints such as time windows, it efficiently demonstrates the importance of incorporating a wider range of factors in EVRPs than conventional VRPs. Lin and Zhou (2020) investigates how various factors impacts daily vehicle routing cost (DVRC), defined as the sum of driver salaries and cost of energy for an

ECV fleet. They conclude that while ECVs can perform on-par with diesel trucks in urban areas with high customer density, inter-city distribution is infeasible due to either technological constraints or the associated cost of circumventing those limitations. The findings highlight an important distinction in literature examining the costs associated with ECVs in logistics; if the objective is to minimize the total cost of ownership, as in Davis and Figliozzi (2013) or Feng and Figliozzi (2013), keeping vehicle fleet size at a minimum is essential due to the high acquisition cost of ECVs. However, if one seeks to minimize daily operational costs, as in Lin et al. (2016) or Lin and Zhou (2020), maintaining a large vehicle fleet to avoid the labour cost associated with en-route charging is preferable.

2.3 Contribution to existing literature

The growing body of work concerning EVRPs is largely focused on closing the gap between theoretical models and real-world systems, thereby increasing their practical applications. The novelty of the field, the increasing urgency to reduce operational emissions in logistics, and the distinct characteristics of ECVs suggest that there are still significant contributions to be made.

Our thesis proposes a pragmatic approach to evaluating the feasibility of operating a large logistics network using ECVs for last-mile deliveries. First, we formulate a Capacitated Electric Vehicle Routing Problem with Time Windows (C-EVRPTW). While incorporating factors such as vehicle load, elevation between nodes and ambient temperature to estimate energy consumption, we solve for multiple real-world problem instances containing up to 648 customers. By not imposing range restrictions on vehicles when first solving each problem instance, a set of routes that minimizes operational costs and energy consumption is generated. Secondly, routes where vehicles travel beyond their estimated battery range are revised to incorporate charging stops, and the final operational cost of the revised route is estimated.

The proposed method has several benefits. By dividing the initial routing and subsequent use of charging infrastructure into two separate problems, we maintain lower computational complexity so that commercially available solvers can be used to identify feasible solutions. Furthermore, we combine elements from recent literature and extensive data collection to provide accurate energy consumption and operational cost functions, which are crucial to determining the practical feasibility and commercial viability of operating an ECV fleet.

The practical application of the proposed method is demonstrated by using BHD’s terminal in Haugenstua, Oslo as a case study. Using historical order data to generate problem instances representing a best-, medium-, and a worst-case scenario of 72, 329 and 648 customers, respectively, we generate feasible routes and estimate the associated operational cost of delivering to all customers. Furthermore, the incorporation of real-world charging infrastructure is done through the collection of publicly available data. It should be noted that our method does not attempt to derive the total cost-of-ownership of an ECV fleet. This reflects the way in which BHD currently operates, where most vehicles used in last-mile deliveries are leased from sub-contractors, and therefore not owned by BHD. Furthermore, we solve the same instances using a C-VRPTW with conventional diesel trucks and conduct comparative analyses of the two.

To the best of our knowledge, this is the largest C-EVRPTW solved. Combined with the extensive use of real-world data, we believe it constitutes a valuable contribution to the literature by demonstrating how the feasibility and cost of operating a real zero-emission vehicle fleet can be assessed.

3 Methodology

The following chapter describes the model design, including its notations and incorporated variables in Section 3.1. Herein, the formulation of the objective function, cost function and model constraints are provided, alongside a description of how sensitivity analysis is conducted. Following a description of the problem complexity, our applied solution method is described, and its performance validated using common benchmarks in Section 3.2. In Section 3.3, the data collection and analysis central to our proposed method is presented. Finally, the applied selection criteria for the problem instances that form the basis of our scenario analyses are described in Section 3.4.

3.1 Model design

The proposed S_{Electric} is solved in a two-stage sequence due to the sheer number of nodes in the problem set, including customers and charging infrastructure. To attain feasible output from the model within an acceptable time limit, the first stage of the model solves each problem instance with an objective function designed to minimize the operational costs of the vehicle fleet. Furthermore, each problem set is divided into daytime and evening routes, and the network of charging locations is omitted to reduce the total number of nodes. When executed, this stage provides output containing the total routes needed, the deliveries included in each route, and the order in which deliveries should be made. It should be noted, however, that additional routes and alterations to the visiting order may occur due to constraints imposed as part of the subsequent stage.

The second stage of the model contains the routes generated in the initial stage and imposes time windows restrictions. Additionally, an energy consumption function is incorporated to track the remaining battery levels of each vehicle. Based on this function, the model predicts the arc on which charging is needed to reach the next customer node, and how much it is expedient to recharge based on remaining route length. In this stage, all charging infrastructure is included, and vehicles are directed to the nearest charging node instead of to the next customer location when required. Charging practices account for the SoC being a concave function, meaning that the time it takes to charge the upper bound of a battery is significantly longer than the middle bound of a battery. As charging the last 20 % takes approximately one-third of the total charging time (Zuo et al., 2019), this implies that charging to full capacity is undesirable en route. Consequently, the model assumes a linear charging function up to 80%

SoC, and prohibits charging beyond this limit before returning to the depot. The actual amount charged is also dependent on the energy required to complete the route, so that if less than a full charge is required to visit the remaining customer nodes and return to the depot, no excess charging is conducted. The time spent at each charging location is calculated, so that the incurred cost of labour and charging can be estimated. Additionally, once a vehicle returns to the terminal, the cost of fully recharging using privately owned infrastructure is added to the total OC. It is assumed that no labour cost is incurred when charging is not done en route.

The model assumes availability at all charging stations without any queueing time and a constant charging rate r_f of 50 kW on all chargers. Due to the significant variation in the density of charging infrastructure in urban and rural areas, the model only searches for the nearest charging station when charging is due. However, it will not account for the additional energy consumption and travel time to and from the charger from the last customer prior to its recharge. This is to prevent infeasibility in the simulation of the scenarios so that the calculation of OC can be completed. As an alternative, the feasibility of the route is assessed by imposing a threshold distance to the nearest charging location, set to 51,220 meters (the median distance to the nearest charging station in the worst-case scenario). I.e., if charging infrastructure is within 51,220 meters of the last customer node prior to required recharging on a route, this part of the route is deemed feasible. This way, we can calculate the OC of the proposed route, even if the current charging infrastructure renders the route infeasible.

Finally, the model calculates the associated costs of the outputs from the second stage of the model and estimates the total OC in each simulated scenario.

By postponing the inclusion of charging infrastructure to the second stage of the model and categorizing the time windows into daytime and evening routes in the first stage of the model, the number of nodes in each problem set is significantly reduced. Notably, the largest problem set to solve is reduced from exceeding 1,300 nodes, to two problems containing less than 400 nodes. Simultaneously, the model still accounts for all nodes by incorporating charging infrastructure in the second stage. It should be noted that postponing the inclusion of charging infrastructure to the second stage of the model may have adverse consequences. Primarily, as the model's objective function does not differentiate between the higher costs of charging en route, relative to charging at the terminal, it is plausible that deployment of additional vehicles could provide lower total OC than fewer routes requiring longer recharging stops. Also, as routes are optimized in the first stage without considering the location of charging infrastructure, it seems likely that travel distances to and from charging stations could be lower than presented in our solutions.

Lastly, as the starting- and end-time of each route is recorded, the model can provide an estimate of the number of vehicles required to operate the routes. The required fleet size is estimated by identifying routes that, due to their time windows, are not operated simultaneously. As the loading time preceding departure from the terminal is included in the estimated duration of a route, and it is assumed ECVs are fully recharged during loading, any routes in a problem instance which do not occur simultaneously can be operated by the same vehicle. It should be noted that the fleet size is primarily of interest if the objective is to avoid unnecessary acquisition costs, which, as described in Section 2.3, is not subject to optimization in this thesis.

The model formulation of both stages are provided in pseudocode in Appendix B.

3.1.1 Graph notations

As the model is designed as a weighted directed graph, multiple notations are attributed to lists incorporated in the model, shown in Table 3.1.

Table 3.1 List notations in model

Notation	Description
O	BHD terminal, denoted as {0} in lists
N	Set of delivery points (customers). Denoted as {1,2,3,…,n} in lists with a size of *n*
V	List of terminal and delivery points. V = N ∪ O
F	Set of charging stations. Denoted as {n+1, n+2, n+3,…,n+f} in lists with a size of *f*
G	List of all nodes (terminal, delivery points and charging stations). G = V ∪ F
A	Set of arcs between all nodes. {(i,j)}, ∀ i ,j ∈ G.
M	Set of vehicles in vehicle fleet. Denoted as {1,2,3,…,m} in list with a size of *m*

3.1.2 Input variables

The retrieval of output which resembles real-world dynamics as closely as possible relies on the quality of input. To this end, matrices containing the travel distance and elevation difference between all nodes are generated using OpenStreetMap and Google Elevation application programming interface (API), respectively. Subsequently, values for the following input variables are derived:

$\boldsymbol{d_{ij}}$: Travel distance in meters on arc (i,j), ∀ i,j ∈ A.

$\boldsymbol{alt_{ij}}$: Elevation difference on arc (i,j), ∀ i,j ∈ A.

In d_{ij} and alt_{ij} and any other notation including i and/or j in subscript, i represents a node in the graph, and j represents the subsequent node.

Based on the distance matrix, an additional travel time matrix is generated. We assume a constant travel speed of 60 km/h, commonly used by BHD to model for time consumption when routes include a mixture of urban, highway and rural roads. Hence:

$\boldsymbol{t_{ij}}$: Travel time in hours on arc (i,j), ∀ i,j ∈ A.

It should be noted that the elevation matrix constitutes a simplification of network topography as it only accounts for the altitude at each node, without concern to changes in elevation on the arc. Due to the sheer size of the problem set, the inclusion of elevation measures for multiple points on every arc would result in tremendous amounts of data. Although the viability of including more precise elevation data when solving smaller problem sets has been demonstrated, see Basso et al. (2019), only accounting for elevation difference between two nodes is consistent with existing literature on larger problem sets (Goeke & Schneider, 2015; Lin et al., 2016; Zhang et al., 2018). Still, it indicates if the sum of road angle on the arc amounts to an uphill or downhill arc, and enables this to be considered in the determination of routes.

To provide accurate energy consumption estimates, d_{ij} is used in conjunction with:

α_{ij} : Arc-specific constant in the model's cost function, which is derived from equation (1) by (Lin & Zhou, 2020):

$$\alpha_{ij} = a_{ij} + g \sin \theta_{ij} + g C_r \cos \theta_{ij} \tag{1}$$

Where a_{ij} is the acceleration on arc (i,j), always set to zero as the vehicle will start and stop at zero speed. Furthermore, g is the gravitational acceleration constant of 9.81 m/s^2, C_r being the coefficient of rolling resistance for the simulated vehicle, and θ_{ij} is the road angle on arc (i,j), derived from equation (2):

$$\theta_{ij} = \arcsin\left({}^{alt_{ij}}\!/_{d_{ij}}\right) \tag{2}$$

Where alt_{ij} is the difference in elevation between the departing and arrival node.
In addition to the arc-specific input parameters, there are several node-specific parameters:

Dw_i : Demanded weight of goods in kg at delivery points i, $\forall$ i $\in$ N.

h_i : Handling time in hours at each customer node and terminal i, $\forall$ i $\in$ V.

$tStart_i$: The earliest time accepted by customer i to receive a delivery, $\forall$ i $\in$ N.

Where $tStart_i$ is the difference between the terminal's opening time at 07:00 a.m. and the earliest time a customer accepts delivery, in hours. I.e., if a customer accepts delivery after 09:00 a.m., $tStart_i$ = 2.00.

Calculated similarly to $tStart_i$:

$tEnd_i$: The latest time accepted by customer i to receive a delivery, $\forall$ i $\in$ N.

Furthermore, vehicle-specific parameters are formulated. While the problem instances considered in this thesis are solved using a homogenous vehicle fleet, this enables the solving of smaller problem sets as agent-based routing problems. The model contains the following vehicle-specific input parameters:

$\boldsymbol{Qw_m}$: Weight capacity of vehicles m in kg, ∀ m ∈ M.

$\boldsymbol{Qe_m}$: Battery capacity of vehicles m in kWh, ∀ m ∈ M.

$\boldsymbol{W_m}$: Curb weight of vehicles m in kg, ∀ m ∈ M.

For the calculation of energy consumption, the vehicle-specific constant β_m, adopted from Lin and Zhou (2020), is formulated as shown in equation (3):

$$\beta_\mathrm{m} = 0.5\mathrm{C_d}\mathrm{A_m}\rho \tag{3}$$

In equation (3), C_d is the coefficient of rolling drag, meaning the friction between a vehicle’s pneumatic tires and the road surface, which is assumed to be equal for all vehicles. A_m is the frontal surface area of vehicle m in m^2 and ρ is the air density measured in kg/m^3.

Lastly, the model contains input parameters that are constant and equal for all arcs, nodes, and vehicles:

$\boldsymbol{C_{tt}}$: Hourly labour cost of drivers in NOK.

$\boldsymbol{C_e}$: Cost of energy in NOK/kWh.

$\boldsymbol{r_f}$: Charging rate at charging stations f in kW, ∀ f ∈ F.

3.1.3 Decision variables

The values of the model’s decision variables are dependent on the purpose of the model, as defined by its objective function, and the constraints imposed to avoid solutions that are not transferable to real-world operations. As the problem instances are solved using a two-stage approach, the decision variables differ in the first and second stage. In the first stage, the following decision variables are incorporated:

$\boldsymbol{X_{ijm}}$ **:** Represents the vehicle flow on arcs (i,j) , $\forall\ i,j \in$ A.

This variable is binary, where the value 1 represents an arc being travelled, while a value of 0 implies that the arc is not traversed.

$\boldsymbol{lw_{im}}$: Total weight delivered on route at node i in kg, $\forall\ i \in$ G.

For each delivery made by a vehicle, lw_{im} amounts to the total weight of demand of all nodes visited prior to and including node i. This decision variable is used to monitor the total weight of the load of a given vehicle, making sure the capacity constraint Qw_m of the vehicle is not violated.

In the second stage of the model, the following decision variables included in addition to those used in the first stage:

$\boldsymbol{\tau_i}$: Duration of route at node i in hours, $\forall\ i \in$ V.

Starting at $\tau_0 = 0$ at the terminal (equivalent to 07:00 a.m.), and tracking time as a function of the travel time (t_{ij}) and handling time (h_i) at each node. Constraints imposed on this variable ensures that the model generates routes in which customers are serviced within their respective time windows (between $tStart_i$ and $tEnd_i$).

$\boldsymbol{e_{ijm}}$: Energy consumption on arc (i,j) in kWh, $\forall\ i,j \in$ A, $\forall\ m \in$ M

This variable measures the energy consumption of a vehicle on arc (i,j). It is used to determine when a vehicle's SoC is insufficient to reach the subsequent customer node, and the amount of energy that should be recharged at a charging location before continuing its route. e_{ijm} is estimated by using the function presented by Basso et al. (2019) and Lin and Zhou (2020), as shown in equation (4):

$$e_{ijm} = \alpha(W_m + l_{ij})d_{ij} + {\beta_m (v_{ij})^2 d_{ij}}/{e_f} \tag{4}$$

In equation (4), W_m is the weight of the vehicle, and l_{ij} is the payload of the vehicle on arc (i,j) in kg, derived from the total weight of demand on route subtracted by the lw_{im}. Furthermore, v_{ij} is the vehicle speed on arc (i,j), assumed to be 60 km/h as when calculating t_{ij}. Lastly, e_f is the engine efficiency of the vehicle, expressed as a percentage of the total energy consumed.

To conduct sensitivity analyses on the impact of ambient temperatures on the feasibility and estimated OC of our solutions, different values for AT, as described in Table 3.5, are applied as a multiplier to the energy consumption function (4). This is done to examine how a factor that is known to have a significant impact on ECV performance, further discussed in 3.3.7, yet is rarely considered in EVRP literature, may disproportionally impact S_{Electric} relative to the alternative S_{Diesel}.

3.1.4 Objective function

The objective function is a linearised function derived from equation (4), and the operational cost functions from equations (6) and (7), described in Section 3.1.5. This objective function accounts for the relevant costs associated with the selection of routes, and by minimizing this function, the model seeks to optimize the routing of the vehicle fleet. The objective function applied in our model is a revision of that of Lin and Zhou (2020), and, as the solution presented in Section 3.2.3 is obtained using a linearised mixed-integer program, the objective function is linearised. Since charging infrastructure is incorporated at a later stage, the cost incurred by time spent at charging locations is not part of the objective function. Consequently, the objective function is as presented in equation (5):

$$\begin{aligned} \min Z = &\sum_{(i,j)\in A}\sum_{m\in M} C_e \alpha_{ij} W_m d_{ij} x_{ijm}/e_f + \sum_{(i,j)\in A}\sum_{m\in M} C_e \alpha_{ij} l_{ij} d_{ij} x_{ijm}/e_f \\ &+ \sum_{(i,j)\in A}\sum_{m\in M} C_e \beta_m (v_{ij})^2 d_{ij} x_{ijm}/e_f + \sum_{(i,j)\in A}\sum_{m\in M} C_{tt} t_{ij} x_{ijm} \end{aligned} \tag{5}$$

Here, the first two terms account for the energy costs based on the weight of vehicle W_m and its payload l_{ij}, while the third term minimizes a vehicle's energy consumption based on its velocity. Lastly, the fourth term measures the labour costs of the staff onboard vehicles.

Additionally, to compare operational costs of ECVs and the existing DCV fleet, the same energy consumption function in equation (4), as well as the objective function in equation (5), is applied to both S_{Electric} and S_{Diesel}, using vehicle-specific variables to differentiate their energy consumption.

3.1.5 Operational cost function

The OC of each solution generated by S_{Electric} is calculated as in equation (6):

$$\mathrm{OC} = \sum_{i,j \in A} \sum_{m \in M} e_{ijm} C_{er} + \sum_{m \in M} Qe_m C_{et} + \sum_{i,j \in A} \sum_{m \in M} RdC_{tt} \tag{6}$$

Where C_{er} is the charging cost en route and C_{et} is the charging cost at the terminal. As the model minimize the en-route charging so that it arrives at the terminal with no remaining battery capacity, as discussed in Section 3.1, a full recharge of the battery at the terminal is incorporated in the OC. Additionally, as labour cost is incurred as long as a vehicle is in operation, the total time spent on the route *Rd* is multiplied accordingly.

Furthermore, the operational cost function incorporated in S_{Diesel} is presented in equation (7):

$$\mathrm{OC} = \sum_{i,j \in A} \sum_{m \in M} e_{ijm} C_{ed} + \sum_{i,j \in A} \sum_{m \in M} RdC_{tt} \tag{7}$$

Where C_{ed} is the cost per unit of energy in kWh for a DCV when refuelling diesel. While equation (6) reflects the fact that the ECV fleet incurs a lower cost by charging at the terminal, relative to using publicly available charging infrastructure, it is assumed that no such alternative exists for DCVs.

3.1.6 Constraints

For the model to generate feasible solutions based on the objective function presented in Section 3.1.4, constraints have been imposed on the model. The purpose of the constraints are multiple: Firstly, they impose restrictions inherent to all single depot VRPs, by stating that vehicles must depart from the terminal, visit their assigned set of customer nodes exactly once, and then return to the same terminal. Constraints are also used to differentiate between nodes that must be visited, as they constitute customer locations, and those that are optional, meaning the charging location nodes. Additionally, as time windows constitute restrictions on when a customer node may be visited, these are formulated as constraints. Furthermore, restrictions are imposed to ensure the model does not propose trivial solutions by generating routes that are not replicable in real-world operations. For instance, constraints prevent the generation of routes where the total weight of demand exceeds the loading capacity of the vehicles.

The first constraint of the model is used in the first stage and ensures that each route has precisely one connection to and from the terminal. This same constraint makes sure all routes start and end at the terminal, meaning sub-tours (routes that start/end elsewhere than the terminal) are prevented. Also, the constraint requires that all customer nodes must be visited exactly one time, as formulated in equation (8):

$$\sum_{j \in V} \sum_{m \in M} x_{ijm} = \sum_{j \in V} \sum_{m \in M} x_{jim} = 1, \forall i \in N \tag{8}$$

In the second stage of the model, where charging infrastructure is incorporated, equation (8) is modified as it would otherwise restrict vehicles from arriving at a customer node or the terminal from a charging station. To allow for visits to charging stations while en route, a reformulation of equation (8) can be seen in equation (9) and (10):

$$\sum_{i \in G} \sum_{m \in M} x_{ijm} = 1, \forall j \in N \tag{9}$$

$$\sum_{j \in G} \sum_{m \in M} x_{ijm} \leq 1, \forall j \in G \tag{10}$$

From equation (9), the model is constrained to visit every node of list N exactly once, irrespective of the departing node. Hence, the model allows for travelling from the terminal, a customer, or charging location, to the next customer node. Additionally, equation (10) restricts the number of times any arc (*i*,*j*) can be travelled. Effectively, no arcs can be traversed more than once, but must not necessarily be travelled at all.

Equation (11) ensures that the total weight of demand on a given route does not exceed the load capacity of a vehicle:

$$\mathrm{lw_{im}} \leq \mathrm{Qw_m}\ , \forall \mathrm{i} \in \mathrm{N}, \forall \mathrm{m} \in \mathrm{M} \tag{11}$$

In the second stage, the model imposes hard constraints on time windows for both ECVs and CDVs, effectively creating enough routes to ensure all customers are visited within their preferred time windows. The time window constraints are formulated in equation (12):

$$\mathrm{tStart_i} \leq \tau_\mathrm{i} \leq \mathrm{tEnd_i}\ , \forall \mathrm{i} \in \mathrm{V} \tag{12}$$

In this second stage, the addition of charging stops is done subsequently to the calculation of τ_i. Consequently, although time windows are imposed as hard constraints, the subsequent addition of charging stops are not subject to equation (12), allowing the generation of routes that do not uphold time windows as the result of required charging.

It should be noted what while the proposed two-stage approach enables the solving of large problem instances, the exclusion of the impact of en-route charging practices on solution conformity to time windows is not considered. However, as real-world operations also regularly result in late deliveries outside time windows due to externalities such as traffic congestion or road work, this is deemed an acceptable compromise. The impact of this approach on our solutions is discussed in Chapter 4, and potential remedies are proposed in Chapter 5.

3.1.7 Sensitivity analysis

As briefly noted in Section 3.1.3 and further discussed in Section 3.3.7, the ambient temperature AT impacts the energy consumption of vehicles (Anisimov et al., 2017; Reyes et al., 2016). AT results in changes to both the cost of recharging C_e and labour cost C_{tt} due to more time spent at charging stations. Intuitively, as these costs make up the OC discussed in this thesis, the sensitivity of AT may have a significant impact on the results. Furthermore, AT is rarely considered in existing EVRP literature, adding relevance to its sensitivity analysis.

3.2 Problem complexity and solution methods

The subsequent sections describe the general problem complexity associated with routing problems, and how heuristic algorithms are utilized to circumvent the challenges posed by NP-hard problems. Furthermore, we describe our applied solution method, and how our model was verified and benchmarked.

3.2.1 Problem complexity

While early iterations of the VRP enabled the determination of near-optimal solutions to problem sets containing a small number of nodes, even allowing for hand computation, current VRP models have developed immensely in both their complexity and incorporation of real-world dynamics. In order to accurately imitate the processes and systems found in logistics and transportation networks, the inclusion of factors such as time windows for deliveries, fluctuating traffic levels, and real-time demand changes have given rise to a wide range of sub-problems (Braekers et al., 2016). Furthermore, while Dantzig and Ramser (1959) and Clarke and Wright (1964) provided solutions for synthetic networks of a single terminal with 15 customers, modern applications of VRP models by large corporations regularly require solutions encompassing multiple terminals and thousands of customers (Hall & Partyka, 2014). As the number of possible routes is a factorial function, the computational complexity of a problem increases significantly just by increasing the network size. For instance, while a network of ten customer nodes results in 362,880 possible routes, a network of 20 customer nodes has 2.43 quintillion (10^{18}) possible routes. As more comprehensive objective functions and model parameters are incorporated to better imitate real-world operations, problem complexity rapidly increases further.

In 1981, Lenstra and Kan (1981) demonstrated that while of varying complexity, nearly all iterations of the VRP are of non-deterministic polynomial-time hardness (NP-hard). Consequently, the problems are unsolvable in polynomial time, meaning that the upper bound of time spent to solve the problem is not a function of n^k where n is the problem size and k is a positive constant. The use of exact algorithms is consequently still inefficient in all but the smallest problem instances, despite significant advancements in computational power and its availability. Due to the sheer scale of real-world applications, one must instead rely on heuristic and metaheuristic algorithms.

3.2.2 Heuristic algorithms

While a heuristic method, or approximation algorithm, enables the solving of real-world problems, selecting the most suitable algorithm necessitates evaluating their performance against a set of criteria. Barr et al. (1995) and Cordeau et al. (2002) proposes running-time, solution quality, flexibility, robustness and ease of implementation.

The first two, running time and solution quality, are commonly considered trade-offs, as the application of any heuristic assumes that obtaining a feasible solution to a problem in shorter time is preferable to solving it at an optimum using an exact algorithm. In other words, arriving at a feasible solution within a specified timeframe increases the value of the solution. For instance, if one imagines the operation of a logistics network, if a VRP is not solved in time to inform the routing of vehicles, its value is significantly diminished. Bräysy and Gendreau (2005) measure approximation algorithms' performance by plotting them in two-dimensional space as shown in Figure 3.1, where one axis constitutes run-time and the other a measure of solution quality, given by the cumulative number of vehicles (CVN) required.

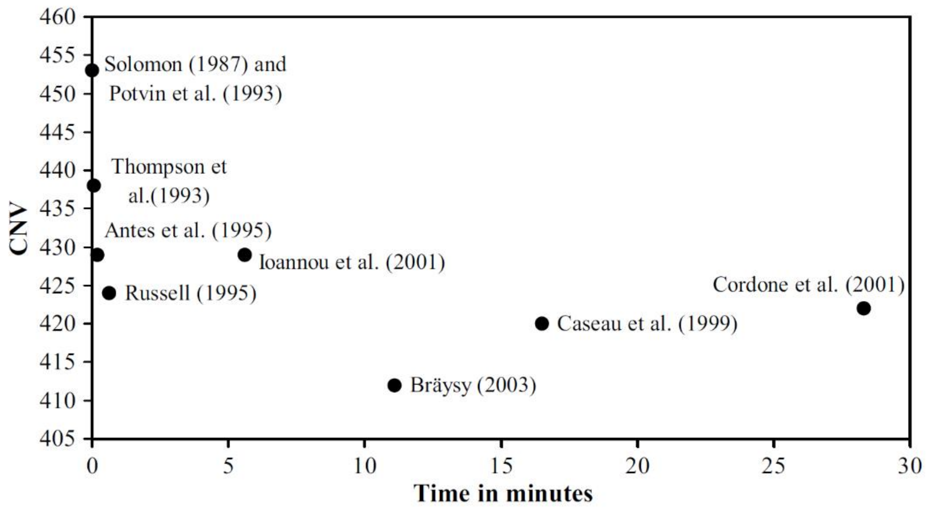


Figure 3.1 Efficiency of proposed solution methods, measured in time and the cumulative number of vehicles (CNV) required (Bräysy & Gendreau, 2005)

Furthermore, the flexibility of an algorithm describes its ability to handle changes to the model, such as its constraints or objective. Robustness, on the other hand, refers to an algorithm's ability to consistently render high-quality solutions, both across ranges of problem instances with differing characteristics, as well as if it is applied to the same instance more than once. The latter is important due to the nondeterministic nature of some heuristics, where the randomization of parameters will result in different solutions to the same problem when executed repeatedly (Cordeau et al., 2002). Consequently, when assessing the suitability of any nondeterministic heuristic algorithm, determining its average performance across multiple executions of the same problem instance is vital.

3.2.3 Solution method

Our model utilizes an academic licence of Gurobi's Python solver API on all problem instances. Gurobi's mixed-integer programming (MIP) solver uses a range of heuristic methods to seek for an optimal solution. As the primary purpose of our model is to assess problem feasibility within reasonable time, the model allows a MIP-gap of 0.6. Allowing a MIP-gap of 0.6 effectively means that when the gap between lower and upper objective bound is less than 0.6 multiplied by the absolute value of the incumbent objective value, the solution is considered a satisfactory compromise between solution quality and running time.

By allowing a MIP-gap, the model can stop its search for an optimal solution to a problem instance at a predetermined point. This was done in the benchmark presented in Section 3.2.4 where the results of this thesis' model were deemed satisfactory compared to best-known results of the benchmarked problem set.

All simulations of the benchmark and case study problem set were executed using a Dell XPS 9570 laptop with an Intel i7-8750H CPU with six cores at 2.20 GHz, 16 GB RAM, running Windows 10 Pro. All modelling was done in Python 3.8 and solved using Gurobi 9.1.1. For the scenario problem instances, run-times during the first stage ranged from 23 seconds to 4.13 hours across problem instances, while second stage run-times ranged from 7 seconds to 1.41 hours.

3.2.4 Model validation

For VRPTW models, the most common way to compare the applied heuristic algorithms' performance and simultaneously validate the model's solutions is by benchmarking it to the problem sets first proposed by Solomon (1987) (Bräysy & Gendreau, 2005). The more than 50 Solomon benchmark problems have distinct characteristics to enable testing for different scenarios, including multiple network sizes, demand levels and node densities. Our model is validated using problem set C1, as it contains customer nodes organized in clusters, which resembles the way BHD's customers tend to be distributed.

C1 comprises nine sub-sets to solve, C101, C102, …, C109, each containing 100 customers organized by Cartesian coordinates. Furthermore, the weight of demand, time windows and handling times at nodes are included in the problem set. As customers' locations are provided in Cartesian coordinates, the cost of travel in the benchmark is the Euclidean distance between each customer. Hence, the objective function for the benchmark model is to minimize the total Euclidean distance travelled, rather than the objective function presented in Section 3.1.4.

As customer one has the location (x_i, y_i) and customer two has the location (x_j, y_j), the Euclidean distance (ed_{ij}) can be calculated using equation (13):

$$\mathrm{ed_{ij}} = \sqrt{(\mathrm{x_j} - \mathrm{x_i})^2 + (\mathrm{y_j} - \mathrm{y_i})^2} \tag{13}$$

Existing solutions to problem set C1 (SINTEF, 2008) indicate that for all nine sub-sets, the optimal vehicle fleet consists of 10 vehicles. Furthermore, the best solutions found indicates a distance averaging 828.38 units with a minimal distance value of 824.78.

The model employed in this thesis generates solutions where the vehicle fleet varies between 10 and 13 vehicles, with an average of 11 and a standard deviation of 1.12 vehicles. Furthermore, the average total travel distance across all nine sub-sets is 1,276.66 units with a standard deviation of 384.71, and the best sub-set solution resulting in a total distance of 826.45 units.

The benchmark results confirm that the model achieves its primary objective: to provide feasible output within an acceptable time. As described in Section 3.2.3, a MIP-gap of 0.6 was accepted in the solving of benchmark sub-sets, which was likely to be the primary reason for the non-negligible standard deviations. A correlation between solving time and solution quality found adds credibility to this assumption.

3.3 Data collection and analysis

The following section details how the various types of data incorporated in the thesis were collected, processed, and analysed. Furthermore, as our work relies heavily on the consideration of how real-world dynamics affects the feasibility of a zero-emission vehicle fleet, justifications for the inclusion or omission of variables are made.

3.3.1 Customer network

The network of nodes considered by the model consists of three types; the depot or terminal from which the vehicles depart (t01), the customer locations (a001, a002,…, a*n*) and the charging locations (c001, c002,..., c*n*). The first type, t01, is simply BHDs terminal in Oslo, Haugenstua, and equal across all problem instances.

The nodes consisting of customer locations (a001, a002,..., a*n*) were collected using historical order data from BHDs proprietary route planning software HappyFlow. Once compiled, the dataset contained information pertaining to all orders delivered from BHDs terminal in Haugenstua, Oslo, in the period 01.01.2017 to 31.12.2020. The inclusion of multiple years in the initial dataset allowed the identification of trends or extremes in demand that do not necessarily occur annually. Meanwhile, orders made prior to 2017 were registered in a different system, and, due to a lack of compatibility with the available dataset from the current system, were therefore omitted from further processing. Next, orders, represented by individual rows, were further parsed so that those which did not result in last-mile deliveries by a BHD vehicle were removed. This included goods forwarded to another BHD terminal before delivery, or orders which were returned or for other reasons not delivered by BHD. For instance, customers may choose to pick up ordered goods themselves at the terminal *t01* and, while this would appear as an individual order in the dataset, it would not have resulted in a BHD vehicle being dispatched to deliver it. The remaining dataset contained approximately 300,000 last-mile deliveries made over the past four years. Each row provides information including a sender's reference (used as a primary key for each order), the recipient's address, the demanded weight Dw_i and volume Dv_i of the goods, the planned delivery date and time window, and the date and time of actual delivery. Furthermore, it includes the name of the route on which the delivery was made. The dataset was then further parsed according to the criteria described in Section 3.4 to determine the set of customer nodes to be included in each problem instance, and network matrices generated as detailed in Section 3.3.3.

3.3.2 Charging network

The dataset containing the final node type, charging locations (c001, c002,..., c*n*) was first derived using a publicly available API from *OpenChargeMap.org*. However, upon parsing and cleaning the exported dataset, it became apparent that the service's reliance on both commercially provided and crowdsourced data resulted in a considerable number of duplicate and erroneous registrations of charging infrastructure. Consequently, we chose to collect data from *info.nobil.no,* a public database compiled by the governmental entity Enova and the Norwegian Electric Vehicle Association (Bøe, 2012). Using an API request, an overview of all charging infrastructure within a 300-kilometre radius of *t01* was compiled, resulting in a list containing 1,981 charging locations. Using data provided by NOBIL, the set was further parsed by removing duplicate locations, identified as rows with identical coordinates, and charging locations that are not available to the public. The final dataset contained 731 charging locations, including their address, owner, number of charging points, as well as the type of charger available at each location.

3.3.3 Compilation of networks and creation of matrices

Once all nodes to be included in the network of a problem instance were determined, each node's location and elevation in the geographic coordinate system were established based on their address using OpenSteetMap API and Google Elevation API, and all addresses were subsequently replaced with geographic coordinates. Then, all nodes were compiled in separate lists constituting the worst-, medium- and best-case scenario according to the criteria described in Section 3.4. For instance, the network of nodes considered in the best-case scenario consists of t01 (the terminal), a001-a083 (the customers), and c001-c731 (the charging locations). For the other scenarios, while t01 and c001-c731 remained identical, the list of customer nodes was replaced to reflect the characteristics of orders made in that scenario.

To accurately measure the distance a vehicle must travel on the arcs between all nodes on a directed graph, distance matrices between all nodes in each scenario were created using proprietary software from the parent company of BHD, Posten Norge AS, with data collected from OpenStreetMap. Furthermore, using Microsoft Excel, matrices containing the elevation difference between the nodes were generated using information available in the compiled datasets.

3.3.4 Labour cost

The hourly labour cost of drivers C_{tt}, is derived from the most recent publicly available collective bargaining agreement for short-distance drivers in Norway (Yrkestrafikkforbundet, 2020). Assuming an equal share of trained and untrained drivers employed and a 37.5-hour working week, the average hourly wage of a driver is NOK 188.75. By adding the corresponding pension contribution of 5.70 % (The Confederation of Norwegian Enterprise, 2018), and a mandatory Employer's National Insurance Contribution of 14.1 % (the Norwegian Tax Administration, 2020), the hourly labour cost per driver is estimated to be NOK 227.64. As BHD exclusively delivers goods in excess of 35 kg, it is assumed that there are two drivers assigned per vehicle, and C_{tt} is therefore set to NOK 455.28 to reflect the incurred cost of labour per hour a vehicle is in operation.

3.3.5 Energy cost

The battery charging cost in NOK per kWh is estimated using publicly available pricing data from all Norwegian charging infrastructure providers (Norwegian Electric Vehicle Association, 2020). As vendors employ different pricing structures, where some charge only per kWh used, while others include an additional fee per minute a charging point is occupied (thereby incentivizing fast charging vehicles), prices were estimated assuming fast charging a 52.8 kWh battery in 60 minutes. Furthermore, to reflect the difference in ownership shares among vendors, prices were weighted according to the number of charging locations operated by each vendor in the network considered, as shown in Table 3.2. Consequently, the estimated cost per kWh C_{er} is NOK 3.96.

Table 3.2 The cost of charging 52.8 kWh in 60 minutes in NOK, weighted by share of ownership in the considered network

Vendor	**Locations**	**Share of total**	**Price (NOK)**
BKK	29	3.97 %	9.05
Circle K	24	3.28 %	8.65
E.ON	12	1.64 %	3.47
Fortum charge & drive	233	31.87 %	59.29
Ionity	9	1.23 %	2.65
Kople	45	6.16 %	13.12
Mer	121	16.55 %	40.38
Supercharge	2	0.27 %	0.62
Tesla	31	4.24 %	5.75
Oslo kommune	225	30.78 %	66.27
Total	**731**	**100.00 %**	**209.26**

The cost of energy at the depot is also estimated to account for the significant difference in the cost of using public charging infrastructure compared to privately owned chargers. Using the average cost of energy in Norway for 2020, including grid rent and taxes, C_{et} is estimated to be NOK 0.79 per kWh (Statistics Norway, 2021a).

Lastly, the cost of energy for DCVs is derived using the average litre price of diesel in 2020, equal to NOK 13.86 (Statistics Norway, 2021b). Assuming an energy density of 12 kWh/kg and 1.16 l/kg diesel, the cost per kWh for DCVs, C_{ed}, is estimated to be NOK 1.34 (Norwegian Environment Agency, 2021).

3.3.6 Vehicle specifications

While the formulations for the proposed models incorporate agent-specific variables, enabling the solving of problems with heterogeneous vehicle fleets, the results in Chapter 4 are obtained using a homogenous fleet where all vehicles have identical characteristics. This is a compromise made to ensure that even the largest problem instances can be solved at a MIP-gap of 0.6 within six hours, a self-imposed limit to ensure model revisions can be made within reasonable time if needed, as the number of possible solutions is significantly reduced. As demonstrated in Lin and Zhou (2020), a heterogeneous fleet of vehicles with different battery sizes, charging times, and loading capacities would likely result in a better solution, as one can tailor vehicle characteristics to specific routes. This is particularly true if one considers the total cost-of-ownership of ECVs, where a vehicle's battery pack constitutes a significant share of its acquisition cost, meaning vehicles with long ranges should only be acquired if that capacity is utilized.

S_{Electric} is solved using a Mitsubishi Fuso eCanter (Mitsubishi Fuso, 2021). The vehicle is selected as it is the only ECV currently available to BHD with the characteristics necessary to deliver all types of goods. Two such vehicles are currently undergoing testing by BHD as part of a pilot project to evaluate their suitability for last-mile deliveries. To determine the diesel vehicle to utilize in the alternative C-VRTPW, a dataset containing all vehicles currently owned or contracted by BHD was obtained. The Mercedes-Benz Sprinter 5500 diesel truck was chosen, as it is the most similar to the aforementioned ECV with regards to loading capacity and vehicle weight, and therefore best suited for comparative analysis (Mercedes-Benz, 2019). A summary of the vehicles' specifications is shown in Table 3.3.

Table 3.3 Vehicle specifications

Manufacturer Model name	**Mitsubishi Fuso eCanter**	**Mercedes Benz Sprinter Long 5500**
Battery capacity, usable (kWh)	66	-
Fuel tank capacity (l)	-	71
Energy per fuel tank (kWh)	-	734
Charging rate (kW)	50	-
Vehicle curb weight (kg)	3,110	2,360
Vehicle load capacity (kg)	4,130	3,140
Frontal surface area (m^2)	4.45	5.80

One should note that a significant difference between the vehicles chosen is the higher load capacity of the ECV compared to the DCV. Depending on the impact of the weight carried by vehicles on the energy consumption, this may significantly influence the number of routes included in a given solution and the node visiting order. However, as the ECV chosen is considered the most viable zero-emission vehicle available to BHD, and the DCV is the most comparable combustion-engine vehicle currently used by BHD, they are deemed suitable for answering the research questions.

3.3.7 Ambient temperatures

The ambient temperature in which ECVs operate is known to significantly impact their range, primarily due to increased energy consumption from auxiliary systems to regulate the temperature of the battery cells and vehicle cabin. While combustion engine vehicles are also affected, their less efficient drivetrains produce excess thermal energy which is redirected to climatize the vehicle cabin, and they contain no batteries which require heating or cooling. Based on the findings of Reyes et al. (2016) and Anisimov et al. (2017), the impact of ambient temperatures on vehicle range relative to their measured range at 20°C is summarized in Figure 3.2.

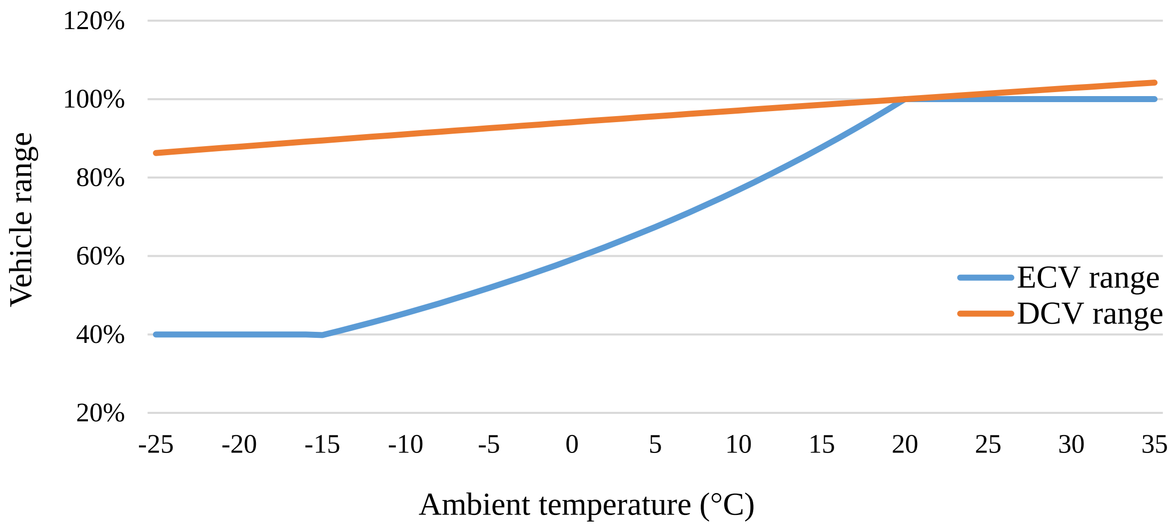


Figure 3.2 Vehicle range at different ambient temperatures, as percentage of measured range at 20 °C

As ECVs are significantly more sensitive to ambient temperatures, their performance will also be subject to greater variation across seasons, or even days. Consequently, the omission of temperatures in modelling would likely render solutions that deviate significantly from real-world operations, particularly in regions subject to large seasonal differences.

With an API request, weather data from the Norwegian Centre for Climate Service's publicly available database was collected, confirming significant variations in ambient temperatures. Daily observations for the period 01.01.2016 to 31.12.2020 from weather station SN18269, located in close vicinity of *t01*, showed that temperatures ranged from -22 to 33 °C, equal to a difference of 55.3 °C. Following the selection of dates that would constitute scenarios, as described in Section 3.4, the scenarios were categorized according to the season in which they occurred, as shown in Table 3.4.

Table 3.4 Categorization of scenarios according to season

Scenario	**Date**	**Season**	**Season span**
Worst case	04.12.2020	Winter	December - February
Medium case	02.07.2019	Summer	June - August
Best case	28.03.2018	Spring	March - May

The AT incorporated in the solution of each problem instance were then derived using the median seasonal temperature in the period 01.01.2016 to 31.12.2020. Furthermore, the minimum seasonal temperatures from the same periods are collected to enable a discussion of how sensitive the proposed solutions are to this variable in Chapter 4. The temperatures and corresponding impact on ECV and DCV range are summarized in Table 3.5.

Table 3.5 Ambient temperatures used in scenarios, and the corresponding impact on vehicle range relative to their performance at 20 °C

	Temperature (°C)		**ECV range (%)**		**DCV range (%)**	
Scenario	**Median**	**Minimum**	**Median**	**Minimum**	**Median**	**Minimum**
Worst case	- 0.7	- 22.0	58 %	40 %	94 %	87 %
Medium case	15.9	12.6	90 %	83 %	99 %	98 %
Best case	5.4	-8.4	67 %	48 %	96 %	92 %

3.4 Scenario selection criteria

As the feasibility of making last-mile deliveries using only ECVs appears dependent on factors such as network size, customer density and total travel distance (Davis & Figliozzi, 2013; Feng & Figliozzi, 2013; Lin et al., 2016), it was deemed appropriate to examine the performance of an ECV fleet in a range of scenarios. Following the steps described in Section 3.3.1, order data from BHD was analysed to identify dates where the level of demand would constitute suitable best-, medium-, and worst-case scenarios. In this context, it should be noted that “best” refers to the lowest, and thereby assumed most manageable, level of demand for last-mile deliveries BHD has had to satisfy in recent years. Similarly, “worst” signifies the scenario in which BHD has had to service the highest level of demand, while “medium” refers to what could be considered a day of average demand.

Firstly, a measure of demand was established. The number of orders scheduled for delivery per date was deemed most appropriate, as each row in the dataset constitutes a single order which is generated automatically as a customer requests delivery of an item from BHD. Consequently, there are no errors stemming from manual input, and no missing data that could cause erroneous quantities of demand. Alternative measures considered included the total weight or volume of goods delivered per day. However, the volume of items delivered appeared prone to incorrect or missing input, evident from frequently missing values or discrepancies between order descriptions and their stated size. Therefore, it was discarded from consideration and subsequently omitted as a model constraint entirely. Meanwhile, the total weight of goods demanded displayed a significant correlation coefficient of 0.83 at the 0.01 level with the daily number of orders, suggesting that the two could be used interchangeably without considerable impact on the final problem set. Another appropriate measure could have been the total distance travelled to make the deliveries historically. However, while the routes in which orders were included could be determined from the data collected, inconsistent registration of delivery times rendered the order in which deliveries were made unattainable. Consequently, reliable estimates of the total distance covered could not be made.

Using on the number of daily deliveries as a measure, the highest level of demand was identified as having occurred on 04.12.2020, and selected as the worst-case scenario. Furthermore, both the mean and median number of orders delivered had occurred on 02.07.2019, which was therefore selected as an appropriate medium-case scenario. Lastly, the dataset contained multiple dates on which only a single order had been delivered, and several others where the level of demand was deemed too small to constitute a meaningful problem instance for analysis. Consequently, the best-case scenario was identified as the date where the level of demand was closest to two standard deviations below the mean, which occurred on 28.03.2018. The subsequent problem set contained three problem instances. Each instance constitutes a scenario, the characteristics of which are summarized in Table 3.6. Coincidentally, the level of demand correlates to network size, so that the best-case scenario constitutes the smallest network geographically, while the worst-case scenario is the largest. A visual representation of the network size and geographic area considered in each scenario is shown in Figure 3.3.

Table 3.6 Summary of scenario characteristics

Scenario	Date	No. of orders	Total weight (kg)	Network size (km^2)
Worst case	04.12.2020	648	88,650	324,978
Medium case	02.07.2019	329	72,143	129,891
Best case	28.03.2018	72	13,217	36,865

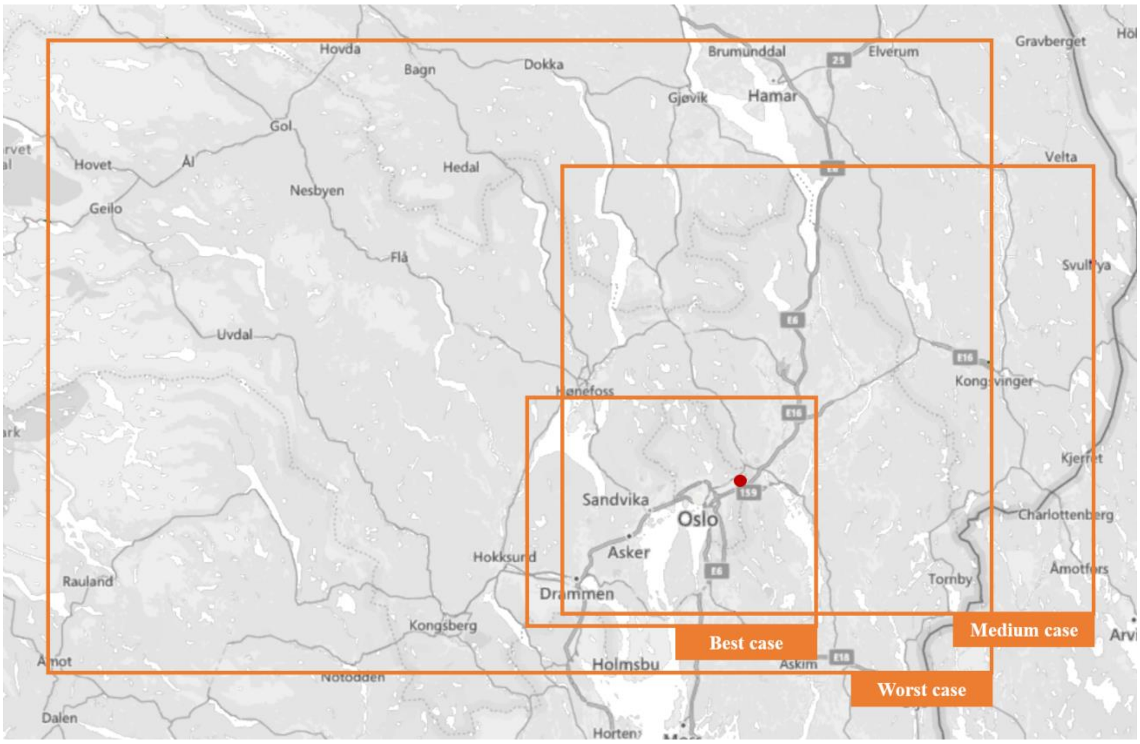


Figure 3.3 The network size and geographic area of each scenario, with the terminal represented as a red dot (scale 1:175 000)

4 Findings and analysis

In the following chapter, the simulation results of S_{Electric} are presented and compared to those of S_{Diesel}. First, the solutions to each scenario are detailed and critically discussed, followed by cross-scenario analyses of how the models' characteristics and sensitivity to a range of factors differ. Detailed solutions to all problem instances are provided in Appendix C.

4.1 Best-case scenario

As shown in Table 4.1, the solution proposed by S_{Electric} for the best-case scenario consists of four routes, denoted by Route_ID, of 21, 22, 19 and 10 deliveries, respectively. Six charging stops are included to reach all customer nodes, and the total time spent at charging locations is estimated to be 3.59 hours. The total operational cost (OC) is estimated to be NOK 12,912.

It should be noted that while the model is solved assuming an ambient temperature of 5.4 °C as shown in Table 3.5, a sensitivity analysis of the impact of this variable shows that delivering on the coldest day observed would increase energy consumption such that nine charging stops would be necessary. On the other hand, if one does not account for ambient temperatures at all, the proposed solution would require only two charging stops in total. This is further discussed in Section 4.4.3.

Table 4.1 Summary of routes in best-case scenario generated by S_{Electric}

Route_ID	Deliveries	In time-window	Charging stops	Payload (kg)	Travel dist. (km)	Travel time (h)	Charging time (h)	Route duration (h)	Energy cost (kWh)	OC (NOK)
r_01	21	16	2	3,559	177.81	6.56	1.23	7.79	127.40	3,840
r_02	22	16	2	3,690	171.55	6.59	1.54	8.13	142.97	4,056
r_03	19	19	1	3,741	124.56	5.42	0.59	6.01	95.64	2,903
r_04	10	8	1	2,227	122.39	4.21	0.22	4.43	77.16	2,113
Total	**72**	**59**	**6**	**13,217**	**596.32**	**22.78**	**3.59**	**26.36**	**443.17**	**12,912**

The solution proposed by S_{Diesel} for the same problem instance is summarized in Table 4.2. Here, six routes of 19, 12, 7, 9, 10 and 15 stops are generated, and the total OC is estimated to be NOK 12,611. The most energy-demanding route is r_04 with 128.55 kWh, well below the energy available per tank of diesel for the chosen DCV, meaning no refuelling stops are required. Sensitivity analysis of the impact of ambient temperatures shows that refuelling stops would not be necessary even in the coldest operating conditions, suggesting that the solution is more robust to changes in weather conditions.

Table 4.2 Summary of routes in best-case scenario generated by S_{Diesel}

Route_ID	Deliveries	In time-window	Payload (kg)	Travel dist. (km)	Route duration (h)	Energy cost (kWh)	OC (NOK)
r_01	19	19	2,612	168.51	6.15	103.35	2,938
r_02	12	12	1,286	37.00	3.05	23.45	1,419
r_03	7	7	2,081	90.78	3.29	58.70	1,578
r_04	9	9	2,807	126.93	4.16	128.55	2,065
r_05	10	10	2,716	133.80	4.40	72.87	2,101
r_06	15	15	1,715	146.60	5.26	122.00	2,560
Total	**72**	**72**	**13,217**	**703.62**	**26.31**	**508.92**	**12,661**

These findings indicate that there is a difference in the total OC of NOK 251 in the best-case scenario in favour of the DCV fleet. This constitutes an arguably negligible difference equal to an average of NOK 3.46 per delivery. It should be noted that the solution proposed by S_{Diesel} requires two more routes, presumably in part due to the lower vehicle load capacity of the DCVs relative to the ECVs, meaning fewer items can be transported simultaneously. However, while 13 of 72 deliveries are made too late when using ECVs, the absence of refuelling stops means that none of the time windows in the problem instance is violated with the DCV fleet. However, while the time windows included in the historical data set are occasionally violated, the duration of all routes in both solutions suggests that demand could be satisfied with both models within a single day of operation.

4.2 Medium-case scenario

In the medium-case scenario, S_{Electric} is solved with 26 routes, with the number of deliveries per route ranging from one to 29. There are 15 charging stops included, and a total of 9.34 hours is spent at charging locations. The resulting total OC is estimated to be NOK 56,964.

Table 4.3 Summary of routes in medium-case scenario generated by S_{Electric}

Route_ID	Deliveries	In time-window	Charging stops	Payload (kg)	Travel dist. (km)	Travel time (h)	Charging time (h)	Route duration (h)	Energy cost (kWh)	OC (NOK)
r_01	9	8	1	4,074	196.13	5.31	0.45	5.75	88.28	2,758
r_02	8	8	0	3,408	55.00	2.83	-	2.83	28.16	1,316
r_03	9	9	0	2,419	97.53	3.67	-	3.67	65.57	1,669
r_04	6	6	1	3,696	220.61	5.33	0.73	6.06	102.56	2,953
r_05	11	11	0	3,209	41.53	2.99	-	2.99	42.41	1,380
r_06	9	9	0	3,203	43.49	2.76	-	2.76	29.24	1,287
r_07	16	16	0	2,329	148.41	5.42	-	5.42	58.19	2,475
r_08	13	12	0	3,844	75.81	3.82	-	3.82	45.36	1,756
r_09	13	13	1	3,770	101.92	4.26	0.22	4.48	76.82	2,130
r_10	9	9	1	3,520	88.12	3.51	0.01	3.52	66.48	1,654
r_11	9	9	3	3,383	355.09	7.96	2.32	10.28	182.04	5,189
r_12	21	21	0	2,312	63.23	4.65	-	4.65	40.88	2,138
r_13	18	9	3	3,807	228.34	7.02	2.24	9.26	178.15	4,710
r_14	17	17	3	4,003	217.29	6.70	2.18	8.88	174.89	4,524
r_15	16	16	0	2,868	101.96	4.65	-	4.65	51.08	2,128
r_16	23	23	1	2,758	129.82	6.02	0.30	6.32	80.80	2,986
r_17	18	18	0	2,328	42.86	3.92	-	3.92	19.29	1,822
r_18	17	17	0	2,687	53.90	3.98	-	3.98	29.93	1,839
r_19	10	10	0	2,013	70.34	3.34	-	3.34	20.55	1,556
r_20	3	3	0	493	26.98	1.71	-	1.71	5.28	825
r_21	13	13	0	2,278	32.91	3.11	-	3.11	10.33	1,458
r_22	10	10	0	2,316	46.97	2.95	-	2.95	21.25	1,378
r_23	2	2	0	188	26.11	1.57	-	1.57	6.55	758
r_24	29	25	1	3,493	128.51	6.78	0.90	7.68	111.05	3,726
r_25	19	19	0	3,331	51.17	4.19	-	4.19	25.94	1,939
r_26	1	1	0	413	14.02	1.23	-	1.23	3.57	609
Total	**329**	**314**	**15**	**72,143**	**2,658.04**	**109.69**	**9.34**	**119.03**	**1,564.66**	**56,964**

As the scenario analysed occurred during the summer season, the problem instance is solved assuming an ambient temperature of 15.9 °C. This is close to the approximate ideal operating temperature of ECVs at 20 °C and above (Reyes et al., 2016), and thereby the most favourable conditions among the considered scenarios. The coldest mean temperature in the sample period was 12.6 °C, in which the increased energy consumption of the ECV fleet would result in a total of 17 charging stops, only two more than the proposed solution. If the effect of ambient temperature is omitted from the model entirely, the total energy consumed would still require 11 charging stops.

Table 4.4 Summary of routes in medium-case scenario, generated by S_{Diesel}

Route_ID	Deliveries	In time-window	Payload (kg)	Travel dist. (km)	Route duration (h)	Energy cost (kWh)	OC (NOK)
r_01	11	11	3,083	173.12	5.19	144.03	2,554
r_02	9	9	3,009	79.88	3.37	52.93	1,606
r_03	9	9	2,580	61.43	3.06	44.13	1,454
r_04	9	9	2,419	165.39	4.80	116.94	2,341
r_05	2	2	368	15.39	1.39	7.04	641
r_06	7	7	2,557	41.10	2.47	21.06	1,151
r_07	1	1	141	8.21	1.14	3.72	523
r_08	9	9	2,689	157.41	4.66	117.07	2,280
r_09	4	4	1,656	23.40	1.78	11.18	825
r_10	2	2	938	22.99	1.51	12.14	705
r_11	10	10	3,054	231.74	6.03	137.46	2,931
r_12	6	6	2,060	302.91	6.70	204.00	3,324
r_13	5	5	2,984	49.46	2.34	32.45	1,111
r_14	13	13	3,081	111.43	4.42	116.89	2,168
r_15	1	1	460	43.78	1.73	19.76	814
r_16	3	3	1,493	20.34	1.60	9.12	740
r_17	9	9	2,717	87.66	3.50	43.30	1,652
r_18	3	3	1,979	177.27	4.21	81.57	2,028
r_19	19	19	2,625	105.07	5.09	86.14	2,434
r_20	18	18	2,235	120.50	5.22	83.83	2,488
r_21	18	18	2,241	49.28	4.03	30.83	1,877
r_22	6	6	1,943	24.32	2.06	13.99	955
r_23	17	17	2,734	64.28	4.15	61.18	1,972
r_24	12	12	2,607	192.07	5.63	144.28	2,758
r_25	7	7	1,675	105.04	3.53	75.21	1,708
r_26	14	14	2,136	165.96	5.46	122.81	2,649
r_27	23	23	2,723	128.10	6.00	119.19	2,890
r_28	9	9	2,136	90.66	3.55	48.23	1,681
r_29	20	20	2,555	54.34	4.38	37.03	2,042
r_30	18	18	2,516	40.94	3.89	24.06	1,804
r_31	10	10	2,090	148.57	4.65	88.48	2,234
r_32	14	14	2,488	47.65	3.48	40.89	1,641
r_33	11	11	2,171	36.76	2.91	20.09	1,353
Total	**329**	**329**	**72,143**	**3,146.43**	**123.92**	**2,171.03**	**59,335**

The solution proposed by S_{Diesel} is summarized in Table 4.4. Once again, the deliveries are distributed across a larger number of routes than the zero-emission alternative, with 33 routes of between one and 23 deliveries. While this may in part be caused by the DVCs limited load capacity, the total payload, 72,143 kgs, would in theory only require 23 routes to be distributed without violating the DCV's weight constraint. This may suggest that other restrictions, such as the hard time windows, are instead the principal driver for the addition of routes. None of the generated routes require refuelling, even if driven in the coldest observed summer conditions.

Of particular interest is the higher total OC than that of the ECV fleet, at NOK 59,335. While the difference is again minor, at an average of NOK 7.21 per delivery, the electrified vehicle fleet is able to deliver to all customers at a lower operational cost than the combustion engine alternative. However, it should again be noted that while the DCV fleet conforms to all time-window constraints, the ECV fleet arrives at 15 customer nodes after the prearranged timeframe.

4.3 Worst-case scenario

In the worst-case scenario, summarized in Table 4.5, the solution proposed by S_{Electric} contains 34 routes of between four and 32 deliveries each. The routing strategy requires 71 charging stops and a total of 57.68 hours spent at charging locations. In total, 4,542 km are travelled, and the resulting total OC is estimated to be NOK 125,504.

It should be noted that eleven of the routes, marked in red in Table 4.5, are deemed infeasible due to an absence of necessary charging locations, preventing the ECV fleet from reaching all customer nodes. As described in Section 3.1, when a route is infeasible due to a lack of charging infrastructure, their OC is calculated as if necessary charging infrastructure exists on the arc between customer nodes, so that the cost of these routes is reflected in the solution. As visually presented in Figure 4.1, the density of charging infrastructure is much higher in urban areas, while deliveries to remote areas often combine long travel distance with poor access to charging locations. Furthermore, a selection of routes requires a considerable number of charging stops, such as r_02, r_07, and r_27, with six, eleven, and nine charging nodes visited, respectively. This reflects the extensive customer network to be covered, at 324,978 km2 as illustrated in Figure 3.3, and the unfavourable weather conditions imposed on the problem instance, which occurs during the winter season. The ambient temperature is assumed to be - 0.7 °C, where the ECV’s range is estimated to be 58 % of its regular range. Furthermore, had the problem been solved using the lowest temperature observed, at - 22 °C, this would require an estimated 106 charging stops. Meanwhile, if one does not account for ambient temperatures at all, the same problem instance could be solved with 28 charging stops.

Table 4.5 Summary of routes in worst-case scenario generated by S_{Electric}

Route_ID	**Deliveries**	**In time-window**	**Charging stops**	**Payload (kg)**	**Travel dist. (km)**	**Travel time (h)**	**Charging time (h)**	**Route duration (h)**	**Energy cost (kWh)**	**OC (NOK)**
r_01	31	25	2	3,743	132.99	7.12	1.87	8.98	159.28	4,509
r_02	18	13	6	3,368	217.59	6.84	4.34	11.17	282.85	5,996
r_03	21	15	3	3,232	189.08	6.75	2.99	9.74	215.30	5,075
r_04	32	17	4	3,900	137.89	7.33	3.41	10.73	236.28	5,611
r_05	24	24	1	3,757	83.49	5.38	0.48	5.86	90.04	2,814
r_06	10	10	0	1,158	44.68	2.91	-	2.91	51.19	1,338
r_07	15	7	11	2,181	354.32	8.73	9.10	17.83	521.21	9,970
r_08	10	10	0	3,617	40.89	2.85	-	2.85	25.26	1,329
r_09	14	14	0	3,318	38.05	3.32	-	3.32	26.89	1,543
r_10	11	11	0	3,008	41.06	2.98	-	2.98	47.55	1,373
r_11	25	25	1	2,930	71.95	5.32	0.02	5.33	66.78	2,482
r_12	23	22	3	2,851	238.64	7.84	2.99	10.83	215.48	5,571
r_13	23	23	0	2,098	42.22	4.56	-	4.56	25.37	2,109
r_14	25	25	0	2,767	62.10	5.16	-	5.16	54.60	2,356
r_15	27	27	2	3,132	94.95	5.96	0.21	6.17	103.20	3,006
r_16	20	20	0	1,993	62.95	4.52	-	4.52	39.65	2,077
r_17	19	19	0	2,013	58.85	4.32	-	4.32	30.86	1,994
r_18	29	14	5	2,889	231.63	8.50	4.07	12.57	269.56	6,580
r_19	15	6	5	1,756	217.81	6.45	4.46	10.91	288.86	5,899
r_20	22	21	1	2,766	96.35	5.34	0.88	6.21	109.81	3,052
r_21	20	14	4	1,595	262.91	7.85	3.55	11.41	243.69	5,947
r_22	4	4	0	125	32.04	1.92	-	1.92	15.21	915
r_23	17	11	3	2,467	233.15	6.97	2.20	9.17	176.15	4,661
r_24	30	26	1	3,797	83.49	6.16	0.73	6.89	102.58	3,333
r_25	26	21	1	2,074	129.06	6.40	0.98	7.38	115.08	3,606
r_26	14	14	0	2,955	30.77	3.20	-	3.20	22.84	1,491
r_27	14	8	9	2,081	536.38	11.63	9.23	20.86	527.30	11,372
r_28	18	18	1	3,833	47.94	4.01	0.02	4.03	66.98	1,888
r_29	22	21	1	3,255	58.60	4.71	0.09	4.79	70.29	2,249
r_30	16	16	2	2,373	137.89	5.25	1.52	6.77	141.95	3,432
r_31	24	16	2	3,354	136.48	6.26	2.03	8.30	167.72	4,231
r_32	11	11	1	928	82.08	3.67	0.43	4.10	87.56	2,002
r_33	6	6	0	1,482	28.63	2.13	-	2.13	19.91	1,003
r_34	12	12	2	1,854	285.35	7.19	2.09	9.28	170.72	4,690
Total	**648**	**546**	**71**	**88,650**	**4,542.26**	**189.52**	**57.68**	**247.20**	**4,788.01**	**125,504**

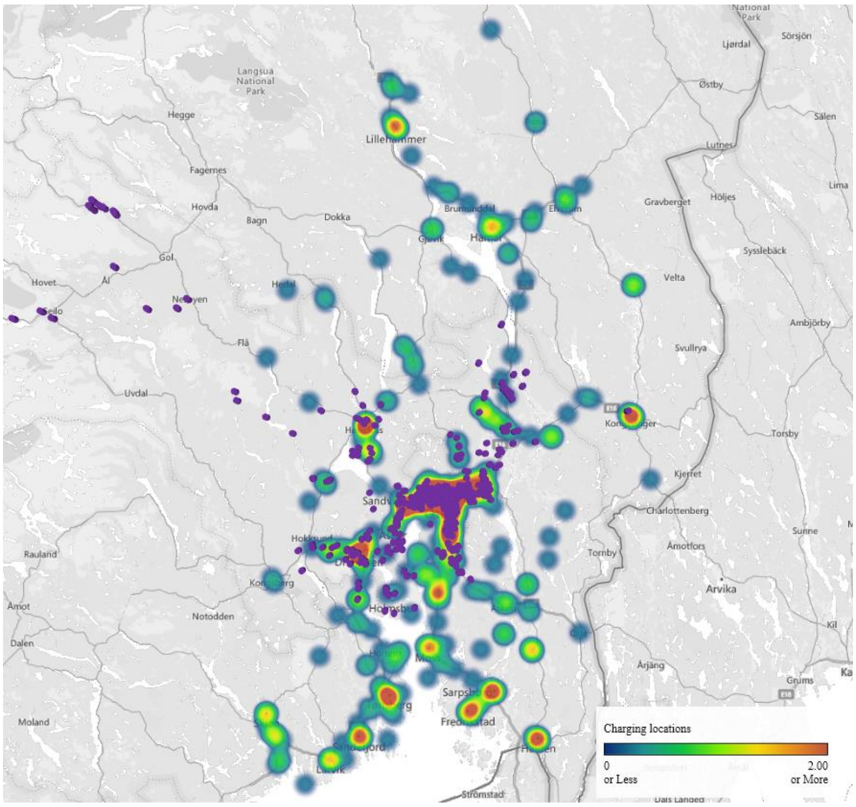


Figure 4.1 A heatmap showing the density of charging locations, with customer nodes from worst-case scenario superimposed in purple (scale 1:270 000)

S_{Diesel} solves the same problem instance as a total of 58 routes, ranging from one to 29 in the number of deliveries, as summarized in Table 4.6. The total distance travelled is 6,294 km, resulting in a total CO of NOK 114,713. Again, no route requires the consumption of one entire tank of diesel, even when subjected to the lowest ambient winter temperature observed. The model estimates that the most energy-intensive route (r_05), would require a total of 512.28 kWh if driven in the coldest weather conditions, nearly 200 kWh less than the 712 kWh stored in one tank of the modelled DCV. Consequently, the DCV fleet can complete all routes without refuelling across all scenarios.

As in the best-case scenario, S_{Diesel} outperforms S_{Electric} both in terms of total cost and timeliness. The total OC using DCVs is lower by NOK 10,791, equal to an average of NOK 16.65 per delivery. Meanwhile, all time windows are upheld, while 102 (or 15.74 %) of the 648 deliveries are made outside their assigned time window with S_{Electric}.

Table 4.6 Summary of routes in worst-case scenario, generated by S_{Diesel}

Route_ID	Deliveries	In time-window	Payload (kg)	Travel dist. (km)	Route duration (h)	Energy cost (kWh)	OC (NOK)
r_01	25	25	2,849	141.09	6.47	82.05	3,057
r_02	26	26	2,904	178.34	7.22	118.64	3,448
r_03	10	10	2,191	81.82	3.53	49.63	1,675
r_04	16	16	1,866	51.85	3.81	39.44	1,790
r_05	23	23	1,765	371.79	10.06	445.68	5,177
r_06	12	12	790	145.07	4.85	66.17	2,296
r_07	24	24	2,392	67.12	5.11	45.44	2,387
r_08	14	14	1,595	88.19	4.16	50.52	1,962
r_09	5	5	1,797	22.67	1.90	10.51	878
r_10	13	13	1,244	32.43	3.10	17.19	1,435
r_11	7	7	520	68.47	2.92	56.31	1,406
r_12	9	9	815	131.03	4.22	63.21	2,008
r_13	6	6	1,279	73.69	2.88	33.52	1,355
r_14	17	17	2,536	205.95	6.51	151.77	3,169
r_15	11	11	1,759	81.56	3.66	45.51	1,727
r_16	20	20	2,622	210.89	6.98	176.95	3,418
r_17	16	16	1,949	210.19	6.45	180.62	3,181
r_18	20	20	2,403	188.34	6.61	181.30	3,252
r_19	16	16	2,363	73.82	4.18	52.57	1,974
r_20	26	26	2,769	92.69	5.79	76.51	2,741
r_21	23	23	2,505	120.77	5.87	92.56	2,798
r_22	2	2	83	25.61	1.56	10.97	724
r_23	7	7	2,962	45.60	2.54	27.15	1,193
r_24	16	16	2,710	220.81	6.63	146.09	3,215
r_25	10	10	1,811	54.95	3.09	39.78	1,458
r_26	12	12	2,326	150.30	4.94	150.92	2,450
r_27	6	6	2,906	62.78	2.70	42.55	1,285
r_28	11	11	1,899	380.39	8.64	259.55	4,282
r_29	3	3	182	265.98	5.69	107.72	2,737
r_30	4	4	973	31.03	1.91	14.01	887
r_31	2	2	398	34.55	1.71	14.75	796
r_32	3	3	198	146.85	3.71	66.17	1,777
r_33	23	23	1,981	187.32	6.98	128.88	3,352
r_34	3	3	317	125.11	3.35	55.21	1,597
r_35	4	4	596	102.98	3.11	46.76	1,477
r_36	13	13	2,148	133.39	4.78	75.24	2,279
r_37	2	2	68	149.55	3.62	64.15	1,735
r_38	2	2	166	11.94	1.33	5.24	612
r_39	16	16	2,595	131.02	5.13	108.00	2,482
r_40	17	17	1,305	299.17	8.07	146.62	3,869
r_41	21	21	2,377	215.02	7.18	132.36	3,448
r_42	3	3	497	18.84	1.57	8.36	728
r_43	2	2	960	41.81	1.83	18.30	856
r_44	5	5	371	50.76	2.37	21.98	1,107
r_45	29	29	2,976	61.61	5.67	53.24	2,652
r_46	14	14	1,162	77.58	3.98	42.26	1,870
r_47	3	3	372	76.43	2.53	34.14	1,199
r_48	2	2	360	71.85	2.33	32.10	1,103
r_49	8	8	2,588	31.15	2.43	18.07	1,130
r_50	16	16	3,068	108.22	4.75	117.19	2,322
r_51	13	13	2,295	64.53	3.64	38.92	1,707
r_52	10	10	1,059	52.84	3.05	26.49	1,424
r_53	6	6	421	54.87	2.56	23.08	1,199

Table 4.6 continued

Route_ID	Deliveries	In time-window	Payload (kg)	Travel dist. (km)	Route duration (h)	Energy cost (kWh)	OC (NOK)
r_54	12	12	1,628	39.73	3.09	24.05	1,440
r_55	2	2	442	25.68	1.56	11.76	725
r_56	4	4	225	44.56	2.13	17.05	994
r_57	2	2	137	44.67	1.87	19.62	880
r_58	1	1	1,175	16.25	1.27	7.77	589
Total	**648**	**648**	**88,650**	**6,293.51**	**239.59**	**4,192.60**	**114,713**

4.4 Cross-scenario analysis of S_{Electric} and S_{Diesel} performance

In the following sections, the characteristics of the solutions generated by S_{Electric} and S_{Diesel} are presented and analysed, alongside cross-scenario performance measures. We identify differences in how the two models solve the considered problem instances and how their sensitivity to input variables vary.

4.4.1 Route characteristics

From the solutions described in the preceding sections, it is evident that minimization of operational costs requires distinctly different routing strategies depending on the mode of transportation employed. A selection of distinct characteristics for S_{Electric} and S_{Diesel} across all scenarios are summarized in Table 4.7 below.

Table 4.7 Summary of solution characteristics

		Avg. distance per delivery (km)	Average route duration (h)	Deliveries per charging stop
Best case	S_{Electric}	8.28	6.59	12.00
	S_{Diesel}	9.77	4.38	N/A
Medium case	S_{Electric}	8.08	4.58	21.93
	S_{Diesel}	9.56	3.76	N/A
Worst case	S_{Electric}	7.01	7.27	9.13
	S_{Diesel}	9.71	4.13	N/A

The total distance travelled by the ECV fleet is consistently shorter than that of the DCVs in all scenarios. This reflects the higher unit cost of energy for ECVs relative to DCVs, which incentivises S_{Electric} to carefully choose routes where travelling distance is minimized, while avoiding arcs where elevation differences between nodes would yield a higher total OC. Furthermore, it should be emphasized that the initial stage in the model solution does not consider the costs associated with charging en route, which would constitute a significant incentive for generating shorter, less energy-intensive routes.

4.4.2 Vehicle fleet size

Additionally, while S_{Electric} generates fewer routes than S_{Diesel} in all problem instances, it should be emphasized that this does not necessarily indicate that BHD could satisfy demand with a smaller ECV fleet than would be needed to service the same customer network using DCVs. While fewer in number, most ECV routes are considerably longer in duration, reflecting the impact charging stops has on the time required to visit all customer nodes. Intuitively, one can assume that a smaller proportion of an ECV fleet would be available to complete two or more routes in a working day than a DCV fleet.

While the acquisition cost and total cost-of-ownership for the respective fleets falls outside the scope of this thesis, and therefore is not subject to optimization in the objective function, the number of vehicles required in the proposed solutions are presented in Table 4.8. Across all scenarios, the solutions of S_{Electric} conform to the constraints proposed by Davis and Figliozzi (2013), where ECV fleets may be competitive in terms of total cost-of-ownership as long as fleet sizes do not exceed that of DCVs. However, factors such as the dissimilar loading capacities of the ECV and DCV modelled, the omission of acquisition costs from the objective function, and the fact that a selection of routes are infeasible using the considered ECV, renders conclusive findings regarding overall cost unattainable. Additionally, it should be noted that in the worst-case scenario, eleven of the routes generated by S_{Electric} are deemed infeasible, which could, in part, be remedied by dispatching more ECVs.

Table 4.8 Estimated size of vehicle fleet in each scenario

	Estimated size of vehicle fleet		
	Best case	**Medium case**	**Worst case**
S_{Electric}	4	15	21
S_{Diesel}	6	15	31

4.4.3 Energy efficiency and sensitivity to ambient temperatures

To examine the impact of energy efficiency on the competitiveness of ECVs, the average energy consumption per kilometre travelled is calculated as shown in Table 4.9 below. In the one problem instance where the ECV fleet outperforms its alternative with regards to total OC, the medium-case scenario, the fleet's energy consumption is significantly more efficient than in the other problem instances, and lower than the DCV in the same scenario. Furthermore, by examining the difference in energy efficiency when ambient temperatures are omitted from the model, we make two observations: Firstly, S_{Electric} would perform far more consistently across scenarios with regards to energy efficiency if the ambient temperatures assigned to each problem instance were equal instead of seasonal. Secondly, S_{Diesel} is far less sensitive to changes in ambient temperatures, possibly explaining in part why it outperforms S_{Electric} with regards to total CO in the scenarios where ambient temperatures deviate most from the vehicles' ideal operating conditions.

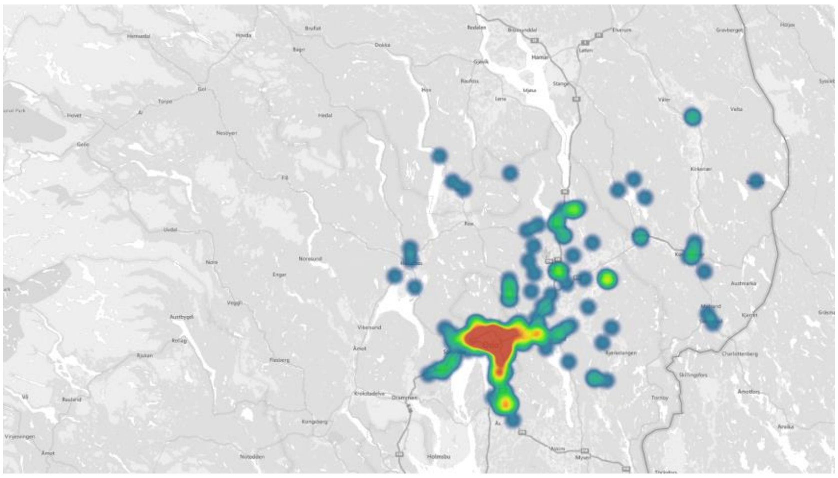
Table 4.9 Comparison of energy consumption sensitivity to ambient temperatures

		Energy use per km (kWh/km)		
		Observed median temperature	**Ambient temperature omitted**	**Difference**
Best case	S_{Electric}	0.74	0.50	0.25
	S_{Diesel}	0.72	0.68	0.04
Medium case	S_{Electric}	0.59	0.53	0.06
	S_{Diesel}	0.69	0.68	0.01
Worst case	S_{Electric}	1.05	0.61	0.44
	S_{Diesel}	0.67	0.64	0.03

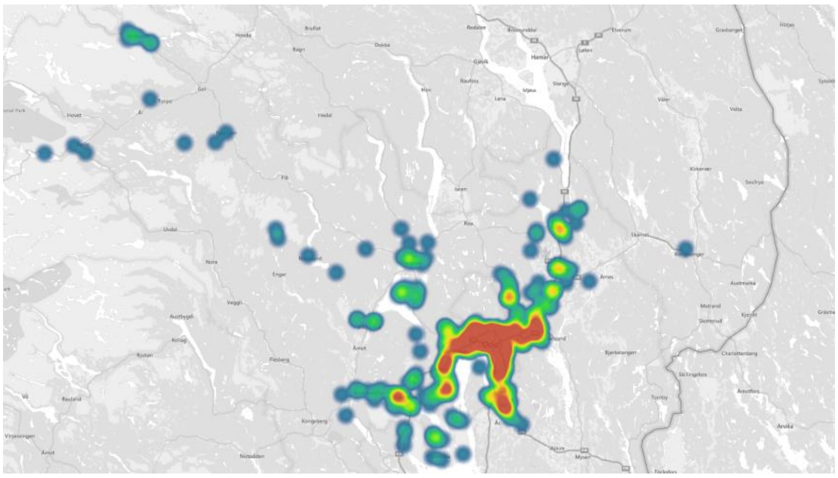
4.4.4 Additional performance measures

An additional measure that indicates when the ECV fleet is most competitive is the number of deliveries per charging stop, as shown in Table 4.7 above. In the medium case scenario, the ECV fleet completes an average of 21.93 deliveries per charge, while this value is 9.13 and 12 in the best- and worst-case scenario, respectively. As the DCV fleet is consistently able to deliver all goods without incurring any penalty from time spent refuelling, maintaining a high number of deliveries per charge is crucial for the ECV fleet to perform at a comparable total OC. While the feasibility of doing so is again dependent on factors such as ambient temperatures, one can assume that the deliveries per charge are negatively correlated with the density of customer nodes in a network. As shown in Figure 4.2, the network size and customer density differ significantly across scenarios, meaning the distance travelled to reach all nodes is subject to substantial variation across dates and their corresponding demand levels.

(a) Best case



(b) Medium case



(c) Worst case

Figure 4.2 A heatmap showing the density of customer nodes in each scenario (scale 1:260 000)

Furthermore, the average OC per delivery, as shown in Table 4.10 below, indicates that while the proposed solution of S_{Electric} outperforms S_{Diesel} in one problem instance, the model's per delivery OC is far less consistent across scenarios. Even when subject to the significant differences in the number of deliveries, customer densities, the number of routes and ambient temperatures unique to the different scenarios, the DCV fleet only differs NOK 4.51 in per delivery OC. In contrast, the ECV fleet exhibits a difference of NOK 20.54 between the highest and lowest observed value. Similarly, if one considers the OC per kilometre driven, the DCV fleet exhibits a difference of only NOK 0.86 across scenarios, while the corresponding value for the ECVs' is NOK 6.20. This suggests that while the solutions of S_{Diesel} are consistently longer with regards to travel distance, this has a negligible impact on the total OC. Meanwhile, as customer nodes in a problem set are increasingly far apart, the ECV fleet becomes less competitive.

Table 4.10 Comparison of OC per delivery and kilometre travelled

		OC per delivery (NOK)	**OC per km (NOK/km)**
Best case	S_{Electric}	179.34	21.65
	S_{Diesel}	175.84	17.99
Medium case	S_{Electric}	173.14	21.43
	S_{Diesel}	180.35	18.86
Worst case	S_{Electric}	193.68	27.63
	S_{Diesel}	177.03	18.23

5 Discussion

The following chapter discusses our main findings in relation to the research questions and their implications to both practice and theory.

5.1 Implications to practice

Through the simulation of real-world data conducted in this thesis, we demonstrate how a logistics provider such as BHD can assess the feasibility of delivering to a set of customers using an ECV fleet. Additionally, the estimation of the incurred OC enables an evaluation of the commercial viability of zero-emission last-mile deliveries. By simulating three distinctly different scenarios, our findings help to not only assess feasibility, but provides insight into how the OC of the respective fleets is impacted by a range of different factors.

Our findings suggest that feasibility is contingent on the availability of charging infrastructure, which, if accessible, alleviates challenges caused by limited vehicle ranges and long travel distances to customers. The results presented in Section 4.3 shows how a selection of routes in the worst-case scenario were deemed infeasible, primarily due to a combination of remote customer locations and the absence of charging infrastructure, as illustrated in Figure 4.1.

For deliveries to rural areas with low customer density to be viable, improvements to either ECV ranges or the expansiveness of charging infrastructure is required. It should be noted, however, that even if charging locations were ubiquitous, the need for multiple recharges to reach customers would render it challenging to uphold time windows. This implies that one would either need to deploy more vehicles to service the same customer set or be willing to compromise on delivery times. In some cases, where customers are densely located far away from the terminal, it is likely the travel time to the cluster itself which has the most impact on total OC and travel time, not the delivery to customer nodes once there. Hence, dispatching additional ECVs would only partially mitigate the challenges posed by deliveries to remote areas. Nevertheless, rapid technological progress and infrastructure expansion could still render all routes feasible before BHD’s self-imposed 2025-time limit to transition to an ECV fleet.

As mentioned, ECVs’ reliance on charging infrastructure to reach remote areas negatively impacts their ability to uphold time windows. One possible remedy is to limit the time windows available to customers depending on their location. For instance, customers located in zip-codes known to incur long travel times, may only be able to schedule deliveries in the afternoon, increasing the likelihood that ECVs can arrive in time. Furthermore, our model employs an ECV with a fixed charging rate of 50 kW and assumes the same rate at all charging locations. In reality, charging rates will vary across locations and vehicles. Assuming a heterogeneous vehicle fleet, BHD could dispatch ECVs with faster charging capabilities where most beneficial, and the unique characteristics of charging nodes could be incorporated in the model to minimize total charging times. Intuitively, one can assume that routes would be modelled to accept longer travel distances in favour of shorter recharging times, if doing so results in lower total OC or the conformity to time windows.

Our second research question concerns the OC associated with an ECV fleet. Our findings suggest that the OC of an ECV fleet is comparable to that of a DCV fleet. Most notably, in the medium-case scenario, ECVs outperformed the DCVs in terms of total OC. However, these findings must be seen in their appropriate context to render meaningful conclusions.

Firstly, as the purpose of this thesis is to compare the cost of operating an ECV fleet relative to BHDs current operations, the vehicles used in simulations are selected accordingly. As discussed in Section 3.3.6, the Mitsubishi Fuso eCanter is chosen as the most viable ECV currently available to BHD, while the Mercedes-Benz Sprinter 5500 is the most similar DCV currently operated by BHD. While the ECV has a higher loading capacity, enabling the delivery of more goods per route on average, the DCV has a more favourable range, meaning their estimated OCs are not directly comparable. Ultimately, this thesis aims to assess OC using real-world data, which is why vehicles with differing characteristics are simulated and compared. Nevertheless, the low difference in OC suggests that a transition to an ECV fleet with characteristics similar to the Fuso eCanter is possible without compromising BHD's competitiveness in the market. It should be noted that the acquisition cost of the respective vehicle fleets is not considered, as BHD's business model relies on the leasing of vehicles from sub-contractors, but this could have a significant impact on the financial viability of an ECV fleet.

Secondly, the OC of an ECV fleet is found to be significantly more sensitive to changes in ambient temperatures. This finding is of particular relevance when operating in Norway, which is subject to significant seasonal changes in ambient temperatures. This sensitivity will cause OC to vary considerably from summer to winter, or potentially between days, even if demand remains constant. This suggests that the competitiveness of ECVs relative to DCVs could be contingent on externalities that are challenging or impossible to mitigate. For instance, while ambient temperatures had no significant impact on the DCV fleet, large variations in ECV range and need for en route charging could suggest that BHD would need to ensure constant access to additional ECVs and drivers in case of unfavourable weather conditions. Maintaining this excess capacity, even if done through sub-suppliers, would undoubtedly incur additional costs,.

Lastly, our proposed model design does not incorporate the costs associated with potential detours of the route for recharging. In remote locations, it is likely that routes will be longer due to the scarcity of available charging infrastructure. The costs associated with time spent driving to and from these charging stations and the incurred energy consumption are not incorporated in the OC. It is likely that these costs can vary from close to zero for routes consisting of deliveries in cities, while they may amount to significant additional costs on remote routes with low density of charging infrastructure.

5.2 Implications to theory

The work presented in this thesis contributes to existing VRP literature by demonstrating how a wide range of real-world dynamics can be incorporated in the solution of a large C-EVRPTW. Due to the multitude of factors to which an ECV fleet is sensitive, EVRPs are inherently limited by their computational complexity. Current literature can be characterized as a balancing-act between the provision of near-optimal solutions to small problem instances (Lin et al., 2016), the incorporation of a high number of real-world variables for accurate cost measures (Basso et al., 2019), or a compromise between the two to enable the solving of larger customer networks (Lin & Zhou, 2020). By employing the two-stage solution method proposed in this thesis, we increase the number of nodes that can be considered as part of a problem instance while retaining a comprehensive objective function, thereby increasing the replicability of dynamics found in real-world systems.

Furthermore, by solving multiple problem instances with distinctly different characteristics, we demonstrate how the same case study subject may render different conclusions regarding the feasibility and competitiveness of ECV fleets, depending on the applied selection criteria for problem sets, model parameters and input variables. For instance, the sensitivity analysis conducted on the impact of ambient temperatures on ECV performance show how the omission of, or changes to, a single variable can have significant impact on whether a solution is deemed feasible. Furthermore, the solutions of S_{Diesel} were more consistent and robust across scenarios and sensitivity analyses than S_{Electric}, indicating that findings from constructed problem sets will be less transferable to real-world problems when concerning ECVs, and emphasizing the importance of careful collection and consideration of data in future work.

6 Conclusion

This thesis examines the feasibility of transitioning to a fully electrified vehicle fleet for last-mile deliveries, using a Norwegian logistics provider as a case study. Our two-stage method enables the solving of a Capacitated Electric Vehicle Routing Problem with Time Windows (C-EVRPTW) with a customer and charging node network equal in magnitude to the highest demand levels experienced by the case study subject, while incorporating a large number of variables that would render the computational complexity too high to solve if not segmented. Using the proposed method, we solve three problem instances representing low, average, and high levels of demand, and incorporate instance-specific data to accurately reflect real-world dynamics. Our findings indicate that the operational costs of an ECV fleet are comparable to that of a conventional DCV fleet in all scenarios, and was in one problem instance found to be lower. However, the performance of an ECV fleet, comprised of measures such as route duration, the operational cost per delivery, and the corresponding total operational cost, is subject to greater variation, and considerably more sensitive to changes in factors such as customer density and ambient temperatures. Furthermore, the servicing of customers in the most remote areas of the networks is deemed infeasible due to limited vehicle ranges, a lack of charging infrastructure and long charging times. However, the utilization of a non-exhaustive overview of charging locations in the model solution, rapid deployment of new infrastructure and technological advancements to battery technology suggests that ECVs may constitute viable substitutes for DCV fleets in the near future.

7 Future research

The purpose of this thesis is to increase the applicability of simulation theory to challenges encountered by providers of last-mile deliveries, as their transition to zero-emission vehicle fleets becomes increasingly urgent. While our model relies heavily on real-world data collection, there are still many factors that could be incorporated to reduce the gap between theoretical models and real-world systems. For instance, while this thesis neglects the total cost-of-ownership of vehicles to reflect the business model of the case study subject, incorporating the acquisition cost and depreciation of vehicles in the objective function could increase its applicability to other enterprises. Additionally, future iterations of the C-EVRPTW would benefit from considering the impact of en-route charging stops in the first stage of the model, as this would increase the number of routes where time windows are upheld. Lastly, the sensitivity of ECVs to variables not considered in this thesis should be explored, such as the impact of drivers' experience and skill level on energy efficiency.

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Appendix A: Numerical values of common input parameters

Notation	Description	Value	Reference
C_{tt}	Hourly labour cost of vehicle (NOK)	455.28	(The Confederation of Norwegian Enterprise, 2018; the Norwegian Tax Administration, 2020; Yrkestrafikkforbundet, 2020)
C_{er}	Cost of energy (NOK/kW) en route	3.96	(Norwegian Electric Vehicle Association, 2020)
C_{et}	Cost of energy (NOK/kW) at terminal	0.79	(Statistics Norway, 2021a)
C_{ed}	Diesel cost (NOK/kW)	1.34	(Norwegian Environment Agency, 2021; Statistics Norway, 2021b)
C_d	Coefficient of air drag	0.70	(Akcelik & Besley, 2007)
C_r	Coefficient of rolling resistance	0.0064	(Basso et al., 2019)
e_f (ECV)	Engine efficiency (input energy/output energy)	85%	(Sripad & Viswanathan, 2017)
e_f (DCV)	Engine efficiency (input energy/output energy)	48%	(Giannelli et al., 2005)
ρ	Air density (kg/m^3)	1.225	
A (ECV)	Frontal surface area of vehicle (m^2)	4.45	(Mitsubishi Fuso, 2021)
A (DCV)	Frontal surface area of vehicle (m^2)	5.80	(Mercedes-Benz, 2019)
r	Charging rate (kW)	50	
g	Gravitational acceleration (m/s^2)	9.81	
W (ECV)	Curb weight of vehicle (kg)	3,110	(Mitsubishi Fuso, 2021)
W (DCV)	Curb weight of vehicle (kg)	2,360	(Mercedes-Benz, 2019)
Qw (ECV)	Vehicle load capacity (kg)	4,130	(Mitsubishi Fuso, 2021)
Qw (DCV)	Vehicle load capacity (kg)	3,140	(Mercedes-Benz, 2019)
Qe (ECV)	Battery capacity, usable (kWh)	66	(Mitsubishi Fuso, 2021)
Qe (DCV)	Fuel tank energy capacity (kWh)	734	(Mercedes-Benz, 2019; Norwegian Environment Agency, 2021)

Appendix B: Model formulation in pseudocode

B.I First stage

```
"""Enumerating locations to lists"""


location = {i : 0 for i in V}

for i,l1 in enumerate(N):

    location[l1] = location from data


for i,l1 in enumerate(O):

    location[l1] = location from data




"""Creating matrices"""

# Distance

locations = locations from distance matrix

dist = {(l, l) : 0 for l in locations}

for i,l1 in enumerate(locations):

    for j,l2 in enumerate(locations):

        if i < j:

            dist[l1,l2] = distances from distance matrix

            dist[l2,l1] = dist[l1,l2]


distance = {(l, l) : 0 for l in V}

for i,l1 in enumerate(V):

    for j,l2 in enumerate(V):

        distance[l1,l2] = dist[location[i], location[j]]
```

```
# Elevation/Alpha
locations = locations from alpha matrix
alt = {(l, l) : 0 for l in locations}
for i,l1 in enumerate(locations):
    for j,l2 in enumerate(locations):
        if i < j:
            alt[l1,l2] = alphas from alpha matrix
            alt[l2,l1] = dist[l1,l2]

alpha = {(l, l) : 0 for l in V}
for i,a1 in enumerate(V):
    for j,a2 in enumerate(V):
        alpha[a1,a2] = alt[location[i], location[j]]

Dw = {i : 0 for i in V}
for i,l1 in enumerate(N):
    Dw[l1] = weight data

Dv = {i : 0 for i in V}
for i,l1 in enumerate(N):
    Dv[l1] = volume data


# Creating Gurobi model
Model('FirstStepElectric)
```

```
# Adding decision variables
x = BINARY, ∈ A
lw = CONTINUOUS, ∈ V


Objective: MINIMIZE(sum((C_e*alpha[i,j]*W*distance[i,j]*x[i,j])/e_f for i,j ∈ A)
            + sum((C_e*beta*v**2*distance[i,j]*x[i,j])/e_f for i,j ∈ A)
            + sum(C_tt*(distance[i,j]/v)*x[i,j] for i,j ∈ A))

"""Restrictions"""

#Customer visit constraints
sum(x[i,j] for j in V if j!=i)= 1 for i ∈ N
sum(x[i,j] for i in V if i!=j)= 1 for j ∈ N

# Weight
(x[i,j]==1) >> (lw[i] + Dw[i] = lw[j])
           for i,j ∈ A if i!=0 if j!=0
lw[i] >= Dw[i] for i ∈ V
lw[i] <= Qw for i ∈ V

"""Model optimization"""
MIPGap = 0.6
optimize()
```

B.II Second stage

```
"""Enumerating locations to lists"""


location = {i : 0 for i in V}

for i,l1 in enumerate(N):

    location[l1] = location from data


for i,l1 in enumerate(O):

    location[l1] = location from data




"""Creating matrices"""

# Distance

locations = locations from distance matrix

dist = {(l, l) : 0 for l in locations}

for i,l1 in enumerate(locations):

    for j,l2 in enumerate(locations):

        if i < j:

            dist[l1,l2] = distances from distance matrix

            dist[l2,l1] = dist[l1,l2]


distance = {(l, l) : 0 for l in V}

for i,l1 in enumerate(V):

    for j,l2 in enumerate(V):

        distance[l1,l2] = dist[location[i], location[j]]
```

```
# Elevation/Alpha

locations = locations from alpha matrix

alt = {(l, l) : 0 for l in locations}

for i,l1 in enumerate(locations):

    for j,l2 in enumerate(locations):

        if i < j:

            alt[l1,l2] = alphas from alpha matrix

            alt[l2,l1] = dist[l1,l2]


alpha = {(l, l) : 0 for l in V}

for i,a1 in enumerate(V):

    for j,a2 in enumerate(V):

        alpha[a1,a2] = alt[location[i], location[j]]


Dw = {i : 0 for i in V}

for i,l1 in enumerate(N):

    Dw[l1] = weight data


Dv = {i : 0 for i in V}

for i,l1 in enumerate(N):

    Dv[l1] = volume data


        tStart = {i : 0 for i in N}

        for i,l1 in enumerate(N):

            tStart[l1] = time window data


        tEnd = {i : 0 for i in N}
```

```
    for i,l1 in enumerate(N):
        tEnd[l1] = time window data



    weight = Dw.values()
    total_weight = sum(weight)

# Creating Gurobi model
Model('C-ERVPTW')

# Adding decision variables
x = BINARY, ∈ A, name="x"
lw = CONTINUOUS, ∈ V, name="weight"
d = CONTINUOUS, ∈ V, name="distance")
t = CONTINUOUS, ∈ V, name="time" # Time tracker
e = CONTINUOUS, ∈ V, name="eConsumption"



Objective: MINIMIZE(sum((C_e*alpha[i,j]*3.11*distance[i,j]*x[i,j])/e_f for i,j ∈ A)
+ sum((C_e*alpha[i,j]*((total_weight-lw[i])/1000)*distance[i,j])/e_f for i,j ∈ A)
            + sum((C_e*beta*v_h**2*distance[i,j]*x[i,j])/e_f for i,j ∈ A)
            + sum(C_tt*(distance[i,j]/v_h)*x[i,j] for i,j ∈ A))



"""Restrictions"""

#Customer visit constraints
```

```
sum(x[i,j] for j in V if j!=i)= 1 for i ∈ N

sum(x[i,j] for i in V if i!=j)= 1 for j ∈ N


# Weight

(x[i,j]==1) >> (lw[i] + Dw[i] = lw[j])

            for i,j ∈ A if i!=0 if j!=0

lw[i] >= Dw[i] for i ∈ V

lw[i] <= Qw for i ∈ V


# Time windows

(x[i,j]==1) >> (t[i]+h[i]+(distance[i,j]/v_h) = t[j])

for i,j ∈ A if j>0

 t[j] >= tStart[j] for j ∈ N

 t[j] <= tEnd[j] for j ∈ N

# Distance tracker

(x[i,j]==1) >> (d[i] + distance[i,j] = d[j])

for i,j ∈ A if j>0;



# Energy consumption

(x[i,j]==1) >> ((alpha[i,j]*(W+(total_weight-lw[i]))

                   + (beta*distance[i,j]*(v**2))/e_f)*joules = e[j])

for i,j ∈ A if j>0


"""Model optimization"""


MIPGap = 0.6
```

```
optimize()

"""Pseudocode incorporation of charginge infrastructure (F)"""

for C-EVRPTW

initialize by setting i=0

for (j=1,n):

    when eConsumption[i,m] ("total energy consumed at node i") + e[i,j,m]

    >= Qe[m] (battery capacity of vehicle m):

        from i of V:

            search nearest f ∈ F

            Update C-EVRPTW with f after i and set i=j

        if d[i,f] <= 51220:

            render feasible

        else:

            render infeasible

    for (j=f,n):

        when eConsumption[i,m] ("total energy consumed at node i") + e[i,j,m]

        >= 0.8*Qe[m] ("80% of battery capacity of vehicle m"):

            from i ∈ V:

                search nearest f ∈ F

                Update C-EVRPTW with f after i and set i=j

            if d[i,f] <= 51220:

                render feasible

            else:

                render infeasible

                return


"""Pseudocode for charging time at charging stations"""
```

for C-EVRPTW

```
for i ∈ F:
    charge_time[i] = (eConsumption[i+1] - eConsumption[i]) / r
```

Appendix C: Model output

C.I Best case $S_{Electric}$

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_01	0	t01	-	-	-	2.23	-	2.23	-	-	66.00
r_01	1	a070	-	16.64	55,091	4.15	-	4.15	8.00	62.00	49.36
r_01	2	a040	-	0.18	55,157	4.28	-	4.28	8.00	74.00	49.18
r_01	3	a010	-	0.23	55,242	4.41	-	4.41	8.00	34.00	48.95
r_01	4	a005	-	11.61	59,516	4.61	-	4.61	8.00	19.00	37.33
r_01	5	a023	-	0.40	60,094	4.75	-	4.75	8.00	43.00	36.94
r_01	6	a022	-	-	60,094	4.88	-	4.88	8.00	34.00	36.94
r_01	7	a006	-	19.21	67,267	5.13	-	5.13	8.00	34.00	17.73
r_01	8	a019	-	1.21	74,410	5.38	-	5.38	8.00	11.00	16.52
r_01	9	a049	-	1.12	77,258	5.56	-	5.56	8.00	550.00	15.41
r_01	10	a067	-	0.02	77,307	5.69	-	5.69	8.00	85.00	15.39
r_01	11	a008	-	2.51	78,354	5.84	-	5.84	8.00	53.00	12.88
r_01	12	a013	-	0.26	78,969	5.98	-	5.98	8.00	19.00	12.61
r_01	13	a061	-	6.46	82,899	6.17	-	6.17	8.00	59.00	6.15
r_01	14	a065	-	0.50	96,614	6.53	-	6.53	8.00	103.00	5.65
r_01	15	c613	850.20	-	-	-	0.93	7.46	-	-	51.96
r_01	16	a012	-	23.85	106,990	6.83	-	7.76	8.00	1.00	28.10
r_01	17	a015	-	0.92	109,375	7.00	-	7.93	8.00	9.00	27.18
r_01	18	a064	-	0.95	110,352	7.15	-	8.08	8.00	1,172.00	26.23
r_01	19	a063	-	4.54	112,863	7.32	-	8.25	8.00	152.00	21.69
r_01	20	a039	-	-	112,863	7.45	-	8.38	8.00	24.00	21.69
r_01	21	a011	-	19.25	123,954	7.77	-	8.69	8.00	83.00	2.44
r_01	22	a024	-	2.44	130,176	8.00	-	8.93	8.00	938.00	-
r_01	23	c469	3,888.57	-	-	0.30	-	9.23	-	-	15.09
r_01	24	t01	-	15.09	177,814	8.79	-	10.02	-	-	-
r_02	0	t01	-	-	-	1.50	-	1.50	-	-	66.00
r_02	1	a029	-	2.79	7,328	2.63	-	2.63	6.00	226.00	63.21
r_02	2	a037	-	1.59	12,372	2.84	-	2.84	6.00	36.00	61.62
r_02	3	a069	-	4.45	20,871	3.11	-	3.11	6.00	19.00	57.17
r_02	4	a046	-	28.10	30,979	3.41	-	3.41	6.00	82.00	29.07
r_02	5	a007	-	6.49	33,342	3.58	-	3.58	6.00	10.00	22.58
r_02	6	a056	-	1.91	40,139	3.82	-	3.82	6.00	77.00	20.67
r_02	7	a033	-	2.49	41,057	3.97	-	3.97	6.00	200.00	18.18
r_02	8	a018	-	1.87	41,769	4.11	-	4.11	6.00	10.00	16.31
r_02	9	a014	-	3.87	43,246	4.27	-	4.27	6.00	10.00	12.44
r_02	10	a002	-	4.40	44,928	4.42	-	4.42	6.00	14.00	8.03
r_02	11	a054	-	0.32	46,639	4.58	-	4.58	6.00	50.00	7.71
r_02	12	a047	-	6.96	49,322	4.76	-	4.76	6.00	59.00	0.76
r_02	13	a053	-	0.39	50,159	4.90	-	4.90	6.00	97.00	0.37
r_02	14	c130	243.28	-	-	-	0.92	5.82	-	-	46.38
r_02	15	a066	-	0.46	52,053	5.06	-	5.98	6.00	32.00	45.92
r_02	16	a071	-	4.67	58,048	5.29	-	6.21	6.00	71.00	41.25
r_02	17	a043	-	6.22	60,551	5.46	-	6.38	6.00	53.00	35.03
r_02	18	a032	-	23.46	70,075	5.75	-	6.67	6.00	855.00	11.57
r_02	19	a059	-	1.22	77,133	6.00	-	6.92	6.00	60.00	10.34
r_02	20	a026	-	5.99	80,010	6.18	-	7.10	8.00	991.00	4.35
r_02	21	a020	-	4.35	82,611	6.35	-	7.27	8.00	108.00	-
r_02	22	c248	166.24	-	-	-	0.62	7.89	-	-	30.96
r_02	23	a036	-	8.98	110,944	6.95	-	8.49	8.00	51.00	21.98
r_02	24	a052	-	10.70	137,509	7.53	-	9.07	8.00	579.00	11.28
r_02	25	t01	-	11.28	171,552	8.09	-	9.63	-	-	-
r_03	0	t01	-	-	-	0.88	-	0.88	-	-	66.00
r_03	1	a042	-	2.83	7,038	2.00	-	2.00	6.00	1,288.00	63.17
r_03	2	a038	-	10.45	11,383	2.20	-	2.20	6.00	98.00	52.72
r_03	3	a045	-	1.18	15,084	2.39	-	2.39	6.00	60.00	51.55

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_03	4	a003	-	7.52	18,298	2.58	-	2.58	6.00	26.00	44.03
r_03	5	a017	-	0.32	19,550	2.73	-	2.73	6.00	18.00	43.71
r_03	6	a021	-	2.08	24,125	2.93	-	2.93	6.00	453.00	41.63
r_03	7	a025	-	0.60	25,108	3.08	-	3.08	6.00	46.00	41.02
r_03	8	a050	-	1.49	27,486	3.25	-	3.25	6.00	137.00	39.54
r_03	9	a057	-	0.28	27,946	3.39	-	3.39	6.00	89.00	39.25
r_03	10	a016	-	5.50	30,669	3.56	-	3.56	6.00	26.00	33.75
r_03	11	a035	-	0.69	31,596	3.71	-	3.71	6.00	91.00	33.06
r_03	12	a062	-	0.36	32,333	3.85	-	3.85	6.00	42.00	32.69
r_03	13	a031	-	3.53	34,138	4.01	-	4.01	6.00	598.00	29.17
r_03	14	a004	-	4.27	36,638	4.18	-	4.18	6.00	12.00	24.90
r_03	15	a051	-	5.65	53,131	4.59	-	4.59	6.00	204.00	19.25
r_03	16	a060	-	2.38	61,093	4.85	-	4.85	6.00	130.00	16.87
r_03	17	a028	-	6.52	65,266	5.05	-	5.05	6.00	49.00	10.34
r_03	18	a048	-	3.28	74,740	5.34	-	5.34	8.00	156.00	7.07
r_03	19	c143	5,148.20	-	5,148	0.59	-	5.93	-	-	36.71
r_03	20	a034	-	26.86	92,914	5.77	-	6.36	8.00	218.00	9.84
r_03	21	t01	-	9.84	124,565	6.30	-	6.89	-	-	-
r_04	0	t01	-	-	-	2.08	-	2.08	-	-	66.00
r_04	1	a041	-	6.39	23,408	3.48	-	3.48	6.00	182.00	59.61
r_04	2	a044	-	0.24	24,061	3.62	-	3.62	6.00	29.00	59.37
r_04	3	a009	-	40.22	49,262	4.17	-	4.17	8.00	210.00	19.15
r_04	4	a030	-	2.22	60,018	4.48	-	4.48	8.00	928.00	16.93
r_04	5	a068	-	1.59	63,972	4.67	-	4.67	8.00	233.00	15.33
r_04	6	a001	-	4.27	68,130	4.87	-	4.87	8.00	1.00	11.06
r_04	7	a058	-	6.79	88,132	5.33	-	5.33	6.00	128.00	4.27
r_04	8	a055	-	4.03	92,268	5.53	-	5.53	6.00	449.00	0.24
r_04	9	c354	2,064.53	-	-	-	0.22	5.76	-	-	11.41
r_04	10	a072	-	3.57	100,838	5.81	-	6.03	6.00	28.00	7.84
r_04	11	a027	-	3.00	104,701	6.00	-	6.22	6.00	39.00	4.84
r_04	12	t01	-	4.84	122,392	6.29	-	6.52	-	-	-

C.II Medium case $S_{Electric}$

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_01	0	t01	-	-	-	0.67	-	0.67	-	-	66
r_01	1	a097	-	4.22	-	2.00	-	2.00	6.00	763.00	61.78
r_01	2	a129	-	14.92	20,015	2.82	-	2.82	8.00	569.00	46.86
r_01	3	a143	-	3.26	61,710	3.16	-	3.16	8.00	1,130.00	43.60
r_01	4	a155	-	2.75	73,851	3.40	-	3.40	8.00	482.00	40.85
r_01	5	a153	-	21.98	80,382	3.77	-	3.77	8.00	7.00	18.87
r_01	6	a189	-	14.84	95,187	4.82	-	4.82	8.00	897.00	4.03
r_01	7	a098	-	-	150,118	4.95	-	4.95	6.00	101.00	4.03
r_01	8	a178	-	1.84	150,118	5.25	-	5.25	6.00	73.00	2.19
r_01	9	c409	876.11	-	160,212	-	0.45	5.69	-	-	24.46
r_01	10	a132	-	18.20	-	5.64	-	6.09	6.00	52.00	6.26
r_01	11	t01	-	6.26	176,012	5.98	-	6.42	-	-	-
r_02	0	t01	-	-	196,127	3.41	-	3.41	-	-	66
r_02	1	a242	-	3.43	-	4.67	-	4.67	6.00	92.00	62.57
r_02	2	a079	-	5.87	15,567	4.85	-	4.85	6.00	813.00	56.70
r_02	3	a090	-	0.56	18,570	5.07	-	5.07	6.00	834.00	56.14
r_02	4	a133	-	0.52	24,009	5.25	-	5.25	6.00	516.00	55.62
r_02	5	a084	-	9.77	27,225	5.51	-	5.51	6.00	175.00	45.85
r_02	6	a227	-	1.03	34,823	5.70	-	5.70	6.00	125.00	44.82
r_02	7	a130	-	1.98	38,415	5.86	-	5.86	6.00	799.00	42.84
r_02	8	a013	-	0.71	40,074	6.00	-	6.00	6.00	54.00	42.13
r_02	9	t01	-	4.28	40,822	6.24	-	6.24	-	-	37.84
r_03	0	t01	-	-	55,002	0.90	-	0.90	-	-	66
r_03	1	a081	-	1.80	-	2.00	-	2.00	6.00	75.00	64.20
r_03	2	a127	-	2.63	6,112	2.31	-	2.31	8.00	57.00	61.57
r_03	3	a017	-	1.80	16,635	2.46	-	2.46	8.00	29.00	59.77
r_03	4	a157	-	1.36	17,988	2.67	-	2.67	8.00	163.00	58.41
r_03	5	a128	-	0.99	23,096	2.82	-	2.82	8.00	437.00	57.42
r_03	6	a142	-	1.24	23,871	3.03	-	3.03	8.00	158.00	56.18
r_03	7	a083	-	44.71	28,644	3.84	-	3.84	8.00	1,288.00	11.47
r_03	8	a326	-	0.76	69,733	4.08	-	4.08	8.00	102.00	10.72
r_03	9	a110	-	8.19	76,140	4.41	-	4.41	8.00	110.00	2.53
r_03	10	t01	-	2.09	88,570	4.56	-	4.56	-	-	0.43
r_04	0	t01	-	-	97,526	2.68	-	2.68	-	-	66
r_04	1	a181	-	19.52	-	5.00	-	5.00	13.00	1,872.00	46.48
r_04	2	a302	-	2.52	79,355	5.28	-	5.28	13.00	55.00	43.95
r_04	3	a323	-	2.30	88,599	5.55	-	5.55	13.00	52.00	41.66
r_04	4	c608	5,345.60	-	96,592	-	0.73	6.28	-	-	78.21
r_04	5	a197	-	54.04	-	6.26	-	6.99	8.00	706.00	24.17
r_04	6	a306	-	6.73	131,476	6.82	-	7.55	8.00	989.00	17.44
r_04	7	a091	-	1.82	157,087	6.98	-	7.71	8.00	22.00	15.62
r_04	8	t01	-	15.62	158,860	8.00	-	8.74	-	-	-
r_05	0	t01	-	-	220,605	0.94	-	0.94	-	-	66
r_05	1	a225	-	2.56	-	2.00	-	2.00	6.00	49.00	63.44
r_05	2	a199	-	10.27	3,666	2.22	-	2.22	6.00	319.00	53.17
r_05	3	a180	-	12.29	9,234	2.47	-	2.47	6.00	464.00	40.88
r_05	4	a174	-	4.98	16,273	2.65	-	2.65	6.00	720.00	35.90
r_05	5	a177	-	0.38	19,380	2.80	-	2.80	6.00	300.00	35.52
r_05	6	a188	-	0.81	20,337	2.98	-	2.98	6.00	73.00	34.71
r_05	7	a212	-	0.11	23,556	3.12	-	3.12	6.00	96.00	34.60
r_05	8	a195	-	4.39	24,048	3.31	-	3.31	6.00	266.00	30.22
r_05	9	a126	-	2.15	27,600	3.47	-	3.47	6.00	82.00	28.06
r_05	10	a239	-	0.25	29,467	3.62	-	3.62	6.00	138.00	27.81
r_05	11	a101	-	0.60	30,608	3.76	-	3.76	6.00	702.00	27.22
r_05	12	t01	-	3.63	31,157	3.93	-	3.93	-	-	23.59
r_06	0	t01	-	-	41,533	3.40	-	3.40	-	-	66
r_06	1	a118	-	1.74	-	4.52	-	4.52	6.00	58.00	64.26

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_06	2	a102	-	8.92	6,794	4.73	-	4.73	6.00	205.00	55.35
r_06	3	a123	-	0.06	11,646	4.89	-	4.89	6.00	816.00	55.29
r_06	4	a175	-	0.90	13,441	5.05	-	5.05	6.00	144.00	54.38
r_06	5	a170	-	3.36	15,047	5.21	-	5.21	6.00	636.00	51.02
r_06	6	a103	-	4.29	17,320	5.40	-	5.40	8.00	935.00	46.73
r_06	7	a038	-	5.91	20,668	5.63	-	5.63	6.00	8.00	40.82
r_06	8	a107	-	0.40	26,616	5.83	-	5.83	6.00	218.00	40.43
r_06	9	a200	-	0.07	30,889	6.00	-	6.00	6.00	183.00	40.36
r_06	10	t01	-	3.60	33,336	6.17	-	6.17	-	-	36.76
r_07	0	t01	-	-	43,493	2.84	-	2.84	-	-	66
r_07	1	a223	-	1.02	-	3.91	-	3.91	6.00	141.00	64.98
r_07	2	a120	-	6.65	4,104	4.13	-	4.13	6.00	29.00	58.34
r_07	3	a119	-	-	9,328	4.26	-	4.26	6.00	21.00	58.34
r_07	4	a253	-	0.49	9,328	4.44	-	4.44	6.00	109.00	57.84
r_07	5	a222	-	0.15	12,461	4.57	-	4.57	6.00	306.00	57.69
r_07	6	a251	-	1.89	12,585	4.80	-	4.80	6.00	124.00	55.81
r_07	7	a036	-	5.86	18,525	5.02	-	5.02	6.00	1.00	49.94
r_07	8	a027	-	6.60	23,899	5.25	-	5.25	6.00	20.00	43.34
r_07	9	a056	-	8.76	29,953	5.89	-	5.89	8.00	28.00	34.58
r_07	10	a316	-	2.21	60,570	6.22	-	6.22	8.00	1,032.00	32.37
r_07	11	a179	-	0.36	72,252	6.36	-	6.36	8.00	59.00	32.01
r_07	12	a176	-	0.99	72,725	6.51	-	6.51	8.00	36.00	31.03
r_07	13	a190	-	0.72	74,061	6.68	-	6.68	8.00	174.00	30.30
r_07	14	a152	-	1.78	76,880	6.86	-	6.86	8.00	118.00	28.53
r_07	15	a086	-	8.86	79,515	7.22	-	7.22	8.00	42.00	19.66
r_07	16	a115	-	8.90	93,411	8.00	-	8.00	8.00	89.00	10.77
r_07	17	t01	-	2.96	132,416	8.27	-	8.27	-	-	7.81
r_08	0	t01	-	-	148,411	2.35	-	2.35	-	-	66
r_08	1	a108	-	3.29	-	3.56	-	3.56	8.00	1,029.00	62.71
r_08	2	a248	-	2.01	13,018	3.77	-	3.77	6.00	56.00	60.70
r_08	3	a226	-	6.63	17,413	3.95	-	3.95	6.00	102.00	54.07
r_08	4	a191	-	1.42	20,657	4.09	-	4.09	6.00	194.00	52.65
r_08	5	a229	-	1.09	21,364	4.33	-	4.33	6.00	86.00	51.56
r_08	6	a216	-	6.85	28,071	4.52	-	4.52	8.00	929.00	44.71
r_08	7	a234	-	0.47	31,626	4.69	-	4.69	8.00	112.00	44.25
r_08	8	a249	-	1.51	33,571	4.91	-	4.91	6.00	124.00	42.73
r_08	9	a136	-	10.83	39,057	5.15	-	5.15	6.00	279.00	31.90
r_08	10	a139	-	0.16	45,970	5.30	-	5.30	6.00	34.00	31.75
r_08	11	a238	-	1.80	46,996	5.58	-	5.58	6.00	65.00	29.95
r_08	12	a244	-	0.17	55,883	5.80	-	5.80	6.00	96.00	29.78
r_08	13	a135	-	6.25	61,193	6.00	-	6.00	6.00	738.00	23.53
r_08	14	t01	-	2.89	65,591	6.17	-	6.17	-	-	20.64
r_26	0	t01	-	-	75,808	2.35	-	2.35		-	66
r_26	1	a218	-	1.72	-	3.46	-	3.46	6.00	413.00	64.28
r_26	2	t01	-	1.85	7,009	3.58	-	3.58	-	-	62.43
r_09	0	t01	-	-	14,018	0.93	-	0.93	-	-	66
r_09	1	a214	-	0.98	-	2.00	-	2.00	6.00	336.00	65.02
r_09	2	a193	-	0.99	4,363	2.14	-	2.14	6.00	86.00	64.04
r_09	3	a122	-	9.24	4,833	2.34	-	2.34	6.00	777.00	54.80
r_09	4	a124	-	-	9,283	2.47	-	2.47	6.00	61.00	54.80
r_09	5	a168	-	7.80	9,283	3.04	-	3.04	8.00	570.00	47.00
r_09	6	a329	-	0.83	35,399	3.20	-	3.20	8.00	301.00	46.17
r_09	7	a035	-	0.30	37,518	3.34	-	3.34	8.00	39.00	45.87
r_09	8	a203	-	1.12	37,710	3.53	-	3.53	8.00	279.00	44.75
r_09	9	a192	-	3.10	41,852	3.70	-	3.70	8.00	130.00	41.66
r_09	10	a077	-	39.96	43,987	4.30	-	4.30	6.00	655.00	1.69
r_09	11	a224	-	1.54	72,335	4.55	-	4.55	6.00	264.00	0.15
r_09	12	c008	674.61	-	79,226	-	0.22	4.76	-	-	10.98
r_09	13	a236	-	1.87	-	4.78	-	5.00	6.00	221.00	9.11

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_09	14	a121	-	7.35	85,632	5.03	-	5.25	6.00	51.00	1.76
r_09	15	t01	-	1.76	92,578	5.19	-	5.40	-	-	-
r_10	0	t01	-	-	101,917	0.64	-	0.64	-	-	66
r_10	1	a145	-	5.50	-	2.00	-	2.00	8.00	460.00	60.50
r_10	2	a319	-	2.97	21,889	2.27	-	2.27	8.00	217.00	57.53
r_10	3	a208	-	15.61	30,273	2.54	-	2.54	8.00	546.00	41.92
r_10	4	a206	-	4.77	38,743	2.72	-	2.72	8.00	182.00	37.16
r_10	5	a150	-	2.98	41,591	2.88	-	2.88	8.00	1,560.00	34.17
r_10	6	a237	-	2.96	43,434	3.19		3.19	8.00	240.00	31.21
r_10	7	a230	-	19.58	54,228	3.63		3.63	6.00	52.00	11.64
r_10	8	a228	-	8.59	72,659	3.89		3.89	6.00	160.00	3.05
r_10	9	a104	-	2.70	80,869	4.07		4.07	6.00	103.00	0.35
r_10	10	c023	460.01	-	83,580		0.01	4.08			0.83
r_10	11	t01	-	0.83		4.14		4.15		-	-
r_11	0	t01	-	-	88,119	2.43		2.43		-	66
r_11	1	a144	-	22.62	-	5.00		5.00	13.00	84.00	43.38
r_11	2	a125	-	12.35	94,432	5.24		5.24	13.00	1,307.00	31.03
r_11	3	a096	-	29.47	100,795	5.69		5.69	8.00	370.00	1.56
r_11	4	c670	125.84	-	119,965		0.43	6.11			22.94
r_11	5	a167	-	2.41		6.00		6.43	8.00	66.00	20.53
r_11	6	a328	-	1.76	130,904	6.19		6.62	8.00	268.00	18.77
r_11	7	a088	-	6.17	134,485	6.40		6.82	8.00	92.00	12.60
r_11	8	c666	5,738.15	-	139,155		1.32	8.14			78.49
r_11	9	a075	-	65.40		7.37		9.11	13.00	820.00	13.09
r_11	10	a028	-	1.70	189,785	7.53		9.27	13.00	89.00	11.39
r_11	11	a322	-	11.39	191,420	8.42		10.16	13.00	287.00	-
r_11	12	c671	1,580.23	-	237,048		0.58	10.74			28.77
r_11	13	t01	-	28.77		10.38		12.71		-	-
r_12	0	t01	-	-	355,085	8.05		8.05		-	66
r_12	1	a318	-	1.71	-	9.19		9.19	10.00	308.00	64.29
r_12	2	a296	-	4.13	8,422	9.38		9.38	10.00	74.00	60.17
r_12	3	a313	-	0.56	11,831	9.54		9.54	10.00	118.00	59.61
r_12	4	a280	-	7.94	13,881	9.79		9.79	10.00	88.00	51.67
r_12	5	a058	-	5.55	20,776	10.00		10.00	15.00	16.00	46.13
r_12	6	a019	-	8.37	25,708	10.25		10.25	15.00	19.00	37.75
r_12	7	a320	-	0.54	33,190	10.49		10.49	15.00	232.00	37.22
r_12	8	a209	-	1.53	39,592	10.65		10.65	15.00	232.00	35.68
r_12	9	a072	-	0.56	41,064	10.79		10.79	15.00	36.00	35.12
r_12	10	a022	-	0.31	41,644	10.92		10.92	15.00	60.00	34.81
r_12	11	a310	-	0.31	41,963	11.09		11.09	15.00	51.00	34.51
r_12	12	a261	-	1.81	44,135	11.25		11.25	15.00	84.00	32.69
r_12	13	a037	-	0.14	46,097	11.38		11.38	15.00	16.00	32.55
r_12	14	a235	-	0.33	46,252	11.54		11.54	15.00	29.00	32.23
r_12	15	a052	-	0.65	47,752	11.68		11.68	15.00	15.00	31.58
r_12	16	a217	-	0.35	48,484	11.83		11.83	15.00	112.00	31.23
r_12	17	a076	-	2.23	49,504	12.00		12.00	15.00	3.00	29.00
r_12	18	a002	-	0.75	52,135	12.15		12.15	15.00	30.00	28.25
r_12	19	a008	-	0.18	53,027	12.28		12.28	15.00	93.00	28.07
r_12	20	a039	-	0.34	53,482	12.43		12.43	15.00	5.00	27.73
r_12	21	a196	-	0.15	54,288	12.56		12.56	15.00	691.00	27.58
r_12	22	t01	-	2.45	54,805	12.71		12.71		-	25.12
r_13	0	t01	-	-	63,227	8.11		8.11		-	66
r_13	1	a205	-	3.96	-	9.39		9.39	15.00	150.00	62.04
r_13	2	a286	-	4.88	16,541	9.70		9.70	15.00	199.00	57.16
r_13	3	a025	-	31.39	27,840	10.08		10.08	15.00	75.00	25.77
r_13	4	a029	-	12.66	42,643	10.86		10.86	15.00	90.00	13.10
r_13	5	a149	-	3.01	81,629	11.25		11.25	15.00	119.00	10.09
r_13	6	a166	-	2.67	97,238	11.47		11.47	15.00	118.00	7.43
r_13	7	c194	1,167.70	-	102,432		1.00	12.46			57.21

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_13	8	a161	-	43.95		11.96		12.96	15.00	1,226.00	13.26
r_13	9	a148	-	13.26	124,444	12.23		13.23	15.00	322.00	-
r_13	10	c482	5,084.13	-	132,637		1.08	14.31			54.24
r_13	11	a160	-	5.64		12.74		14.82	15.00	79.00	48.60
r_13	12	a171	-	2.15	155,270	12.97		15.05	15.00	213.00	46.45
r_13	13	a134	-	1.91	161,278	13.12		15.20	15.00	839.00	44.54
r_13	14	a099	-	21.60	162,611	13.56		15.64	15.00	27.00	22.95
r_13	15	a297	-	3.45	181,071	13.91		15.99	15.00	71.00	19.50
r_13	16	a137	-	1.31	194,195	14.06	-	16.14	15.00	124.00	18.19
r_13	17	a082	-	12.35	195,349	14.37	-	16.45	15.00	14.00	5.84
r_13	18	a005	-	4.67	206,560	14.57	-	16.65	15.00	74.00	1.17
r_13	19	a309	-	1.17	210,817	14.76	-	16.84	15.00	29.00	0.00
r_13	20	c035	146.56	-	214,340	-	0.16	17.01	-	-	8.12
r_13	21	a070	-	6.89	-	15.00	-	17.24	15.00	38.00	1.23
r_13	22	t01	-	1.23	220,808	15.13	-	17.37	-	-	-
r_14	0	t01	-	-	228,343	6.49	-	6.49	-	-	66
r_14	1	a049	-	8.12	-	8.00	-	8.00	15.00	12.00	57.88
r_14	2	a262	-	4.81	30,436	8.35	-	8.35	15.00	64.00	53.07
r_14	3	a207	-	22.13	43,840	8.64	-	8.64	15.00	364.00	30.94
r_14	4	a146	-	2.67	53,352	8.79	-	8.79	15.00	71.00	28.27
r_14	5	a031	-	13.23	54,558	9.02	-	9.02	15.00	47.00	15.04
r_14	6	a194	-	0.32	60,596	9.18	-	9.18	15.00	258.00	14.72
r_14	7	a138	-	4.53	62,185	9.35	-	9.35	15.00	793.00	10.19
r_14	8	a006	-	8.06	64,344	9.55	-	9.55	15.00	242.00	2.13
r_14	9	a140	-	0.53	68,695	9.77	-	9.77	15.00	644.00	1.60
r_14	10	a162	-	-	74,116	9.90	-	9.90	15.00	49.00	1.60
r_14	11	a154	-	-	74,116	10.03	-	10.03	15.00	18.00	1.60
r_14	12	c410	4,406.02	-	74,116	-	1.02	11.05	-	-	52.48
r_14	13	a113	-	1.75	-	10.18	-	11.19	15.00	1,040.00	50.73
r_14	14	a164	-	1.54	75,238	10.36	-	11.38	15.00	37.00	49.19
r_14	15	a151	-	49.19	78,330	11.16	-	12.17	15.00	208.00	-
r_14	16	c441	7,219.33	-	118,442	-	0.94	13.12	-	-	47.23
r_14	17	a007	-	45.13	-	11.93	-	13.90	15.00	40.00	2.10
r_14	18	a030	-	0.22	157,278	12.18	-	14.15	15.00	72.00	1.88
r_14	19	a294	-	1.88	164,523	12.45	-	14.41	15.00	44.00	-,,,0.00
r_14	20	c349	2,867.98	-	172,574	-	0.22	14.63	-	-	10.78
r_14	21	t01	-	10.78	-	13.19	-	15.37	-	-	-
r_15	0	t01	-	-	217,286	7.96	-	7.96	-	-	66
r_15	1	a284	-	3.84	-	9.29	-	9.29	10.00	254.00	62.16
r_15	2	a295	-	1.85	19,653	9.48	-	9.48	10.00	889.00	60.31
r_15	3	a169	-	1.45	23,539	9.63	-	9.63	10.00	213.00	58.86
r_15	4	a259	-	1.13	24,660	9.85	-	9.85	10.00	149.00	57.72
r_15	5	a275	-	0.53	29,909	10.00	-	10.00	10.00	229.00	57.19
r_15	6	a046	-	11.47	31,333	10.30	-	10.30	15.00	16.00	45.72
r_15	7	a210	-	0.38	41,634	10.51	-	10.51	15.00	95.00	45.34
r_15	8	a041	-	4.96	46,179	10.71	-	10.71	15.00	18.00	40.38
r_15	9	a024	-	5.28	50,773	10.93	-	10.93	15.00	67.00	35.10
r_15	10	a273	-	1.28	55,691	11.14	-	11.14	15.00	632.00	33.82
r_15	11	a109	-	2.56	60,594	11.32	-	11.32	15.00	44.00	31.26
r_15	12	a298	-	0.15	63,576	11.48	-	11.48	15.00	18.00	31.10
r_15	13	a057	-	4.57	65,608	11.70	-	11.70	15.00	6.00	26.53
r_15	14	a201	-	0.18	71,058	11.85	-	11.85	15.00	133.00	26.35
r_15	15	a034	-	4.21	72,189	12.07	-	12.07	15.00	55.00	22.14
r_15	16	a060	-	1.24	77,472	12.28	-	12.28	15.00	50.00	20.90
r_15	17	t01	-	5.99	82,411	12.61	-	12.61	-	-	14.92
r_16	0	t01	-	-	101,961	7.60	-	7.60	-	-	66
r_16	1	a283	-	2.40	-	8.79	-	8.79	10.00	180.00	63.60
r_16	2	a213	-	1.37	11,055	8.93	-	8.93	10.00	149.00	62.23
r_16	3	a315	-	1.05	11,956	9.13	-	9.13	10.00	80.00	61.17

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_16	4	a185	-	1.87	16,346	9.29	-	9.29	10.00	70.00	59.30
r_16	5	a172	-	4.11	17,634	9.46	-	9.46	10.00	848.00	55.19
r_16	6	a021	-	3.61	20,503	9.64	-	9.64	10.00	30.00	51.58
r_16	7	a078	-	3.68	23,584	10.00	-	10.00	10.00	92.00	47.90
r_16	8	a066	-	5.45	37,084	10.21	-	10.21	15.00	7.00	42.45
r_16	9	a204	-	1.16	41,893	10.39	-	10.39	15.00	314.00	41.29
r_16	10	a055	-	2.94	44,679	10.56	-	10.56	15.00	20.00	38.35
r_16	11	a232	-	2.15	47,523	10.81	-	10.81	15.00	141.00	36.20
r_16	12	a047	-	21.63	54,370	11.30	-	11.30	15.00	66.00	14.57
r_16	13	a245	-	2.08	76,334	11.52	-	11.52	15.00	156.00	12.48
r_16	14	a105	-	4.09	81,274	11.72	-	11.72	15.00	58.00	8.39
r_16	15	a051	-	5.11	85,740	11.95	-	11.95	15.00	15.00	3.28
r_16	16	a211	-	0.18	91,426	12.13	-	12.13	15.00	85.00	3.10
r_16	17	a061	-	2.70	94,498	12.31	-	12.31	15.00	43.00	0.40
r_16	18	a065	-	0.07	97,609	12.44	-	12.44	15.00	20.00	0.33
r_16	19	c316	3,902.00	-	97,654	-	0.30	12.74	-	-	15.13
r_16	20	a042	-	8.13	-	12.73	-	13.03	15.00	18.00	7.00
r_16	21	a184	-	0.17	107,239	12.87	-	13.16	15.00	65.00	6.83
r_16	22	a001	-	1.01	107,759	13.02	-	13.31	15.00	80.00	5.81
r_16	23	a198	-	1.27	108,992	13.22	-	13.51	15.00	73.00	4.55
r_16	24	a220	-	1.31	113,016	13.43	-	13.72	15.00	148.00	3.24
r_16	25	t01	-	3.24	117,875	13.63	-	13.92	-	-	-
r_17	0	t01	-	-	129,820	7.73	-	7.73	-	-	66
r_17	1	a304	-	1.72	-	8.87	-	8.87	10.00	412.00	64.28
r_17	2	a308	-	0.11	8,453	9.00	-	9.00	10.00	151.00	64.17
r_17	3	a282	-	0.22	8,645	9.13	-	9.13	10.00	146.00	63.95
r_17	4	a299	-	0.84	8,838	9.33	-	9.33	10.00	157.00	63.10
r_17	5	a221	-	3.64	12,720	9.52	-	9.52	10.00	94.00	59.47
r_17	6	a325	-	0.54	16,189	9.68	-	9.68	10.00	107.00	58.92
r_17	7	a288	-	2.08	18,387	9.85	-	9.85	10.00	375.00	56.84
r_17	8	a141	-	1.17	20,499	10.00	-	10.00	15.00	149.00	55.67
r_17	9	a014	-	3.13	21,846	10.19	-	10.19	15.00	14.00	52.54
r_17	10	a252	-	0.32	25,640	10.38	-	10.38	15.00	102.00	52.22
r_17	11	a073	-	0.57	28,950	10.52	-	10.52	15.00	13.00	51.65
r_17	12	a069	-	0.49	29,668	10.66	-	10.66	15.00	2.00	51.16
r_17	13	a043	-	0.06	30,291	10.79	-	10.79	15.00	2.00	51.10
r_17	14	a269	-	0.01	30,374	10.93	-	10.93	15.00	150.00	51.09
r_17	15	a062	-	0.31	30,754	11.07	-	11.07	15.00	30.00	50.78
r_17	16	a260	-	0.12	31,177	11.20	-	11.20	15.00	131.00	50.65
r_17	17	a131	-	0.23	31,644	11.34	-	11.34	15.00	274.00	50.43
r_17	18	a054	-	1.23	31,971	11.50	-	11.50	15.00	19.00	49.20
r_17	19	t01	-	2.49	34,010	11.65	-	11.65	-	-	46.71
r_18	0	t01	-	-	42,864	7.93	-	7.93	-	-	66
r_18	1	a085	-	2.08	-	9.05	-	9.05	10.00	16.00	63.92
r_18	2	a186	-	2.34	7,213	9.35	-	9.35	10.00	11.00	61.58
r_18	3	a111	-	4.19	17,378	9.53	-	9.53	10.00	629.00	57.39
r_18	4	a292	-	0.04	20,117	9.68	-	9.68	10.00	18.00	57.35
r_18	5	a289	-	3.99	21,200	9.86	-	9.86	10.00	555.00	53.36
r_18	6	a010	-	0.97	24,204	10.00	-	10.00	15.00	50.00	52.39
r_18	7	a023	-	0.20	25,045	10.17	-	10.17	15.00	32.00	52.19
r_18	8	a095	-	0.02	27,456	10.31	-	10.31	15.00	609.00	52.17
r_18	9	a094	-	-	28,104	10.44	-	10.44	15.00	107.00	52.17
r_18	10	a089	-	0.18	28,104	10.57	-	10.57	15.00	30.00	51.99
r_18	11	a219	-	0.76	28,301	10.74	-	10.74	15.00	88.00	51.23
r_18	12	a263	-	0.03	30,232	10.87	-	10.87	15.00	62.00	51.20
r_18	13	a183	-	2.80	30,426	11.05	-	11.05	15.00	253.00	48.40
r_18	14	a048	-	2.89	33,698	11.25	-	11.25	15.00	34.00	45.51
r_18	15	a011	-	5.21	37,408	11.49	-	11.49	15.00	84.00	40.30
r_18	16	a112	-	0.85	44,200	11.66	-	11.66	15.00	83.00	39.45

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_18	17	a040	-	3.36	46,722	11.87	-	11.87	15.00	26.00	36.09
r_18	18	t01	-	0.02	51,414	11.91	-	11.91	-	-	36.07
r_19	0	t01	-	-	53,901	7.65	-	7.65	-	-	66
r_19	1	a277	-	2.47	-	8.83	-	8.83	10.00	184.00	63.53
r_19	2	a116	-	1.07	10,801	8.98	-	8.98	10.00	108.00	62.45
r_19	3	a240	-	4.05	11,810	9.41	-	9.41	15.00	47.00	58.40
r_19	4	a012	-	1.92	30,093	9.57	-	9.57	15.00	138.00	56.48
r_19	5	a182	-	4.76	31,984	10.00	-	10.00	15.00	186.00	51.72
r_19	6	a020	-	0.88	49,826	10.15	-	10.15	15.00	50.00	50.85
r_19	7	a018	-	1.71	50,785	10.31	-	10.31	15.00	47.00	49.13
r_19	8	a080	-	0.55	52,687	10.48	-	10.48	15.00	793.00	48.58
r_19	9	a241	-	2.15	54,986	10.73	-	10.73	15.00	137.00	46.43
r_19	10	a276	-	0.68	62,371	10.95	-	10.95	15.00	323.00	45.75
r_19	11	t01	-	0.30	67,547	10.99	-	10.99	-	-	45.45
r_20	0	t01	-	-	70,337	8.64	-	8.64	-	-	66
r_20	1	a312	-	2.33	-	9.86	-	9.86	10.00	111.00	63.67
r_20	2	a285	-	0.10	13,110	10.00	-	10.00	15.00	280.00	63.56
r_20	3	a254	-	0.02	13,797	10.13	-	10.13	15.00	102.00	63.55
r_20	4	t01	-	2.82	14,065	10.35	-	10.35	-	-	60.72
r_21	0	t01	-	-	26,984	7.82	-	7.82	-	-	66
r_21	1	a300	-	1.34	-	9.00	-	9.00	10.00	94.00	64.66
r_21	2	a314	-	0.14	10,799	9.15	-	9.15	10.00	5.00	64.52
r_21	3	a092	-	0.94	11,637	9.29	-	9.29	10.00	481.00	63.59
r_21	4	a256	-	0.10	12,384	9.43	-	9.43	10.00	70.00	63.49
r_21	5	a267	-	0.18	12,876	9.57	-	9.57	10.00	59.00	63.31
r_21	6	a324	-	0.43	13,563	9.73	-	9.73	10.00	508.00	62.88
r_21	7	a327	-	-	15,243	9.86	-	9.86	10.00	152.00	62.88
r_21	8	a281	-	0.68	15,243	10.00	-	10.00	15.00	109.00	62.20
r_21	9	a044	-	1.29	16,029	10.16	-	10.16	15.00	26.00	60.91
r_21	10	a004	-	0.12	17,590	10.29	-	10.29	15.00	74.00	60.79
r_21	11	a106	-	0.73	17,739	10.46	-	10.46	15.00	60.00	60.06
r_21	12	a158	-	0.12	20,061	10.61	-	10.61	15.00	625.00	59.94
r_21	13	a093	-	0.44	21,273	10.75	-	10.75	15.00	15.00	59.50
r_21	14	t01	-	3.83	22,025	10.93	-	10.93	-	-	55.67
r_22	0	t01	-	-	32,905	8.28	-	8.28	-	-	66
r_22	1	a317	-	2.81	-	9.50	-	9.50	10.00	899.00	63.19
r_22	2	a287	-	3.56	13,000	9.69	-	9.69	10.00	143.00	59.62
r_22	3	a265	-	1.46	16,457	9.84	-	9.84	10.00	136.00	58.16
r_22	4	a059	-	1.54	17,939	10.00	-	10.00	15.00	6.00	56.62
r_22	5	a270	-	1.20	19,567	10.19	-	10.19	15.00	715.00	55.42
r_22	6	a279	-	0.89	22,904	10.37	-	10.37	15.00	101.00	54.53
r_22	7	a071	-	0.26	25,921	10.50	-	10.50	15.00	47.00	54.27
r_22	8	a009	-	2.80	26,303	10.70	-	10.70	15.00	52.00	51.47
r_22	9	a064	-	0.41	30,440	10.86	-	10.86	15.00	20.00	51.06
r_22	10	a016	-	3.41	31,981	11.07	-	11.07	15.00	197.00	47.65
r_22	11	t01	-	2.90	37,190	11.24	-	11.24	-	-	44.75
r_23	0	t01	-	-	46,967	13.65	-	13.65	-	-	66
r_23	1	a264	-	2.51	-	14.87	-	14.87	15.00	127.00	63.49
r_23	2	a266	-	-	13,056	15.00	-	15.00	15.00	61.00	63.49
r_23	3	t01	-	4.04	13,056	15.22	-	15.22	-	-	59.45
r_24	0	t01	-	-	26,112	7.98	-	7.98	-	-	66
r_24	1	a165	-	1.68	-	9.15	-	9.15	10.00	174.00	64.32
r_24	2	a268	-	0.36	10,294	9.29	-	9.29	10.00	170.00	63.96
r_24	3	a187	-	3.88	10,847	9.45	-	9.45	10.00	164.00	60.09
r_24	4	a303	-	4.76	12,857	9.81	-	9.81	10.00	29.00	55.33
r_24	5	a117	-	6.21	26,833	10.00	-	10.00	10.00	125.00	49.12
r_24	6	a087	-	4.00	30,154	10.17	-	10.17	15.00	3.00	45.13
r_24	7	a243	-	1.72	32,338	10.41	-	10.41	15.00	93.00	43.41
r_24	8	a291	-	2.63	38,931	10.61	-	10.61	15.00	129.00	40.77

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_24	9	a278	-	9.54	43,470	10.83	-	10.83	15.00	138.00	31.24
r_24	10	a114	-	14.40	48,887	11.10	-	11.10	15.00	397.00	16.84
r_24	11	a074	-	10.59	57,265	11.34	-	11.34	15.00	24.00	6.25
r_24	12	a147	-	2.70	63,900	11.58	-	11.58	15.00	147.00	3.55
r_24	13	a033	-	0.01	70,534	11.71	-	11.71	15.00	46.00	3.54
r_24	14	a293	-	1.15	70,539	11.91	-	11.91	15.00	127.00	2.39
r_24	15	a321	-	0.37	74,807	12.14	-	12.14	15.00	155.00	2.02
r_24	16	c340	2,408.25	-	80,404	-	0.90	13.04	-	-	47.07
r_24	17	a015	-	31.11	-	12.63	-	13.53	15.00	46.00	15.96
r_24	18	a003	-	2.90	101,979	12.79	-	13.69	15.00	54.00	13.07
r_24	19	a307	-	1.08	104,009	12.98	-	13.88	15.00	46.00	11.99
r_24	20	a053	-	2.05	107,420	13.13	-	14.03	15.00	16.00	9.93
r_24	21	a246	-	0.04	108,891	13.28	-	14.18	15.00	55.00	9.89
r_24	22	a159	-	1.71	109,977	13.43	-	14.33	15.00	38.00	8.18
r_24	23	a231	-	0.11	111,219	13.57	-	14.47	15.00	99.00	8.07
r_24	24	a163	-	0.89	111,813	13.71	-	14.61	15.00	594.00	7.18
r_24	25	a100	-	1.66	112,484	13.87	-	14.77	15.00	57.00	5.52
r_24	26	a257	-	0.81	113,927	14.02	-	14.92	15.00	72.00	4.71
r_24	27	a272	-	0.20	115,568	14.17	-	15.07	15.00	251.00	4.51
r_24	28	a068	-	0.18	116,775	14.31	-	15.21	15.00	52.00	4.33
r_24	29	a250	-	0.16	116,951	14.46	-	15.36	15.00	149.00	4.17
r_24	30	a067	-	1.16	118,120	14.61	-	15.51	15.00	43.00	3.01
r_24	31	t01	-	3.01	119,313	14.76	-	15.66	-	-	0.00
r_25	0	t01	-	-	128,513	8.01	-	8.01	-	-	66
r_25	1	a202	-	2.37	-	9.21	-	9.21	10.00	182.00	63.63
r_25	2	a247	-	0.35	12,094	9.38	-	9.38	10.00	151.00	63.28
r_25	3	a301	-	0.01	14,374	9.52	-	9.52	10.00	112.00	63.27
r_25	4	a255	-	1.78	15,033	9.66	-	9.66	10.00	70.00	61.48
r_25	5	a290	-	0.22	16,026	9.80	-	9.80	10.00	188.00	61.26
r_25	6	a305	-	2.19	16,596	10.00	-	10.00	10.00	734.00	59.07
r_25	7	a156	-	5.39	20,642	10.19	-	10.19	15.00	328.00	53.69
r_25	8	a050	-	3.41	24,254	10.36	-	10.36	15.00	16.00	50.28
r_25	9	a215	-	0.43	26,704	10.58	-	10.58	15.00	29.00	49.85
r_25	10	a258	-	0.08	32,135	10.72	-	10.72	15.00	173.00	49.77
r_25	11	a274	-	0.07	32,605	10.86	-	10.86	15.00	124.00	49.70
r_25	12	a233	-	1.23	33,433	11.01	-	11.01	15.00	201.00	48.47
r_25	13	a026	-	1.15	34,388	11.15	-	11.15	15.00	28.00	47.32
r_25	14	a045	-	0.30	35,332	11.30	-	11.30	15.00	8.00	47.02
r_25	15	a311	-	0.23	36,219	11.44	-	11.44	15.00	98.00	46.79
r_25	16	a271	-	2.50	36,818	11.60	-	11.60	15.00	128.00	44.29
r_25	17	a063	-	0.21	38,938	11.74	-	11.74	15.00	16.00	44.07
r_25	18	a173	-	0.28	39,125	11.90	-	11.90	15.00	713.00	43.79
r_25	19	a032	-	0.61	41,247	12.04	-	12.04	15.00	32.00	43.18
r_25	20	t01	-	3.12	41,915	12.20	-	12.20	-	-	40.06

C.III Worst case $S_{Electric}$

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_01	0	t01	-	-	-	1.15	-	1.15	-	-	66
r_01	1	a386	-	8.02	19,830	2.49	-	2.49	6.00	750.00	57.98
r_01	2	a314	-	6.83	22,078	2.65	-	2.65	6.00	45.00	51.15
r_01	3	a243	-	-	22,078	2.78	-	2.78	6.00	19.00	51.15
r_01	4	a060	-	12.35	26,184	2.98	-	2.98	6.00	30.00	38.80
r_01	5	a209	-	0.21	26,769	3.12	-	3.12	6.00	26.00	38.59
r_01	6	a068	-	7.97	29,444	3.30	-	3.30	6.00	27.00	30.62
r_01	7	a456	-	0.07	30,123	3.44	-	3.44	6.00	132.00	30.55
r_01	8	a302	-	2.46	30,971	3.58	-	3.58	6.00	8.00	28.09
r_01	9	a258	-	8.30	33,834	3.76	-	3.76	6.00	28.00	19.78
r_01	10	a074	-	16.47	39,539	3.98	-	3.98	6.00	32.00	3.31
r_01	11	a463	-	3.14	46,273	4.23	-	4.23	6.00	387.00	0.18
r_01	12	c413	19,717.41	-	-	-	1.01	1.01	-	-	50.89
r_01	13	a348	-	10.68	50,248	4.42	-	5.44	6.00	1,046.00	40.21
r_01	14	a401	-	1.08	53,985	4.61	-	5.63	6.00	86.00	39.14
r_01	15	a420	-	0.60	57,753	4.81	-	5.82	6.00	114.00	38.54
r_01	16	a402	-	4.20	59,762	4.97	-	5.98	6.00	72.00	34.34
r_01	17	a166	-	9.01	64,146	5.17	-	6.19	6.00	36.00	25.33
r_01	18	a263	-	0.45	66,780	5.35	-	6.36	6.00	57.00	24.88
r_01	19	a213	-	7.69	70,607	5.54	-	6.56	6.00	27.00	17.19
r_01	20	a007	-	3.18	72,199	5.70	-	6.71	6.00	36.00	14.01
r_01	21	a460	-	0.35	72,833	5.84	-	6.85	6.00	41.00	13.66
r_01	22	a070	-	3.70	74,721	6.00	-	7.01	6.00	40.00	9.96
r_01	23	a486	-	0.39	75,685	6.15	-	7.16	10.00	48.00	9.57
r_01	24	a231	-	9.57	80,673	6.36	-	7.37	10.00	33.00	-
r_01	25	c370	5,274.43	-	-	-	0.85	1.87	-	-	42.57
r_01	26	a133	-	15.07	88,593	6.62	-	8.49	10.00	200.00	27.50
r_01	27	a494	-	2.66	95,145	6.86	-	8.73	10.00	74.00	24.84
r_01	28	a008	-	6.80	98,982	7.05	-	8.92	10.00	80.00	18.05
r_01	29	a527	-	1.70	102,780	7.25	-	9.11	10.00	44.00	16.35
r_01	30	a318	-	3.48	104,813	7.41	-	9.28	10.00	18.00	12.87
r_01	31	a283	-	2.79	106,454	7.57	-	9.43	10.00	136.00	10.07
r_01	32	a290	-	1.03	108,868	7.74	-	9.60	10.00	25.00	9.05
r_01	33	a503	-	2.99	111,681	7.92	-	9.78	10.00	46.00	6.06
r_01	34	t01	-	6.06	132,988	8.27	-	10.14		-	-
r_02	0	t01	-	-	-	0.70	-	0.70		-	66
r_02	1	a435	-	2.88	9,121	1.85	-	1.85	6.00	155.00	63.12
r_02	2	a287	-	3.91	10,442	2.00	-	2.00	2.00	63.00	59.20
r_02	3	a145	-	0.14	10,490	2.13	-	2.13	6.00	20.00	59.06
r_02	4	a001	-	2.16	11,228	2.27	-	2.27	6.00	82.00	56.91
r_02	5	a384	-	5.26	17,211	2.50	-	2.50	6.00	435.00	51.65
r_02	6	a440	-	0.18	18,013	2.65	-	2.65	6.00	64.00	51.46
r_02	7	a150	-	15.75	23,967	2.88	-	2.88	6.00	30.00	35.71
r_02	8	a201	-	0.07	24,198	3.01	-	3.01	6.00	39.00	35.64
r_02	9	a059	-	9.40	27,795	3.20	-	3.20	6.00	134.00	26.25
r_02	10	c167	16,233.34	-	-	-	1.04	1.04	-	-	78.40
r_02	11	a003	-	53.96	48,973	3.68	-	4.73	6.00	65.00	24.44
r_02	12	a599	-	23.44	109,873	4.83	-	5.87	8.00	893.00	1.00
r_02	13	a601	-	1.00	112,471	5.00	-	6.04	8.00	56.00	-
r_02	14	c643	20,648.86	-	-	-	0.28	1.32	-	-	13.80
r_02	15	a569	-	13.80	119,163	5.24	-	6.56	8.00	168.00	-
r_02	16	c643	25,167.08	-	-	-	2.63	3.95	-	-	131.46
r_02	17	c643	20,044.04	-	-	-	-	3.95	-	-	131.46
r_02	18	c332	79,901.03	-	-	-	-	3.95	-	-	131.46
r_02	19	a526	-	131.46	185,491	6.48	-	10.43	10.00	117.00	-
r_02	20	c332	58,988.15	-	-	-	0.39	4.34	-	-	19.43
r_02	21	a366	-	-	185,491	6.61	-	10.94	10.00	788.00	19.43

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_02	22	a502	-	3.91	197,697	6.94	-	11.28	10.00	119.00	15.52
r_02	23	a500	-	2.32	199,250	7.10	-	11.43	10.00	80.00	13.21
r_02	24	a320	-	8.76	205,276	7.33	-	11.66	10.00	60.00	4.45
r_02	25	t01	-	4.45	217,591	7.53	-	11.87	-	-	-
r_03	0	t01	-	-	-	0.57	-	0.57	-	-	66
r_03	1	a364	-	2.93	9,312	1.72	-	1.72	6.00	40.00	63.07
r_03	2	a244	-	16.35	14,971	1.94	-	1.94	6.00	31.00	46.72
r_03	3	a445	-	4.04	26,317	2.26	-	2.26	6.00	59.00	42.69
r_03	4	a167	-	37.37	39,451	2.61	-	2.61	6.00	117.00	5.32
r_03	5	c424	3,129.44	-	-	-	0.73	0.73	-	-	41.86
r_03	6	a624	-	9.41	52,445	2.96	-	3.69	8.00	199.00	32.45
r_03	7	a330	-	32.45	64,491	3.29	-	4.02	8.00	1,348.00	-
r_03	8	c502	35,981.18	-	-	-	0.86	1.59	-	-	42.91
r_03	9	a052	-	22.37	75,412	3.60	-	5.19	8.00	137.00	20.54
r_03	10	a610	-	6.81	98,998	4.13	-	5.71	8.00	38.00	13.73
r_03	11	a354	-	10.81	104,503	4.35	-	5.94	8.00	173.00	2.92
r_03	12	a618	-	2.92	108,618	4.55	-	6.13	8.00	193.00	-
r_03	13	c425	10,235.70	-	-	-	0.80	2.39	-	-	39.92
r_03	14	a173	-	19.96	119,776	4.86	-	7.25	6.00	80.00	19.96
r_03	15	a242	-	1.66	121,555	5.02	-	7.41	6.00	35.00	18.30
r_03	16	a142	-	10.86	127,818	5.26	-	7.64	6.00	46.00	7.44
r_03	17	a447	-	0.65	131,840	5.45	-	7.84	6.00	48.00	6.79
r_03	18	a077	-	2.43	133,279	5.61	-	7.99	6.00	56.00	4.36
r_03	19	a254	-	3.35	138,588	5.83	-	8.21	6.00	61.00	1.01
r_03	20	a382	-	1.01	141,278	6.00	-	8.39	10.00	182.00	0.00
r_03	21	-	-	-	-	-	0.60	2.99	-	-	29.93
r_03	22	a316	-	13.27	149,862	6.27	-	9.26	10.00	14.00	16.66
r_03	23	a321	-	1.57	153,296	6.46	-	9.45	10.00	55.00	15.09
r_03	24	a471	-	0.29	154,127	6.60	-	9.59	10.00	119.00	14.80
r_03	25	a380	-	0.45	154,435	6.74	-	9.73	10.00	201.00	14.35
r_03	26	t01	-	14.35	189,080	7.32	-	10.30	-	-	-
r_04	0	t01	-	-	-	1.35	-	1.35	-	-	66
r_04	1	a464	-	3.45	8,091	2.49	-	2.49	6.00	96.00	62.55
r_04	2	a438	-	48.01	21,805	2.85	-	2.85	6.00	40.00	14.54
r_04	3	a378	-	13.24	25,608	3.04	-	3.04	6.00	254.00	1.29
r_04	4	a237	-	0.04	25,619	3.17	-	3.17	6.00	31.00	1.25
r_04	5	c167	11,949.67	-	-	-	0.97	0.97	-	-	49.80
r_04	6	a409	-	1.65	27,818	3.34	-	4.31	6.00	187.00	48.15
r_04	7	a430	-	1.22	31,055	3.52	-	4.49	6.00	136.00	46.93
r_04	8	a191	-	3.48	32,147	3.67	-	4.64	6.00	31.00	43.44
r_04	9	a374	-	3.78	36,173	3.87	-	4.84	6.00	122.00	39.66
r_04	10	a223	-	21.75	43,149	4.11	-	5.08	6.00	28.00	17.91
r_04	11	a097	-	7.17	45,458	4.28	-	5.25	6.00	86.00	10.75
r_04	12	a078	-	5.71	47,323	4.44	-	5.41	6.00	30.00	5.03
r_04	13	a414	-	5.03	54,326	4.69	-	5.66	6.00	74.00	-
r_04	14	c299	27,502.98	-	-	-	0.86	1.83	-	-	43.11
r_04	15	a295	-	11.59	58,172	4.88	-	6.72	6.00	50.00	31.52
r_04	16	a189	-	12.28	62,280	5.08	-	6.92	6.00	31.00	19.24
r_04	17	a071	-	7.46	64,788	5.25	-	7.09	6.00	31.00	11.78
r_04	18	a454	-	1.25	67,294	5.43	-	7.26	6.00	186.00	10.52
r_04	19	a421	-	5.79	69,313	5.59	-	7.42	6.00	530.00	4.73
r_04	20	a184	-	0.67	69,570	5.72	-	7.56	6.00	8.00	4.06
r_04	21	a452	-	0.58	70,524	5.87	-	7.70	6.00	480.00	3.48
r_04	22	a205	-	-	70,524	6.00	-	7.83	6.00	39.00	3.48
r_04	23	a496	-	0.14	70,783	6.13	-	7.97	10.00	198.00	3.34
r_04	24	a518	-	2.48	75,409	6.34	-	8.17	10.00	174.00	0.86
r_04	25	a109	-	0.27	75,535	6.47	-	8.31	10.00	32.00	0.58
r_04	26	a284	-	0.58	81,675	6.71	-	8.54	10.00	45.00	-
r_04	27	c340	35,519.73	-	-	-	1.04	2.87	-	-	52.02

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_04	28	a248	-	14.33	88,344	6.95	-	9.82	10.00	31.00	37.69
r_04	29	a179	-	17.30	96,451	7.21	-	10.09	10.00	31.00	20.39
r_04	30	a018	-	11.71	101,978	7.43	-	10.31	10.00	36.00	8.67
r_04	31	a517	-	4.66	109,679	7.69	-	10.57	10.00	415.00	4.02
r_04	32	a583	-	1.81	115,062	7.91	-	10.79	10.00	175.00	2.21
r_04	33	a493	-	2.18	116,260	8.06	-	10.94	10.00	147.00	0.03
r_04	34	a468	-	0.03	116,277	8.19	-	11.07	10.00	114.00	0.00
r_04	35	c099	12,324.51	-	-	-	0.53	3.41	-	-	26.61
r_04	36	a047	-	24.25	130,585	8.56	-	11.97	10.00	32.00	2.36
r_04	37	t01	-	2.36	137,894	8.68	-	12.09	-	-	-
r_05	0	t01	-	-	-	2.21	-	2.21	-	-	66
r_05	1	a431	-	4.49	14,451	3.45	-	3.45	6.00	165.00	61.51
r_05	2	a011	-	1.97	15,041	3.59	-	3.59	6.00	38.00	59.54
r_05	3	a365	-	0.28	15,502	3.73	-	3.73	6.00	40.00	59.27
r_05	4	a210	-	2.30	16,200	3.87	-	3.87	6.00	39.00	56.97
r_05	5	a298	-	0.21	17,962	4.03	-	4.03	6.00	40.00	56.76
r_05	6	a344	-	0.06	18,761	4.18	-	4.18	6.00	416.00	56.70
r_05	7	a411	-	1.82	22,471	4.37	-	4.37	6.00	130.00	54.88
r_05	8	a423	-	3.91	25,175	4.54	-	4.54	6.00	131.00	50.97
r_05	9	a426	-	1.06	28,292	4.72	-	4.72	6.00	164.00	49.91
r_05	10	a398	-	3.50	29,520	4.87	-	4.87	6.00	800.00	46.41
r_05	11	a005	-	6.92	32,320	5.05	-	5.05	6.00	25.00	39.49
r_05	12	a118	-	2.03	34,551	5.22	-	5.22	6.00	40.00	37.46
r_05	13	a015	-	4.45	36,375	5.38	-	5.38	6.00	27.00	33.01
r_05	14	a418	-	6.24	42,152	5.61	-	5.61	6.00	95.00	26.77
r_05	15	a279	-	13.56	47,848	5.83	-	5.83	6.00	7.00	13.21
r_05	16	a368	-	2.39	50,231	6.00	-	6.00	10.00	293.00	10.82
r_05	17	a357	-	7.19	53,447	6.18	-	6.18	10.00	188.00	3.62
r_05	18	a508	-	0.72	56,700	6.37	-	6.37	10.00	278.00	2.90
r_05	19	c332	56,306.85	-	-	-	0.48	0.48	-	-	26.94
r_05	20	a465	-	7.87	60,610	6.56	-	7.04	10.00	143.00	19.07
r_05	21	a448	-	4.96	63,158	6.74	-	7.22	10.00	50.00	14.11
r_05	22	a513	-	0.33	64,558	6.89	-	7.37	10.00	70.00	13.78
r_05	23	a499	-	2.45	65,858	7.04	-	7.52	10.00	74.00	11.33
r_05	24	a476	-	3.71	67,863	7.20	-	7.68	10.00	380.00	7.61
r_05	25	a510	-	0.34	68,415	7.34	-	7.82	10.00	124.00	7.27
r_05	26	t01	-	7.27	83,490	7.59	-	8.08	-	-	-
r_06	0	t01	-	-	-	1.44	-	1.44	-	-	66
r_06	1	a319	-	4.44	8,300	2.58	-	2.58	6.00	40.00	61.56
r_06	2	a310	-	1.22	8,835	2.72	-	2.72	6.00	18.00	60.34
r_06	3	a169	-	24.75	19,707	3.03	-	3.03	6.00	184.00	35.59
r_06	4	a168	-	2.47	20,835	3.18	-	3.18	6.00	101.00	33.12
r_06	5	a193	-	0.77	22,372	3.34	-	3.34	8.00	31.00	32.34
r_06	6	a246	-	0.46	27,107	3.55	-	3.55	6.00	8.00	31.88
r_06	7	a458	-	1.86	29,602	3.72	-	3.72	6.00	109.00	30.02
r_06	8	a387	-	4.02	31,545	3.88	-	3.88	6.00	599.00	26.00
r_06	9	a264	-	6.46	35,172	4.07	-	4.07	6.00	39.00	19.54
r_06	10	a185	-	2.14	36,386	4.22	-	4.22	6.00	29.00	17.40
r_06	11	t01	-	2.59	44,679	4.36	-	4.36	-	-	14.81
r_07	0	t01	-	-	-	0.63	-	0.63	-	-	66
r_07	1	a099	-	22.14	58,018	2.60	-	2.60	8.00	93.00	43.86
r_07	2	a590	-	1.99	62,896	2.81	-	2.81	8.00	61.00	41.87
r_07	3	c475	2,638.31	-	-	-	1.05	1.05	-	-	94.28
r_07	4	a053	-	92.00	97,381	3.51	-	4.56	8.00	50.00	2.28
r_07	5	a636	-	2.28	102,550	3.73	-	4.78	8.00	175.00	0.00
r_07	6	c616	160,546.02	-	-	-	0.59	1.64	-	-	29.74
r_07	7	a609	-	0.67	102,811	3.87	-	5.51	8.00	48.00	29.07
r_07	8	a608	-	28.63	114,096	4.18	-	5.83	8.00	34.00	0.44
r_07	9	a606	-	0.44	114,269	4.32	-	5.96	8.00	129.00	-

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_07	10	c620	64,532.09	-	-	-	3.57	5.21	-	-	178.60
r_07	11	c620	60,827.23	-	-	-	-	5.21	-	-	178.60
r_07	12	c620	60,827.23	-	-	-	-	5.21	-	-	178.60
r_07	13	c620	60,827.23	-	-	-	-	5.21	-	-	178.60
r_07	14	a029	-	178.60	186,899	5.66		10.87	8.00	102.00	-
r_07	15	c642	76,216.49	-	-	-	0.08	5.30	-	-	4.22
r_07	16	a600	-	4.22	199,847	6.00		11.30	8.00	63.00	-
r_07	17	c641	204,098.89	-	-	-	3.09	8.39	-	-	154.51
r_07	18	c641	162,790.18	-	-	-	-	8.39	-	-	154.51
r_07	19	c509	169,666.15	-	-	-	-	8.39	-	-	154.51
r_07	20	a090	-	152.60	263,966	7.20	-	15.59	8.00	98.00	1.90
r_07	21	a294	-	0.90	267,202	7.39	-	15.77	8.00	10.00	1.00
r_07	22	a328	-	1.00	271,139	7.58	-	15.97	8.00	968.00	- ,,,,,0.00
r_07	23	c494	1,954.08	-	-	-	0.71	9.10	-	-	35.73
r_07	24	a586	-	4.08	277,743	7.82	-	16.92	8.00	108.00	31.65
r_07	25	a093	-	5.36	280,700	8.00	-	17.10	8.00	102.00	26.29
r_07	26	a515	-	22.52	344,776	9.20	-	18.30	10.00	140.00	3.77
r_07	27	t01	-	3.77	354,317	9.36	-	18.46	-	-	0.00
r_08	0	t01	-	-	-	4.18	-	4.18	-	-	66
r_08	1	a141	-	4.76	12,435	5.38	-	5.38	6.00	36.00	61.24
r_08	2	a340	-	0.07	13,906	5.54	-	5.54	6.00	902.00	61.17
r_08	3	a153	-	2.85	14,914	5.69	-	5.69	6.00	76.00	58.32
r_08	4	a342	-	2.02	17,601	5.86	-	5.86	6.00	672.00	56.31
r_08	5	a400	-	0.52	18,135	6.00	-	6.00	10.00	10.00	55.79
r_08	6	a470	-	0.27	18,871	6.14	-	6.14	10.00	141.00	55.52
r_08	7	a519	-	0.46	19,858	6.29	-	6.29	10.00	738.00	55.06
r_08	8	a433	-	3.66	21,647	6.45	-	6.45	10.00	325.00	51.40
r_08	9	a478	-	0.61	24,179	6.62	-	6.62	10.00	693.00	50.79
r_08	10	a392	-	4.97	27,373	6.80	-	6.80	10.00	24.00	45.82
r_08	11	t01	-	5.08	40,886	7.03	-	7.03	-	-	40.74
r_09	0	t01	-	-	-	3.52	-	3.52	-	-	66
r_09	1	a086	-	2.44	7,197	4.64	-	4.64	6.00	433.00	63.56
r_09	2	a338	-	1.41	11,649	4.85	-	4.85	6.00	826.00	62.14
r_09	3	a635	-	0.08	12,053	4.98	-	4.98	6.00	101.00	62.06
r_09	4	a345	-	1.64	12,756	5.12	-	5.12	6.00	327.00	60.42
r_09	5	a186	-	1.75	13,557	5.27	-	5.27	6.00	25.00	58.67
r_09	6	a405	-	0.48	14,362	5.41	-	5.41	6.00	147.00	58.19
r_09	7	a202	-	0.90	14,789	5.55	-	5.55	6.00	26.00	57.30
r_09	8	a459	-	0.17	15,039	5.68	-	5.68	6.00	69.00	57.13
r_09	9	a239	-	5.10	17,523	5.85	-	5.85	6.00	44.00	52.03
r_09	10	a143	-	2.04	18,527	6.00	-	6.00	10.00	46.00	49.98
r_09	11	a371	-	2.11	21,868	6.19	-	6.19	10.00	1,093.00	47.88
r_09	12	a511	-	0.84	24,868	6.37	-	6.37	10.00	42.00	47.04
r_09	13	a388	-	1.36	25,796	6.51	-	6.51	10.00	138.00	45.68
r_09	14	a300	-	1.74	27,037	6.66	-	6.66	10.00	1.00	43.94
r_09	15	t01	-	4.83	38,054	6.85	-	6.85	-	-	39.11
r_10	0	t01	-	-	-	3.62	-	3.62	-	-	66
r_10	1	a203	-	2.11	3,893	4.69	-	4.69	6.00	44.00	63.89
r_10	2	a436	-	1.78	9,151	4.91	-	4.91	6.00	226.00	62.10
r_10	3	a362	-	7.91	12,238	5.09	-	5.09	6.00	1,287.00	54.19
r_10	4	a267	-	7.96	16,324	5.29	-	5.29	6.00	8.00	46.24
r_10	5	a117	-	5.62	19,216	5.46	-	5.46	6.00	85.00	40.62
r_10	6	a643	-	0.09	21,320	5.63	-	5.63	6.00	65.00	40.53
r_10	7	a455	-	8.69	25,966	5.84	-	5.84	6.00	163.00	31.84
r_10	8	a528	-	0.73	27,924	6.00	-	6.00	10.00	113.00	31.11
r_10	9	a521	-	7.66	32,329	6.20	-	6.20	10.00	50.00	23.45
r_10	10	a349	-	2.78	33,949	6.36	-	6.36	10.00	265.00	20.67
r_10	11	a492	-	1.98	38,242	6.56	-	6.56	10.00	702.00	18.69

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_10	12	t01	-	0.24	41,057	6.61	-	6.61	-	-	18.45
r_11	0	t01	-	-	-	2.41	-	2.41	-	-	66
r_11	1	a024	-	2.73	9,153	3.56	-	3.56	6.00	76.00	63.27
r_11	2	a178	-	0.22	9,874	3.70	-	3.70	6.00	31.00	63.05
r_11	3	a410	-	0.43	11,224	3.86	-	3.86	6.00	102.00	62.61
r_11	4	a408	-	2.51	12,220	4.00	-	4.00	6.00	90.00	60.11
r_11	5	a057	-	4.49	14,035	4.16	-	4.16	6.00	4.00	55.62
r_11	6	a391	-	0.61	15,662	4.32	-	4.32	6.00	524.00	55.00
r_11	7	a207	-	3.27	17,135	4.47	-	4.47	6.00	31.00	51.73
r_11	8	a280	-	3.72	21,331	4.67	-	4.67	6.00	28.00	48.01
r_11	9	a229	-	3.37	22,867	4.83	-	4.83	6.00	31.00	44.64
r_11	10	a187	-	3.31	24,385	4.99	-	4.99	6.00	40.00	41.33
r_11	11	a102	-	3.48	25,996	5.14	-	5.14	6.00	70.00	37.85
r_11	12	a183	-	1.04	29,723	5.33	-	5.33	6.00	23.00	36.81
r_11	13	a276	-	1.10	32,187	5.51	-	5.51	6.00	44.00	35.71
r_11	14	a461	-	0.12	34,415	5.67	-	5.67	6.00	65.00	35.58
r_11	15	a009	-	7.00	37,809	5.86	-	5.86	6.00	48.00	28.58
r_11	16	a333	-	0.35	38,444	6.00	-	6.00	10.00	6.00	28.24
r_11	17	a376	-	0.20	39,274	6.14	-	6.14	10.00	88.00	28.04
r_11	18	a504	-	1.03	42,098	6.32	-	6.32	10.00	239.00	27.00
r_11	19	a432	-	8.70	46,725	6.53	-	6.53	10.00	128.00	18.30
r_11	20	a498	-	0.69	48,559	6.69	-	6.69	10.00	98.00	17.61
r_11	21	a020	-	6.10	52,001	6.88	-	6.88	10.00	67.00	11.51
r_11	22	a481	-	0.75	56,152	7.08	-	7.08	10.00	62.00	10.76
r_11	23	a424	-	3.41	58,147	7.24	-	7.24	10.00	145.00	7.35
r_11	24	a484	-	1.25	60,436	7.41	-	7.41	10.00	524.00	6.10
r_11	25	a479	-	2.01	61,884	7.56	-	7.56	10.00	366.00	4.09
r_11	26	c092	6,829.47	-	-	-	0.02	0.02	-	-	4.87
r_11	27	t01	-	4.87	71,952	7.73	-	7.74	-	-	-
r_12	0	t01	-	-	-	-	-	-	-	-	66
r_12	1	a585	-	18.73	55,716	1.93	-	1.93	8.00	114.00	47.27
r_12	2	a584	-	3.68	57,194	2.08	-	2.08	8.00	74.00	43.59
r_12	3	a307	-	0.16	57,258	2.21	-	2.21	8.00	49.00	43.43
r_12	4	a587	-	0.35	58,210	2.36	-	2.36	8.00	351.00	43.08
r_12	5	a579	-	1.81	59,011	2.50	-	2.50	8.00	96.00	41.27
r_12	6	a269	-	4.53	61,055	2.67	-	2.67	8.00	24.00	36.75
r_12	7	a091	-	5.83	63,701	2.84	-	2.84	8.00	99.00	30.92
r_12	8	a360	-	0.25	65,955	3.01	-	3.01	8.00	640.00	30.66
r_12	9	a159	-	2.88	67,513	3.17	-	3.17	8.00	75.00	27.78
r_12	10	a629	-	3.13	72,400	3.38	-	3.38	8.00	22.00	24.66
r_12	11	a630	-	3.75	78,421	3.61	-	3.61	8.00	125.00	20.91
r_12	12	a623	-	9.74	84,007	3.83	-	3.83	8.00	261.00	11.18
r_12	13	c613	31,523.41	-	-	-	0.97	0.97	-	-	59.46
r_12	14	a598	-	31.42	103,425	4.28	-	5.25	8.00	56.00	28.04
r_12	15	a176	-	28.04	121,046	4.71	-	5.67	8.00	90.00	-
r_12	16	c617	32,852.15	-	-	-	0.50	1.46	-	-	24.90
r_12	17	a088	-	12.01	128,806	4.97	-	6.43	8.00	73.00	12.89
r_12	18	a039	-	5.06	132,151	5.15	-	6.62	8.00	45.00	7.83
r_12	19	a163	-	0.08	138,193	5.38	-	6.85	8.00	60.00	7.75
r_12	20	a581	-	2.71	142,605	5.59	-	7.05	8.00	191.00	5.04
r_12	21	a589	-	0.55	145,988	5.77	-	7.24	8.00	51.00	4.49
r_12	22	a031	-	4.16	149,075	5.95	-	7.42	8.00	110.00	0.33
r_12	23	a105	-	0.10	149,697	6.09	-	7.56	8.00	50.00	0.23
r_12	24	a588	-	0.23	150,661	6.24	-	7.70	8.00	170.00	-
r_12	25	c528	51,220.15	-	-	-	1.53	2.99	-	-	76.29
r_12	26	a170	-	59.90	201,050	7.21	-	10.20	10.00	25.00	16.39
r_12	27	t01	-	16.39	238,641	7.84	-	10.83	-	-	-
r_13	0	t01	-	-	-	2.82	-	2.82	-	-	66
r_13	1	a250	-	3.78	10,597	4.00	-	4.00	6.00	31.00	62.22

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_13	2	a218	-	1.30	11,318	4.14	-	4.14	6.00	25.00	60.91
r_13	3	a278	-	0.00	11,915	4.28	-	4.28	6.00	22.00	60.91
r_13	4	a417	-	0.13	12,677	4.42	-	4.42	6.00	94.00	60.78
r_13	5	a233	-	0.22	12,801	4.55	-	4.55	6.00	31.00	60.56
r_13	6	a273	-	0.08	13,010	4.69	-	4.69	6.00	23.00	60.48
r_13	7	a227	-	0.86	13,512	4.82	-	4.82	6.00	29.00	59.62
r_13	8	a180	-	0.59	13,859	4.96	-	4.96	6.00	24.00	59.03
r_13	9	a232	-	0.73	15,321	5.11	-	5.11	6.00	22.00	58.31
r_13	10	a226	-	4.05	17,736	5.28	-	5.28	6.00	31.00	54.26
r_13	11	a230	-	0.44	18,741	5.43	-	5.43	6.00	26.00	53.82
r_13	12	a449	-	0.52	20,370	5.59	-	5.59	6.00	279.00	53.30
r_13	13	a422	-	0.41	20,640	5.72	-	5.72	6.00	38.00	52.89
r_13	14	a453	-	0.13	21,236	5.86	-	5.86	6.00	92.00	52.76
r_13	15	a129	-	0.65	21,681	6.00	-	6.00	10.00	140.00	52.11
r_13	16	a215	-	0.11	21,954	6.13	-	6.13	10.00	76.00	52.00
r_13	17	a014	-	1.35	22,955	6.28	-	6.28	10.00	76.00	50.65
r_13	18	a204	-	0.53	24,304	6.43	-	6.43	10.00	22.00	50.12
r_13	19	a224	-	0.17	24,923	6.57	-	6.57	10.00	25.00	49.96
r_13	20	a514	-	0.63	26,207	6.73	-	6.73	10.00	36.00	49.33
r_13	21	a473	-	1.53	27,407	6.88	-	6.88	10.00	207.00	47.80
r_13	22	a253	-	2.21	29,286	7.04	-	7.04	10.00	4.00	45.59
r_13	23	a346	-	2.55	33,587	7.24	-	7.24	10.00	745.00	43.04
r_13	24	t01	-	2.41	42,216	7.38	-	7.38	-	-	40.63
r_14	0	t01	-	-	-	3.02	-	3.02	-	-	66
r_14	1	a032	-	2.57	5,645	4.12	-	4.12	6.00	110.00	63.43
r_14	2	a429	-	2.44	13,870	4.38	-	4.38	6.00	101.00	60.99
r_14	3	a247	-	1.23	14,391	4.52	-	4.52	6.00	27.00	59.76
r_14	4	a195	-	6.67	17,231	4.70	-	4.70	6.00	22.00	53.09
r_14	5	a044	-	0.81	17,578	4.84	-	4.84	6.00	162.00	52.28
r_14	6	a306	-	0.13	17,888	4.97	-	4.97	6.00	23.00	52.15
r_14	7	a303	-	0.92	18,298	5.11	-	5.11	6.00	34.00	51.23
r_14	8	a339	-	0.27	18,775	5.25	-	5.25	6.00	415.00	50.96
r_14	9	a194	-	1.00	19,267	5.38	-	5.38	6.00	25.00	49.96
r_14	10	a245	-	1.34	20,697	5.54	-	5.54	6.00	31.00	48.62
r_14	11	a076	-	0.18	20,785	5.67	-	5.67	6.00	10.00	48.44
r_14	12	a181	-	2.39	23,339	5.84	-	5.84	6.00	31.00	46.05
r_14	13	a457	-	0.29	25,007	6.00	-	6.00	6.00	68.00	45.76
r_14	14	a241	-	8.12	29,160	6.20	-	6.20	10.00	44.00	37.64
r_14	15	a216	-	3.02	30,721	6.36	-	6.36	10.00	11.00	34.63
r_14	16	a480	-	0.95	35,457	6.56	-	6.56	10.00	52.00	33.68
r_14	17	a266	-	6.62	38,935	6.75	-	6.75	10.00	1.00	27.06
r_14	18	a370	-	0.25	39,663	6.89	-	6.89	10.00	534.00	26.81
r_14	19	a016	-	0.73	40,106	7.03	-	7.03	10.00	29.00	26.08
r_14	20	a291	-	0.82	42,016	7.19	-	7.19	10.00	12.00	25.25
r_14	21	a238	-	0.59	42,379	7.33	-	7.33	10.00	22.00	24.66
r_14	22	a477	-	0.92	44,398	7.49	-	7.49	10.00	40.00	23.75
r_14	23	a026	-	8.98	50,018	7.72	-	7.72	10.00	48.00	14.77
r_14	24	a281	-	0.71	53,020	7.90	-	7.90	10.00	37.00	14.05
r_14	25	a582	-	2.18	57,263	8.10	-	8.10	10.00	878.00	11.87
r_14	26	t01	-	0.47	62,102	8.18	-	8.18	-	-	11.40
r_15	0	t01	-	-	-	1.45	-	1.45	-	-	66
r_15	1	a416	-	3.68	12,450	2.66	-	2.66	6.00	91.00	62.32
r_15	2	a214	-	2.22	13,252	2.80	-	2.80	6.00	31.00	60.10
r_15	3	a108	-	1.32	13,730	2.94	-	2.94	6.00	20.00	58.79
r_15	4	a359	-	0.65	15,018	3.09	-	3.09	6.00	7.00	58.13
r_15	5	a571	-	0.17	15,451	3.23	-	3.23	6.00	196.00	57.96
r_15	6	a197	-	3.27	16,687	3.38	-	3.38	6.00	25.00	54.69
r_15	7	a236	-	0.23	17,595	3.52	-	3.52	6.00	22.00	54.47
r_15	8	a190	-	6.53	20,085	3.69	-	3.69	6.00	10.00	47.93

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_15	9	a397	-	0.48	22,325	3.86	-	3.86	6.00	64.00	47.45
r_15	10	a251	-	4.39	24,023	4.02	-	4.02	6.00	9.00	43.06
r_15	11	a240	-	2.49	24,986	4.17	-	4.17	6.00	31.00	40.57
r_15	12	a272	-	0.24	25,599	4.31	-	4.31	6.00	30.00	40.33
r_15	13	a255	-	0.87	25,940	4.44	-	4.44	6.00	57.00	39.46
r_15	14	a441	-	1.52	28,837	4.62	-	4.62	6.00	47.00	37.94
r_15	15	a066	-	10.48	33,020	4.82	-	4.82	6.00	27.00	27.46
r_15	16	a367	-	1.56	34,867	4.98	-	4.98	6.00	53.00	25.89
r_15	17	c314	1,948.97	-	-	-	-	-	-	-	52.73
r_15	18	a069	-	33.84	48,587	5.34	-	5.34	6.00	23.00	18.89
r_15	19	a274	-	0.99	49,841	5.49	-	5.49	6.00	8.00	17.90
r_15	20	a419	-	7.59	64,799	5.87	-	5.87	6.00	181.00	10.31
r_15	21	a337	-	-	64,799	6.00	-	6.00	10.00	607.00	10.31
r_15	22	a506	-	1.54	72,419	6.26	-	6.26	10.00	770.00	8.78
r_15	23	a466	-	8.16	77,205	6.47	-	6.47	10.00	255.00	0.61
r_15	24	a497	-	0.61	78,531	6.62	-	6.62	10.00	87.00	-
r_15	25	c277	5,822.04	-	-	-	0.21	0.21	-	-	10.36
r_15	26	a171	-	1.74	79,662	6.77	-	6.98	10.00	80.00	8.62
r_15	27	a505	-	0.22	80,316	6.91	-	7.12	10.00	167.00	8.40
r_15	28	a620	-	0.48	81,241	7.05	-	7.26	10.00	148.00	7.92
r_15	29	a485	-	1.94	82,678	7.21	-	7.42	10.00	86.00	5.97
r_15	30	t01	-	5.97	94,945	7.41	-	7.62	-	-	-
r_16	0	t01	-	-	-	5.68	-	5.68	-	-	66
r_16	1	a042	-	2.32	6,918	6.80	-	6.80	10.00	232.00	63.68
r_16	2	a523	-	0.00	7,170	6.93	-	6.93	10.00	78.00	63.68
r_16	3	a327	-	4.43	9,990	7.11	-	7.11	10.00	60.00	59.25
r_16	4	a317	-	0.39	10,245	7.24	-	7.24	10.00	50.00	58.85
r_16	5	a396	-	0.02	14,950	7.45	-	7.45	10.00	457.00	58.83
r_16	6	a041	-	1.46	16,075	7.60	-	7.60	10.00	39.00	57.37
r_16	7	a495	-	0.47	17,821	7.76	-	7.76	10.00	126.00	56.90
r_16	8	a509	-	1.01	19,666	7.92	-	7.92	10.00	94.00	55.89
r_16	9	a033	-	9.63	27,852	8.18	-	8.18	10.00	40.00	46.26
r_16	10	a516	-	1.23	34,247	8.42	-	8.42	10.00	107.00	45.03
r_16	11	a512	-	0.92	35,083	8.56	-	8.56	10.00	68.00	44.11
r_16	12	a036	-	2.63	37,536	8.74	-	8.74	10.00	57.00	41.48
r_16	13	a520	-	0.47	38,825	8.89	-	8.89	10.00	58.00	41.01
r_16	14	a489	-	1.80	40,595	9.05	-	9.05	10.00	73.00	39.21
r_16	15	a072	-	0.38	40,981	9.18	-	9.18	10.00	10.00	38.83
r_16	16	a621	-	1.26	43,802	9.36	-	9.36	10.00	130.00	37.57
r_16	17	a522	-	2.03	46,012	9.53	-	9.53	10.00	48.00	35.55
r_16	18	a488	-	1.81	48,038	9.69	-	9.69	10.00	193.00	33.74
r_16	19	a256	-	1.49	49,903	9.85	-	9.85	10.00	28.00	32.24
r_16	20	a040	-	0.86	51,001	10.00	-	10.00	10.00	45.00	31.38
r_16	21	t01	-	5.03	62,946	10.20	-	10.20	-	-	26.35
r_17	0	t01	-	-	-	1.82	-	1.82	-	-	66
r_17	1	a123	-	4.21	12,868	3.04	-	3.04	6.00	40.00	61.79
r_17	2	a399	-	2.81	20,626	3.30	-	3.30	6.00	232.00	58.98
r_17	3	a450	-	0.66	25,630	3.51	-	3.51	6.00	364.00	58.32
r_17	4	a212	-	1.30	26,537	3.66	-	3.66	6.00	22.00	57.02
r_17	5	a434	-	0.40	27,583	3.80	-	3.80	6.00	62.00	56.61
r_17	6	a006	-	2.71	29,528	3.97	-	3.97	6.00	28.00	53.90
r_17	7	a437	-	1.18	31,740	4.13	-	4.13	6.00	60.00	52.72
r_17	8	a252	-	1.55	32,883	4.28	-	4.28	6.00	28.00	51.18
r_17	9	a404	-	0.41	34,140	4.43	-	4.43	6.00	342.00	50.76
r_17	10	a351	-	1.59	35,490	4.58	-	4.58	6.00	437.00	49.18
r_17	11	a462	-	0.63	36,817	4.74	-	4.74	6.00	48.00	48.55
r_17	12	a446	-	1.22	38,114	4.89	-	4.89	6.00	52.00	47.33
r_17	13	a439	-	1.39	39,629	5.04	-	5.04	6.00	58.00	45.94
r_17	14	a002	-	1.62	41,443	5.20	-	5.20	6.00	49.00	44.32

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_17	15	a442	-	0.25	42,596	5.35	-	5.35	6.00	59.00	44.07
r_17	16	a627	-	0.09	42,870	5.49	-	5.49	6.00	22.00	43.97
r_17	17	a249	-	2.32	45,669	5.66	-	5.66	6.00	31.00	41.65
r_17	18	a425	-	0.23	47,081	5.82	-	5.82	6.00	52.00	41.42
r_17	19	a013	-	2.47	50,219	6.00	-	6.00	6.00	27.00	38.95
r_17	20	t01	-	3.81	58,854	6.14	-	6.14	-	-	35.14
r_18	0	t01	-	-	-	1.44	-	1.44	-	-	66
r_18	1	a172	-	4.09	10,540	2.62	-	2.62	6.00	29.00	61.91
r_18	2	a311	-	2.38	14,671	2.82	-	2.82	6.00	51.00	59.53
r_18	3	a075	-	8.66	17,470	2.99	-	2.99	6.00	11.00	50.87
r_18	4	a228	-	5.29	25,599	3.26	-	3.26	6.00	31.00	45.58
r_18	5	a221	-	19.77	32,028	3.50	-	3.50	6.00	30.00	25.81
r_18	6	c143	23,236.44	-	-	-	0.99	0.99	-	-	75.18
r_18	7	a177	-	29.93	41,808	3.79	-	4.78	8.00	60.00	45.24
r_18	8	a648	-	0.94	45,373	3.98	-	4.97	8.00	116.00	44.30
r_18	9	a637	-	22.81	53,036	4.24	-	5.22	8.00	40.00	21.49
r_18	10	a304	-	1.61	53,581	4.38	-	5.36	8.00	25.00	19.88
r_18	11	a104	-	0.05	53,597	4.51	-	5.49	8.00	50.00	19.83
r_18	12	a642	-	0.66	55,097	4.66	-	5.65	8.00	104.00	19.18
r_18	13	a379	-	1.21	55,517	4.80	-	5.79	8.00	200.00	17.97
r_18	14	a235	-	17.97	61,992	5.04	-	6.02	8.00	61.00	-
r_18	15	c375	78,766.49	-	-	-	1.05	2.04	-	-	52.56
r_18	16	a331	-	23.43	115,902	6.07	-	8.10	15.00	5.00	29.13
r_18	17	a632	-	23.73	165,917	7.03	-	9.07	8.00	121.00	5.40
r_18	18	a297	-	5.40	167,926	7.19	-	9.23	8.00	40.00	-
r_18	19	c375	83,972.53	-	-	-	0.41	2.45	-	-	20.37
r_18	20	a130	-	11.33	172,173	7.39		9.84	8.00	100.00	9.04
r_18	21	a646	-	0.25	172,699	7.53		9.98	8.00	200.00	8.79
r_18	22	a645	-	2.81	173,812	7.68		10.13	8.00	130.00	5.98
r_18	23	a639	-	5.06	175,867	7.84		10.29	8.00	146.00	0.92
r_18	24	a644	-	0.92	177,376	8.00		10.45	8.00	651.00	-
r_18	25	c367	4,672.07	-	-	-	1.03	3.47	-	-	51.33
r_18	26	a525		51.33	202,062	8.54	-	12.01	10.00	45.00	-
r_18	27	c180	22,154.69	-	-	-	0.60	4.07	-	-	29.93
r_18	28	a115	-	4.76	204,374	8.71	-	12.78	10.00	105.00	25.18
r_18	29	a116	-	1.26	206,930	8.88	-	12.95	10.00	56.00	23.92
r_18	30	a622	-	1.63	208,838	9.04	-	13.12	10.00	138.00	22.28
r_18	31	a530	-	5.85	211,892	9.23	-	13.30	10.00	61.00	16.44
r_18	32	a443	-	9.84	217,109	9.44	-	13.51	10.00	183.00	6.60
r_18	33	a309	-	1.37	217,871	9.58	-	13.66	10.00	18.00	5.23
r_18	34	a487	-	1.76	220,240	9.75	-	13.83	10.00	82.00	3.47
r_18	35	t01	-	3.47	231,633	9.94	-	14.02	-	-	-
r_19	0	t01	-	-	-	0.63	-	0.63	-	-	66
r_19	1	a369	-	4.69	8,108	1.77	-	1.77	6.00	142.00	61.31
r_19	2	c016	12,854.87	-	-	-	0.66	0.66	-	-	94.53
r_19	3	a286	-	88.99	44,135	2.50	-	3.16	8.00	22.00	5.54
r_19	4	a638	-	5.02	52,497	2.77	-	3.43	8.00	145.00	0.52
r_19	5	a647	-	0.52	56,016	2.96	-	3.62	8.00	58.00	- ,,,,,0.00
r_19	6	c347	67,163.09	-	-	-	2.27	2.94	-	-	113.67
r_19	7	c457	117,792.46	-	-	-	-	2.94	-	-	113.67
r_19	8	a096	-	107.28	101,430	3.84	-	6.78	8.00	86.00	6.39
r_19	9	a483	-	6.39	115,365	4.20	-	7.14	8.00	271.00	-
r_19	10	c492	10,542.43	-	-	-	1.07	4.01	-	-	53.64
r_19	11	a022	-	14.21	121,848	4.44	-	8.45	8.00	26.00	39.43
r_19	12	a361	-	0.56	122,633	4.59	-	8.60	8.00	56.00	38.88
r_19	13	a592	-	7.36	140,240	5.01	-	9.02	8.00	472.00	31.52
r_19	14	a208	-	4.36	142,504	5.18	-	9.19	8.00	39.00	27.16
r_19	15	a325	-	1.27	144,312	5.34	-	9.35	8.00	38.00	25.89

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_19	16	a612	-	1.03	146,811	5.51	-	9.52	8.00	111.00	24.85
r_19	17	a594	-	5.47	149,789	5.69	-	9.70	8.00	96.00	19.39
r_19	18	a067	-	19.18	160,506	6.00	-	10.01	8.00	190.00	0.20
r_19	19	a293	-	0.20	162,304	6.16	-	10.17	8.00	4.00	- ,,,,,0.00
r_19	20	c463	97,157.78	-	-	-	0.45	4.46	-	-	22.34
r_19	21	t01	-	22.34	217,805	7.08	-	11.54	-	-	-
r_20	0	t01	-	-	-	8.96	-	8.96	-	-	66
r_20	1	a501	-	1.19	2,317	10.00	-	10.00	15.00	71.00	64.81
r_20	2	a125	-	12.38	7,416	10.21	-	10.21	15.00	120.00	52.43
r_20	3	a012	-	0.04	7,433	10.35	-	10.35	15.00	46.00	52.39
r_20	4	a536	-	4.45	11,926	10.55	-	10.55	15.00	175.00	47.95
r_20	5	a017	-	34.71	27,261	10.94	-	10.94	15.00	76.00	13.23
r_20	6	a613	-	1.42	30,575	11.12	-	11.12	15.00	64.00	11.81
r_20	7	a050	-	2.74	31,821	11.27	-	11.27	15.00	60.00	9.08
r_20	8	a148	-	3.26	36,446	11.48	-	11.48	15.00	30.00	5.82
r_20	9	c179	31,243.36	-	-	-	0.88	0.88	-	-	49.63
r_20	10	a051	-	8.39	40,342	11.67	-	12.55	15.00	66.00	41.24
r_20	11	a591	-	4.14	51,359	11.99	-	12.86	15.00	143.00	37.10
r_20	12	a631	-	0.89	51,768	12.12	-	13.00	15.00	706.00	36.21
r_20	13	a597	-	2.68	53,330	12.28	-	13.16	15.00	41.00	33.54
r_20	14	a602	-	0.43	55,564	12.45	-	13.32	15.00	357.00	33.10
r_20	15	a625	-	0.47	57,056	12.60	-	13.48	15.00	93.00	32.64
r_20	16	a196	-	0.09	57,118	12.73	-	13.61	15.00	31.00	32.55
r_20	17	a539	-	2.64	64,344	12.98	-	13.86	15.00	125.00	29.90
r_20	18	a343	-	18.37	77,418	13.33	-	14.21	15.00	376.00	11.53
r_20	19	a363	-	0.20	77,928	13.47	-	14.35	15.00	66.00	11.33
r_20	20	a140	-	4.27	81,507	13.66	-	14.54	15.00	46.00	7.06
r_20	21	a080	-	3.95	84,881	13.85	-	14.72	15.00	10.00	3.11
r_20	22	a259	-	0.30	87,574	14.02	-	14.90	15.00	27.00	2.81
r_20	23	a271	-	0.43	89,203	14.18	-	15.05	15.00	37.00	2.38
r_20	24	t01	-	2.38	96,354	14.30	-	15.17	-	-	-
r_21	0	t01	-	-	-	7.31	-	7.31	-	-	66
r_21	1	a605	-	24.79	66,808	9.42	-	9.42	15.00	81.00	41.21
r_21	2	a146	-	5.50	69,065	9.59	-	9.59	15.00	36.00	35.71
r_21	3	a021	-	13.48	74,634	9.81	-	9.81	15.00	81.00	22.24
r_21	4	a611	-	6.96	90,297	10.20	-	10.20	15.00	73.00	15.28
r_21	5	a616	-	2.02	96,562	10.44	-	10.44	15.00	490.00	13.26
r_21	6	a155	-	5.22	99,032	10.61	-	10.61	15.00	42.00	8.05
r_21	7	a064	-	2.55	100,251	10.76	-	10.76	15.00	51.00	5.50
r_21	8	a149	-	1.38	101,736	10.91	-	10.91	15.00	72.00	4.12
r_21	9	a596	-	2.62	110,086	11.18	-	11.18	15.00	99.00	1.50
r_21	10	c439	55,135.33	-	-	-	0.95	0.95	-	-	48.98
r_21	11	a614	-	3.03	121,247	11.50		12.45	15.00	41.00	45.95
r_21	12	a261	-	26.02	134,488	11.85		12.80	15.00	27.00	19.93
r_21	13	a475	-	5.45	152,141	12.27		13.22	15.00	97.00	14.48
r_21	14	a089	-	12.70	158,804	12.51		13.46	15.00	98.00	1.78
r_21	15	a406	-	1.78	163,505	12.72		13.67	15.00	92.00	0.00
r_21	16	c419	48,690.34	-	-	-	1.09	2.04	-	-	54.67
r_21	17	a395	-	54.67	193,629	13.35		15.40	15.00	82.00	-
r_21	18	c331	52,844.88	-	-	-	0.96	3.00	-	-	47.92
r_21	19	a305	-	39.41	215,825	13.85	-	16.86	15.00	24.00	8.51
r_21	20	a098	-	3.59	217,862	14.02	-	17.02	15.00	86.00	4.92
r_21	21	a219	-	4.92	227,158	14.30	-	17.31	15.00	1.00	-
r_21	22	c299	26,226.88	-	-	-	0.55	3.55	-	-	27.62
r_21	23	a082	-	17.36	237,237	14.60	-	18.16	15.00	14.00	10.26
r_21	24	a312	-	5.75	253,333	15.00	-	18.55	15.00	8.00	4.51
r_21	25	t01	-	4.51	262,907	15.16	-	18.71	-	-	-
r_22	0	t01	-	-	-	8.98	-	8.98	-	-	66

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_22	1	a073	-	4.97	13,389	10.21	-	10.21	15.00	11.00	61.03
r_22	2	a234	-	0.06	14,053	10.35	-	10.35	15.00	31.00	60.96
r_22	3	a034	-	4.17	16,804	10.52	-	10.52	15.00	60.00	56.79
r_22	4	a277	-	2.46	23,827	10.77	-	10.77	15.00	23.00	54.33
r_22	5	t01	-	3.54	32,036	10.91	-	10.91	-	-	50.79
r_23	0	t01	-	-	-	8.73	-	8.73	-	-	66
r_23	1	a607	-	15.83	40,424	10.40	-	10.40	15.00	71.00	50.17
r_23	2	a372	-	43.01	57,061	10.81	-	10.81	15.00	119.00	7.17
r_23	3	a619	-	6.29	73,143	11.21	-	11.21	15.00	1,067.00	0.88
r_23	4	c405	75,889.47	-	-	-	0.95	0.95	-	-	48.22
r_23	5	a356	-	3.66	74,956	11.37	-	12.32	15.00	38.00	44.57
r_23	6	a134	-	4.48	77,199	11.54	-	12.48	15.00	66.00	40.08
r_23	7	a313	-	0.05	77,717	11.68	-	12.62	15.00	9.00	40.04
r_23	8	a200	-	2.67	79,075	11.83	-	12.77	15.00	54.00	37.37
r_23	9	a580	-	2.07	84,410	12.05	-	12.99	15.00	45.00	35.30
r_23	10	a633	-	1.91	88,440	12.24	-	13.19	15.00	198.00	33.39
r_23	11	a634	-	0.83	89,606	12.39	-	13.34	15.00	146.00	32.56
r_23	12	a111	-	32.56	108,203	12.83	-	13.78	15.00	52.00	-
r_23	13	c405	92843.52	-	-	-	0.92	1.87	-	-	45.92
r_23	14	a137	-	12.33	140,355	13.50	-	15.36	15.00	44.00	33.59
r_23	15	a562	-	7.25	162,617	14.00	-	15.87	15.00	155.00	26.34
r_23	16	a081	-	9.34	168,347	14.23	-	16.09	15.00	23.00	17.00
r_23	17	a626	-	0.27	169,288	14.37	-	16.24	15.00	129.00	16.73
r_23	18	a094	-	12.73	177,459	14.64	-	16.50	15.00	165.00	4.00
r_23	19	a095	-	4.00	187,892	14.94	-	16.81	15.00	86.00	-
r_23	20	c405	74,557.53	-	-	-	0.34	2.20	-	-	16.89
r_23	21	t01	-	16.89	233,154	15.70	-	17.90	-	-	-
r_24	0	t01	-	-	-	8.80	-	8.80	-	-	66
r_24	1	a355	-	3.66	12,185	10.00	-	10.00	15.00	842.00	62.34
r_24	2	a375	-	1.36	14,042	10.16	-	10.16	15.00	165.00	60.98
r_24	3	a132	-	2.98	15,045	10.31	-	10.31	15.00	107.00	58.00
r_24	4	a472	-	0.11	15,912	10.45	-	10.45	15.00	338.00	57.90
r_24	5	a265	-	7.79	18,742	10.63	-	10.63	15.00	7.00	50.11
r_24	6	a257	-	8.11	21,690	10.81	-	10.81	15.00	27.00	42.00
r_24	7	a043	-	12.90	26,405	11.02	-	11.02	15.00	93.00	29.10
r_24	8	a158	-	2.33	31,221	11.23	-	11.23	15.00	82.00	26.77
r_24	9	a107	-	5.53	33,304	11.39	-	11.39	15.00	100.00	21.24
r_24	10	a199	-	0.99	36,207	11.57	-	11.57	15.00	39.00	20.25
r_24	11	a323	-	5.23	42,589	11.81	-	11.81	15.00	5.00	15.02
r_24	12	a292	-	9.65	46,325	12.00	-	12.00	15.00	12.00	5.37
r_24	13	c336	1,326.76	-	-	-	0.73	0.73	-	-	41.95
r_24	14	a127	-	6.79	48,957	12.17	-	12.90	15.00	100.00	35.16
r_24	15	a540	-	0.14	51,222	12.34	-	13.07	15.00	118.00	35.02
r_24	16	a394	-	12.50	56,274	12.55	-	13.29	15.00	58.00	22.52
r_24	17	a100	-	5.15	58,380	12.72	-	13.45	15.00	91.00	17.37
r_24	18	a217	-	0.91	61,114	12.90	-	13.63	15.00	39.00	16.46
r_24	19	a119	-	1.55	61,762	13.04	-	13.77	15.00	70.00	14.92
r_24	20	a025	-	1.37	62,344	13.18	-	13.91	15.00	58.00	13.55
r_24	21	a113	-	0.14	62,776	13.31	-	14.04	15.00	78.00	13.40
r_24	22	a299	-	0.22	64,699	13.48	-	14.21	15.00	30.00	13.18
r_24	23	a065	-	-	64,699	13.61	-	14.34	15.00	50.00	13.18
r_24	24	a556	-	0.80	65,729	13.75	-	14.48	15.00	154.00	12.38
r_24	25	a559	-	0.69	66,726	13.90	-	14.63	15.00	280.00	11.69
r_24	26	a144	-	1.36	67,395	14.04	-	14.77	15.00	55.00	10.33
r_24	27	a548	-	0.17	67,731	14.18	-	14.91	15.00	228.00	10.15
r_24	28	a529	-	1.32	68,425	14.32	-	15.05	15.00	463.00	8.83
r_24	29	a381	-	0.80	68,901	14.46	-	15.19	15.00	84.00	8.03
r_24	30	a385	-	0.17	69,624	14.60	-	15.33	15.00	6.00	7.86
r_24	31	a110	-	1.59	70,592	14.74	-	15.48	15.00	18.00	6.28

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_24	32	t01	-	6.28	83,490	14.96	-	15.69	-	-	-
r_25	0	t01	-	-	-	8.79	-	8.79	-	-	66
r_25	1	a092	-	6.39	16,041	10.05	-	10.05	15.00	102.00	59.61
r_25	2	a469	-	1.22	19,405	10.24	-	10.24	15.00	55.00	58.39
r_25	3	a565	-	1.46	21,899	10.41	-	10.41	15.00	216.00	56.93
r_25	4	a063	-	12.99	27,476	10.64	-	10.64	15.00	153.00	43.94
r_25	5	a162	-	0.20	28,999	10.79	-	10.79	15.00	76.00	43.74
r_25	6	a188	-	1.08	33,110	10.99	-	10.99	15.00	18.00	42.66
r_25	7	a103	-	21.63	42,894	11.28	-	11.28	15.00	155.00	21.03
r_25	8	a037	-	4.49	44,994	11.45	-	11.45	15.00	43.00	16.54
r_25	9	a296	-	0.07	46,375	11.60	-	11.60	15.00	10.00	16.47
r_25	10	a139	-	3.22	47,898	11.76	-	11.76	15.00	42.00	13.25
r_25	11	a128	-	7.56	51,513	11.95	-	11.95	15.00	40.00	5.69
r_25	12	a324	-	1.28	57,039	12.17	-	12.17	15.00	131.00	4.42
r_25	13	a023	-	3.39	58,728	12.33	-	12.33	15.00	33.00	1.02
r_25	14	a157	-	0.94	60,188	12.48	-	12.48	15.00	82.00	0.08
r_25	15	c409	5,895.64	-	-	-	0.98	0.98	-	-	49.17
r_25	16	a152	-	2.18	61,304	12.63	-	13.61	15.00	82.00	46.99
r_25	17	a120	-	4.50	63,652	12.80	-	13.78	15.00	28.00	42.49
r_25	18	a572	-	4.03	71,790	13.06	-	14.05	15.00	140.00	38.46
r_25	19	a049	-	10.89	77,727	13.29	-	14.27	15.00	92.00	27.57
r_25	20	a084	-	2.26	81,569	13.49	-	14.47	15.00	40.00	25.31
r_25	21	a533	-	0.88	82,376	13.63	-	14.61	15.00	88.00	24.43
r_25	22	a079	-	1.62	83,313	13.78	-	14.76	15.00	20.00	22.81
r_25	23	a268	-	2.23	92,646	14.06	-	15.04	15.00	28.00	20.58
r_25	24	a558	-	0.76	96,215	14.25	-	15.23	15.00	94.00	19.81
r_25	25	a538	-	4.86	99,142	14.43	-	15.41	15.00	224.00	14.95
r_25	26	a156	-	2.98	101,058	14.59	-	15.57	15.00	54.00	11.97
r_25	27	a262	-	4.72	110,038	14.87	-	15.85	15.00	28.00	7.25
r_25	28	t01	-	7.25	129,062	15.19	-	16.17	-	-	-
r_26	0	t01	-	-	-	11.94	-	11.94	-	-	66
r_26	1	a576	-	2.69	8,256	13.08	-	13.08	15.00	505.00	63.31
r_26	2	a350	-	0.37	8,412	13.21	-	13.21	15.00	1,175.00	62.94
r_26	3	a544	-	0.07	8,607	13.34	-	13.34	15.00	57.00	62.87
r_26	4	a567	-	0.19	9,813	13.50	-	13.50	15.00	52.00	62.68
r_26	5	a555	-	1.66	10,741	13.64	-	13.64	15.00	84.00	61.03
r_26	6	a578	-	1.26	13,188	13.81	-	13.81	15.00	47.00	59.77
r_26	7	a315	-	2.02	14,359	13.96	-	13.96	15.00	15.00	57.75
r_26	8	a301	-	7.09	18,494	14.16	-	14.16	15.00	45.00	50.66
r_26	9	a451	-	0.40	19,250	14.30	-	14.30	15.00	24.00	50.26
r_26	10	a055	-	1.77	20,302	14.45	-	14.45	15.00	106.00	48.49
r_26	11	a165	-	-	20,302	14.58	-	14.58	15.00	51.00	48.49
r_26	12	a531	-	0.25	20,760	14.72	-	14.72	15.00	530.00	48.24
r_26	13	a407	-	0.52	21,145	14.85	-	14.85	15.00	181.00	47.72
r_26	14	a550	-	0.52	22,110	15.00	-	15.00	15.00	83.00	47.20
r_26	15	t01	-	4.04	30,771	15.14	-	15.14	-	-	43.16
r_27	0	t01	-	-	-	4.53	-	4.53	-	-	66
r_27	1	a046	-	21.68	37,387	6.15	-	6.15	13.00	96.00	44.32
r_27	2	a352	-	11.04	44,887	6.41	-	6.41	13.00	81.00	33.27
r_27	3	a353	-	-	44,887	6.54	-	6.54	13.00	5.00	33.27
r_27	4	a045	-	17.87	51,744	6.78	-	6.78	13.00	147.00	15.41
r_27	5	a393	-	2.47	59,048	7.03	-	7.03	13.00	354.00	12.93
r_27	6	c708	181,368.66	-	-	-	1.98	1.98	-	-	112.10
r_27	7	c708	204,779.44	-	-	-	-	1.98	-	-	112.10
r_27	8	a085	-	112.10	106,436	7.95	-	9.94	13.00	208.00	-
r_27	9	c708	183,003.34	-	-	-	0.71	2.69	-	-	35.48
r_27	10	a027	-	25.82	117,830	8.27	-	10.97	13.00	73.00	9.67
r_27	11	a285	-	9.67	133,443	8.66	-	11.36	13.00	144.00	-
r_27	12	c708	200,719.80	-	-	-	2.55	5.25	-	-	127.67

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_27	13	c708	204,779.44	-	-	-	-	5.25	-	-	127.67
r_27	14	a028	-	118.65	188,319	9.71	-	14.96	13.00	21.00	9.03
r_27	15	a373	-	9.03	210,513	10.21	-	15.45	13.00	307.00	-
r_27	16	c708	227,070.99	-	-	-	0.50	5.75	-	-	25.18
r_27	17	a341	-	25.18	223,070	10.55	-	16.30	13.00	177.00	-
r_27	18	c708	215,558.83	-	-	-	1.56	7.31	-	-	78.05
r_27	19	a087	-	78.05	263,718	11.36	-	18.67	13.00	73.00	-
r_27	20	c708	186,404.63	-	-	-	0.36	7.67	-	-	18.08
r_27	21	a138	-	13.93	311,741	12.29	-	19.96	13.00	42.00	4.15
r_27	22	a383	-	4.15	320,381	12.56	-	20.23	13.00	353.00	-
r_27	23	c708	-	-	-	-	-	9.23	-	-	77.66
r_27	24	t01	-	77.66	536,381	16.16	-	25.39	-	-	-
r_28	0	t01	-	-	-	11.13	-	11.13	-	-	66
r_28	1	a175	-	0.91	2,006	12.16	-	12.16	15.00	20.00	65.09
r_28	2	a549	-	2.60	6,324	12.37	-	12.37	15.00	363.00	62.49
r_28	3	a490	-	11.52	9,814	12.55	-	12.55	15.00	123.00	50.97
r_28	4	a561	-	1.91	14,255	12.76	-	12.76	15.00	102.00	49.06
r_28	5	a541	-	4.42	15,640	12.91	-	12.91	15.00	116.00	44.65
r_28	6	a403	-	13.50	19,944	13.11	-	13.11	15.00	667.00	31.15
r_28	7	a551	-	0.86	22,484	13.28	-	13.28	15.00	93.00	30.28
r_28	8	a552	-	0.60	23,106	13.43	-	13.43	15.00	405.00	29.68
r_28	9	a482	-	9.03	26,608	13.61	-	13.61	15.00	285.00	20.65
r_28	10	a038	-	2.69	27,708	13.76	-	13.76	15.00	51.00	17.96
r_28	11	a542	-	0.41	27,885	13.89	-	13.89	15.00	62.00	17.55
r_28	12	a122	-	7.12	30,865	14.07	-	14.07	15.00	60.00	10.43
r_28	13	a568	-	0.21	31,841	14.22	-	14.22	15.00	580.00	10.22
r_28	14	a121	-	1.68	32,648	14.36	-	14.36	15.00	75.00	8.54
r_28	15	a604	-	0.72	34,224	14.52	-	14.52	15.00	158.00	7.82
r_28	16	a427	-	2.23	35,355	14.67	-	14.67	15.00	34.00	5.59
r_28	17	a377	-	1.19	35,967	14.81	-	14.81	15.00	361.00	4.40
r_28	18	a563	-	1.57	39,600	15.00	-	15.00	15.00	278.00	2.82
r_28	19	c081	15,722.70	-	-	-	0.02	0.02	-	-	3.80
r_28	20	t01	-	3.80	47,937	15.14	-	15.16	-	-	-
r_29	0	t01	-	-	-	10.43	-	10.43	-	-	66
r_29	1	a566	-	4.10	11,059	11.62	-	11.62	15.00	47.00	61.90
r_29	2	a211	-	17.88	17,209	11.85	-	11.85	15.00	1.00	44.02
r_29	3	a577	-	0.33	18,152	12.00	-	12.00	15.00	128.00	43.69
r_29	4	a557	-	4.28	19,657	12.15	-	12.15	15.00	190.00	39.41
r_29	5	a507	-	3.96	21,094	12.30	-	12.30	15.00	67.00	35.45
r_29	6	a336	-	3.09	22,229	12.45	-	12.45	15.00	865.00	32.36
r_29	7	a467	-	0.26	23,455	12.60	-	12.60	15.00	128.00	32.10
r_29	8	a560	-	0.10	23,661	12.74	-	12.74	15.00	218.00	32.01
r_29	9	a491	-	1.50	24,363	12.88	-	12.88	15.00	179.00	30.51
r_29	10	a389	-	3.36	25,999	13.04	-	13.04	15.00	510.00	27.14
r_29	11	a545	-	0.58	26,907	13.18	-	13.18	15.00	278.00	26.56
r_29	12	a206	-	0.87	27,425	13.32	-	13.32	15.00	40.00	25.69
r_29	13	a225	-	0.28	27,926	13.46	-	13.46	15.00	31.00	25.41
r_29	14	a048	-	1.47	28,818	13.60	-	13.60	15.00	69.00	23.94
r_29	15	a288	-	0.24	29,603	13.75	-	13.75	15.00	12.00	23.70
r_29	16	a192	-	0.96	30,203	13.89	-	13.89	15.00	31.00	22.73
r_29	17	a058	-	5.92	33,926	14.08	-	14.08	15.00	92.00	16.81
r_29	18	a131	-	0.30	36,108	14.25	-	14.25	15.00	100.00	16.51
r_29	19	a004	-	7.49	41,103	14.46	-	14.46	15.00	29.00	9.02
r_29	20	a112	-	1.18	43,580	14.63	-	14.63	15.00	48.00	7.84
r_29	21	c087	9,931.26	-	-	-	0.09	0.09	-	-	12.13
r_29	22	a083	-	8.15	49,153	14.85	-	14.94	15.00	162.00	3.98
r_29	23	a326	-	0.22	50,199	15.00	-	15.09	15.00	30.00	3.76
r_29	24	t01	-	3.76	58,601	15.14	-	15.23	-	-	-
r_30	0	t01	-	-	-	7.31	-	7.31	-	-	66

Route ID	Route stop	Node ID	Distance to charger (m)	Energy consumption (kWh)	Distance (m)	Time (h)	Charge time (h)	Total time (h)	End of TW (h)	Weight (kg)	SoC (kWh)
r_30	1	a289	-	18.19	47,312	9.10	-	9.10	15.00	35.00	47.81
r_30	2	a161	-	6.20	49,500	9.26	-	9.26	15.00	154.00	41.62
r_30	3	a030	-	19.77	56,670	9.51	-	9.51	15.00	45.00	21.84
r_30	4	a603	-	0.98	64,694	9.78	-	9.78	15.00	41.00	20.87
r_30	5	a628	-	5.40	70,793	10.01	-	10.01	15.00	50.00	15.47
r_30	6	a061	-	13.20	75,696	10.22	-	10.22	15.00	514.00	2.27
r_30	7	a136	-	0.26	76,131	10.36	-	10.36	15.00	90.00	2.01
r_30	8	c442	97,912.17	-	-	-	0.46	0.46	-	-	24.95
r_30	9	a101	-	5.25	78,315	10.52	-	10.98	15.00	91.00	19.70
r_30	10	a617	-	1.43	79,852	10.68	-	11.14	15.00	69.00	18.27
r_30	11	a593	-	0.72	80,162	10.81	-	11.27	15.00	699.00	17.55
r_30	12	a358	-	6.73	83,541	11.00	-	11.46	15.00	196.00	10.81
r_30	13	a010	-	7.52	87,505	11.20	-	11.65	15.00	48.00	3.29
r_30	14	a615	-	0.57	88,335	11.34	-	11.80	15.00	85.00	2.72
r_30	15	a595	-	2.72	89,816	11.49	-	11.95	15.00	79.00	-
r_30	16	c442	95,837.71	-	-	-	1.06	1.52	-	-	53.01
r_30	17	a322	-	40.57	112,399	12.00	-	13.52	15.00	23.00	12.44
r_30	18	a062	-	1.73	113,369	12.15	-	13.67	15.00	154.00	10.70
r_30	19	t01	-	10.70	137,889	12.56	-	14.07	-	-	-
r_31	0	t01	-	-	-	8.98	-	8.98	-	-	66
r_31	1	a275	-	7.83	20,087	10.32	-	10.32	15.00	22.00	58.17
r_31	2	a147	-	8.58	22,877	10.49	-	10.49	15.00	20.00	49.60
r_31	3	a019	-	11.93	26,771	10.69	-	10.69	15.00	77.00	37.67
r_31	4	a124	-	0.63	27,543	10.83	-	10.83	15.00	60.00	37.04
r_31	5	a535	-	4.42	40,607	11.18	-	11.18	15.00	46.00	32.62
r_31	6	a564	-	1.17	42,450	11.34	-	11.34	15.00	224.00	31.45
r_31	7	a332	-	16.97	48,364	11.57	-	11.57	15.00	194.00	14.49
r_31	8	a543	-	0.01	48,652	11.70	-	11.70	15.00	166.00	14.48
r_31	9	c322	41,837.89	-	-	-	0.87	0.87	-	-	57.80
r_31	10	a154	-	16.94	54,935	11.94	-	12.81	15.00	46.00	40.86
r_31	11	a413	-	4.62	61,513	12.18	-	13.04	15.00	150.00	36.24
r_31	12	a547	-	1.82	68,453	12.42	-	13.29	15.00	396.00	34.42
r_31	13	a270	-	17.69	75,786	12.68	-	13.54	15.00	78.00	16.72
r_31	14	a524	-	0.31	76,079	12.81	-	13.68	15.00	234.00	16.42
r_31	15	a415	-	4.22	77,942	12.97	-	13.84	15.00	60.00	12.20
r_31	16	a575	-	1.19	84,981	13.22	-	14.09	15.00	186.00	11.01
r_31	17	a553	-	11.01	90,112	13.43	-	14.30	15.00	59.00	-
r_31	18	c340	39,174.05	-	-	-	1.17	2.03	-	-	58.40
r_31	19	a174	-	31.48	104,978	13.81	-	15.85	15.00	35.00	26.92
r_31	20	a546	-	0.19	107,366	13.98	-	16.02	15.00	155.00	26.73
r_31	21	a574	-	0.87	108,895	14.14	-	16.17	15.00	142.00	25.85
r_31	22	a573	-	6.27	112,096	14.32	-	16.36	15.00	228.00	19.58
r_31	23	a198	-	11.19	118,145	14.55	-	16.59	15.00	28.00	8.40
r_31	24	a554	-	0.34	118,550	14.69	-	16.72	15.00	650.00	8.05
r_31	25	a054	-	1.73	119,688	14.84	-	16.87	15.00	48.00	6.32
r_31	26	a570	-	0.90	121,616	15.00	-	17.03	15.00	50.00	5.42
r_31	27	t01	-	5.42	136,481	15.25	-	17.28	-	-	-
r_32	0	t01	-	-	-	8.73	-	8.73	-	-	66
r_32	1	a428	-	7.51	16,206	10.00	-	10.00	15.00	145.00	58.49
r_32	2	a220	-	7.38	20,279	10.20	-	10.20	15.00	10.00	51.11
r_32	3	a135	-	6.70	23,988	10.39	-	10.39	15.00	30.00	44.41
r_32	4	a641	-	1.89	28,559	10.60	-	10.60	15.00	352.00	42.52
r_32	5	a640	-	15.14	37,879	10.88	-	10.88	15.00	54.00	27.37
r_32	6	a160	-	19.90	50,325	11.22	-	11.22	15.00	40.00	7.47
r_32	7	c143	21,922.98	-	-	-	0.43	0.43	-	-	29.04
r_32	8	a035	-	9.98	56,641	11.45	-	11.89	15.00	20.00	19.06
r_32	9	a164	-	0.70	58,713	11.62	-	12.05	15.00	144.00	18.36
r_32	10	a182	-	3.49	65,869	11.87	-	12.30	15.00	17.00	14.87
r_32	11	a126	-	12.19	74,036	12.13	-	12.57	15.00	40.00	2.68

Route ID	**Route stop**	**Node ID**	**Distance to charger (m)**	**Energy consumption (kWh)**	**Distance (m)**	**Time (h)**	**Charge time (h)**	**Total time (h)**	**End of TW (h)**	**Weight (kg)**	**SoC (kWh)**
r_32	12	a151	-	1.33	77,413	12.32	-	12.75	15.00	76.00	1.35
r_32	13	t01	-	1.35	82,082	12.40	-	12.83	-	-	0.00
r_33	0	t01	-	-	-	8.79	-	8.79	-	-	66
r_33	1	a260	-	3.49	12,771	10.00	-	10.00	15.00	28.00	62.51
r_33	2	a474	-	0.79	13,807	10.15	-	10.15	15.00	122.00	61.72
r_33	3	a412	-	1.26	14,391	10.29	-	10.29	15.00	84.00	60.47
r_33	4	a347	-	2.83	15,732	10.44	-	10.44	15.00	971.00	57.63
r_33	5	a534	-	4.19	21,500	10.67	-	10.67	15.00	235.00	53.44
r_33	6	a308	-	6.49	25,731	10.87	-	10.87	15.00	42.00	46.95
r_33	7	t01	-	0.86	28,628	10.91	-	10.91	-	-	46.09
r_34	0	t01	-	-	-	4.53	-	4.53	-	-	66
r_34	1	a329	-	44.21	113,397	7.42	-	7.42	13.00	40.00	21.79
r_34	2	c641	183,239.96	-	-	-	0.75	0.75	-	-	59.08
r_34	3	a106	-	34.62	126,893	7.77	-	8.52	13.00	88.00	24.46
r_34	4	a282	-	10.98	152,262	8.33	-	9.07	13.00	154.00	13.47
r_34	5	a335	-	13.47	182,485	8.96	-	9.71	13.00	37.00	-
r_34	6	c492	17,253.61	-	-	-	1.35	2.09	-	-	67.44
r_34	7	a532	-	20.94	237,008	10.00	-	12.09	15.00	61.00	46.50
r_34	8	a056	-	17.24	244,185	10.25	-	12.34	15.00	106.00	29.26
r_34	9	a114	-	0.50	245,625	10.40	-	12.50	15.00	116.00	28.76
r_34	10	a222	-	5.72	253,363	10.66	-	12.76	15.00	39.00	23.04
r_34	11	a537	-	0.58	255,336	10.83	-	12.92	15.00	33.00	22.45
r_34	12	a334	-	15.78	262,316	11.07	-	13.17	15.00	737.00	6.67
r_34	13	a390	-	0.94	263,574	11.22	-	13.32	15.00	223.00	5.73
r_34	14	a444	-	3.03	278,677	11.60	-	13.70	15.00	220.00	2.70
r_34	15	t01	-	2.70	285,354	11.72	-	13.81	-	-	0.00

C.IV Best case S_{Diesel}

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_01	0	t01	-	2.77	-	-
r_01	1	a038	6,453	3.88	98.00	2.83
r_01	2	a063	55,615	4.83	152.00	23.66
r_01	3	a064	58,126	5.00	1 172.00	1.34
r_01	4	a015	59,102	5.14	9.00	1.27
r_01	5	a012	61,488	5.31	1.00	3.10
r_01	6	a065	71,864	5.62	103.00	4.96
r_01	7	a061	85,579	5.98	59.00	17.39
r_01	8	a013	89,509	6.17	19.00	4.92
r_01	9	a008	90,124	6.31	53.00	0.77
r_01	10	a049	91,140	6.46	550.00	0.48
r_01	11	a067	91,189	6.59	85.00	0.02
r_01	12	a005	94,853	6.78	19.00	3.83
r_01	13	a023	95,431	6.92	43.00	0.31
r_01	14	a022	95,431	7.05	34.00	-
r_01	15	a006	102,604	7.30	34.00	7.30
r_01	16	a019	109,747	7.55	11.00	2.87
r_01	17	a070	113,268	7.74	62.00	1.63
r_01	18	a040	113,334	7.87	74.00	0.07
r_01	19	a010	113,419	8.00	34.00	0.08
r_01	20	t01	168,510	8.92	-	26.53
r_02	0	t01	-	0.85	-	-
r_02	1	a045	8,923	2.00	60.00	3.91
r_02	2	a053	11,332	2.17	97.00	0.51
r_02	3	a047	12,168	2.31	59.00	1.17
r_02	4	a002	14,968	2.49	14.00	3.86
r_02	5	a016	15,807	2.63	26.00	0.64
r_02	6	a033	15,874	2.77	200.00	0.01
r_02	7	a018	16,586	2.91	10.00	0.93
r_02	8	a035	17,294	3.05	91.00	0.48
r_02	9	a062	18,031	3.19	42.00	0.40
r_02	10	a031	19,836	3.35	598.00	2.29
r_02	11	a004	22,336	3.52	12.00	2.74
r_02	12	a056	26,039	3.72	77.00	1.05
r_02	13	t01	37,004	3.90	-	5.45
r_03	0	t01	-	0.88	-	-
r_03	1	a042	7,038	2.00	1 288.00	3.31
r_03	2	a037	19,092	2.33	36.00	12.43
r_03	3	a060	20,968	2.49	130.00	0.88
r_03	4	a028	25,140	2.69	49.00	4.10
r_03	5	a048	34,614	2.98	156.00	4.36
r_03	6	a034	52,788	3.41	218.00	16.79
r_03	7	a051	82,785	4.04	204.00	13.39
r_03	8	t01	90,777	4.18	-	3.43
r_04	0	t01	-	0.82	-	-
r_04	1	a046	11,026	2.00	82.00	5.33
r_04	2	a032	21,878	2.31	855.00	19.57
r_04	3	a052	39,656	2.74	579.00	8.47
r_04	4	a036	66,221	3.31	51.00	36.84
r_04	5	a020	94,553	3.91	108.00	38.88
r_04	6	a026	97,154	4.09	991.00	1.82
r_04	7	a059	100,031	4.26	60.00	0.99
r_04	8	a071	106,783	4.51	71.00	3.18
r_04	9	a007	114,040	4.76	10.00	7.36
r_04	10	t01	126,929	4.97	-	6.10
r_05	0	t01	-	1.68	-	-
r_05	1	a011	52,623	3.56	83.00	24.53

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_05	2	a024	58,845	3.79	938.00	3.39
r_05	3	a009	59,351	3.93	210.00	0.75
r_05	4	a030	70,108	4.24	928.00	4.10
r_05	5	a068	74,062	4.44	233.00	2.15
r_05	6	a001	78,219	4.64	1.00	4.49
r_05	7	a025	102,234	5.17	46.00	11.22
r_05	8	a066	110,476	5.43	32.00	3.72
r_05	9	a029	123,924	5.79	226.00	14.21
r_05	10	a069	128,885	6.00	19.00	2.36
r_05	11	t01	133,801	6.08	-	1.96
r_06	0	t01	-	0.85	-	-
r_06	1	a043	17,216	2.14	53.00	8.17
r_06	2	a017	26,539	2.42	18.00	14.46
r_06	3	a003	27,791	2.57	26.00	1.94
r_06	4	a054	28,640	2.72	50.00	0.54
r_06	5	a021	31,499	2.90	453.00	4.36
r_06	6	a041	39,644	3.16	182.00	4.21
r_06	7	a044	40,297	3.30	29.00	0.32
r_06	8	a039	74,204	4.00	24.00	45.13
r_06	9	a058	109,581	4.72	128.00	17.69
r_06	10	a055	113,717	4.92	449.00	5.32
r_06	11	a072	122,287	5.19	28.00	5.49
r_06	12	a027	126,150	5.38	39.00	4.44
r_06	13	a057	131,618	5.60	89.00	1.47
r_06	14	a050	132,077	5.74	137.00	0.51
r_06	15	a014	133,366	5.89	10.00	1.38
r_06	16	t01	146,600	6.11	-	6.57

C.V Medium case S_{Diesel}

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_01	0	t01	-	-	-	-
r_01	1	a129	61,317	2.02	569.00	27.60
r_01	2	a143	73,459	2.35	1,130.00	5.66
r_01	3	a155	79,990	2.59	482.00	3.75
r_01	4	a153	94,795	2.97	7.00	19.40
r_01	5	a084	152,470	4.06	175.00	75.45
r_01	6	a227	156,062	4.25	125.00	1.75
r_01	7	a212	157,556	4.41	96.00	1.83
r_01	8	a244	160,339	4.58	96.00	1.10
r_01	9	a126	161,469	4.73	82.00	1.32
r_01	10	a239	162,610	4.88	138.00	0.49
r_01	11	a200	162,967	5.02	183.00	0.40
r_01	12	t01	173,124	5.19	-	5.29
r_02	0	t01	-	0.80	-	-
r_02	1	a123	12,010	2.00	816.00	4.90
r_02	2	a175	13,616	2.16	144.00	1.21
r_02	3	a013	15,493	2.32	54.00	3.03
r_02	4	a189	38,069	2.82	897.00	11.12
r_02	5	a098	38,069	2.95	101.00	-
r_02	6	a178	48,162	3.25	73.00	4.03
r_02	7	a132	63,963	3.65	52.00	20.47
r_02	8	a188	65,486	3.80	73.00	0.77
r_02	9	a130	65,830	3.94	799.00	0.43
r_02	10	t01	79,876	4.17	-	6.97
r_03	0	t01	-	0.83	-	-
r_03	1	a101	10,376	2.00	702.00	4.05
r_03	2	a195	12,891	2.17	266.00	0.93
r_03	3	a238	18,437	2.39	65.00	3.64
r_03	4	a234	28,794	2.70	112.00	13.98
r_03	5	a216	30,740	2.86	929.00	2.57
r_03	6	a249	34,698	3.06	124.00	1.73
r_03	7	a229	37,667	3.23	86.00	3.04
r_03	8	a191	44,374	3.48	194.00	6.70
r_03	9	a226	45,081	3.62	102.00	0.29
r_03	10	t01	61,425	3.89	-	7.20
r_04	0	t01	-	0.90	-	-
r_04	1	a081	6,112	2.00	75.00	3.17
r_04	2	a127	16,635	2.31	57.00	4.89
r_04	3	a017	17,988	2.46	29.00	2.05
r_04	4	a157	23,096	2.67	163.00	2.45
r_04	5	a128	23,871	2.82	437.00	1.13
r_04	6	a142	28,644	3.03	158.00	2.27
r_04	7	a083	69,733	3.84	1,288.00	53.07
r_04	8	a326	76,140	4.08	102.00	2.12
r_04	9	a110	88,570	4.41	110.00	11.20
r_04	10	t01	165,385	5.69	-	34.60
r_05	0	t01	-	3.77	-	-
r_05	1	a199	6,155	4.87	319.00	3.02
r_05	2	a225	11,723	5.09	49.00	2.84
r_05	3	t01	15,389	5.16	-	1.18
r_06	0	t01	-	3.61	-	-
r_06	1	a038	12,097	4.81	8.00	5.56
r_06	2	a242	18,461	5.05	92.00	2.06
r_06	3	a103	21,749	5.23	935.00	5.26
r_06	4	a170	25,097	5.42	636.00	0.72
r_06	5	a180	27,252	5.58	464.00	1.04
r_06	6	a193	36,269	5.86	86.00	4.19

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_06	7	a214	36,739	6.00	336.00	0.20
r_06	8	t01	41,102	6.07	-	2.05
r_07	0	t01	-	0.93	-	-
r_07	1	a223	4,104	2.00	141.00	2.06
r_07	2	t01	8,208	2.07	-	1.66
r_08	0	t01	-	0.64	-	-
r_08	1	a319	28,384	2.11	217.00	13.17
r_08	2	a152	46,401	2.54	118.00	31.89
r_08	3	a316	48,459	2.70	1,032.00	1.35
r_08	4	a179	48,932	2.84	59.00	0.68
r_08	5	a176	50,268	2.99	36.00	1.91
r_08	6	a190	53,088	3.17	174.00	1.50
r_08	7	a306	77,284	3.70	989.00	11.32
r_08	8	a091	79,058	3.86	22.00	1.94
r_08	9	a086	107,768	4.47	42.00	31.21
r_08	10	t01	157,412	5.30	-	22.11
r_09	0	t01	-	0.85	-	-
r_09	1	a135	10,217	2.02	738.00	4.40
r_09	2	a102	10,718	2.16	205.00	0.67
r_09	3	a177	12,092	2.32	300.00	0.24
r_09	4	a218	16,391	2.52	413.00	2.65
r_09	5	t01	23,400	2.63	-	3.21
r_10	0	t01	-	0.80	-	-
r_10	1	a174	12,046	2.00	720.00	4.69
r_10	2	a107	14,782	2.18	218.00	3.50
r_10	3	t01	22,994	2.31	-	3.94
r_11	0	t01	-	1.36	-	-
r_11	1	a224	5,952	2.46	264.00	2.78
r_11	2	a236	12,358	2.70	221.00	3.59
r_11	3	a253	21,317	2.97	109.00	4.30
r_11	4	a222	21,440	3.11	306.00	0.21
r_11	5	a251	27,381	3.34	124.00	3.41
r_11	6	a036	32,755	3.56	1.00	8.70
r_11	7	a144	111,620	5.00	84.00	38.59
r_11	8	a125	117,983	5.24	1,307.00	10.15
r_11	9	a096	137,153	5.69	370.00	23.54
r_11	10	a328	149,636	6.02	268.00	5.83
r_11	11	t01	231,741	7.39	-	36.36
r_12	0	t01	-	2.68	-	-
r_12	1	a167	82,528	5.05	66.00	38.90
r_12	2	a088	86,905	5.26	92.00	8.25
r_12	3	a197	90,022	5.44	706.00	1.16
r_12	4	a075	137,607	6.36	820.00	79.06
r_12	5	a028	139,242	6.52	89.00	2.34
r_12	6	a322	184,871	7.41	287.00	21.82
r_12	7	t01	302,908	9.38	-	52.47
r_13	0	t01	-	3.77	-	-
r_13	1	a133	20,115	5.10	516.00	8.72
r_13	2	a097	22,055	5.27	763.00	3.54
r_13	3	a090	24,617	5.44	834.00	4.13
r_13	4	a079	30,055	5.66	813.00	7.49
r_13	5	a118	42,664	6.00	58.00	5.64
r_13	6	t01	49,458	6.11	-	2.93
r_14	0	t01	-	0.93	-	-
r_14	1	a115	15,995	2.20	89.00	8.02
r_14	2	a056	42,937	2.78	28.00	52.18
r_14	3	a208	55,455	3.12	546.00	5.78
r_14	4	a206	58,303	3.29	182.00	5.06
r_14	5	a150	60,147	3.45	1,560.00	3.18

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_14	6	a237	70,940	3.76	240.00	5.23
r_14	7	a230	89,372	4.20	52.00	22.46
r_14	8	a027	93,386	4.40	20.00	4.83
r_14	9	a121	101,368	4.66	51.00	4.36
r_14	10	a120	101,368	4.79	29.00	0.00
r_14	11	a119	101,368	4.92	21.00	-
r_14	12	a228	104,178	5.10	160.00	0.92
r_14	13	a104	106,889	5.27	103.00	3.05
r_14	14	t01	111,428	5.35	-	1.82
r_15	0	t01	-	0.64	-	-
r_15	1	a145	21,889	2.00	460.00	10.06
r_15	2	t01	43,778	2.36	-	9.70
r_16	0	t01	-	0.85	-	-
r_16	1	a077	8,726	2.00	655.00	4.19
r_16	2	a122	11,313	2.17	777.00	0.83
r_16	3	a124	11,313	2.30	61.00	-
r_16	4	t01	20,337	2.45	-	4.10
r_17	0	t01	-	0.80	-	-
r_17	1	a108	13,018	2.02	1,029.00	5.96
r_17	2	a136	23,043	2.31	279.00	5.46
r_17	3	a139	24,069	2.46	34.00	0.38
r_17	4	a168	41,768	2.89	570.00	8.26
r_17	5	a329	43,886	3.05	301.00	1.17
r_17	6	a035	44,079	3.18	39.00	0.26
r_17	7	a203	48,221	3.38	279.00	1.92
r_17	8	a192	50,356	3.55	130.00	2.71
r_17	9	a248	73,250	4.06	56.00	10.88
r_17	10	t01	87,660	4.30	-	6.30
r_18	0	t01	-	2.68	-	-
r_18	1	a181	79,355	5.00	1,872.00	37.14
r_18	2	a302	88,599	5.28	55.00	4.29
r_18	3	a323	96,592	5.55	52.00	3.78
r_18	4	t01	177,269	6.89	-	36.35
r_19	0	t01	-	8.00	-	-
r_19	1	a312	13,110	9.22	111.00	6.01
r_19	2	a265	17,466	9.42	136.00	7.12
r_19	3	a287	18,947	9.58	143.00	0.78
r_19	4	a303	25,317	9.81	29.00	2.71
r_19	5	a117	28,638	10.00	125.00	5.14
r_19	6	a087	30,821	10.17	3.00	3.30
r_19	7	a291	37,522	10.41	129.00	3.94
r_19	8	a278	42,939	10.63	138.00	7.99
r_19	9	a012	47,320	10.83	138.00	6.29
r_19	10	a240	49,210	10.99	47.00	0.80
r_19	11	a293	55,742	11.23	127.00	3.31
r_19	12	a321	61,339	11.46	155.00	1.78
r_19	13	a243	72,259	11.77	93.00	14.26
r_19	14	a059	80,682	12.04	6.00	10.78
r_19	15	a270	84,019	12.22	715.00	2.01
r_19	16	a279	87,036	12.40	101.00	1.62
r_19	17	a071	87,418	12.54	47.00	0.40
r_19	18	a285	91,884	12.74	280.00	2.12
r_19	19	a254	92,152	12.88	102.00	0.26
r_19	20	t01	105,071	13.09	-	5.52
r_20	0	t01	-	7.60	-	-
r_20	1	a305	18,310	8.90	734.00	7.91
r_20	2	a275	27,368	9.19	229.00	11.23
r_20	3	a066	40,799	9.54	7.00	15.79
r_20	4	a078	45,609	9.75	92.00	2.16

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_20	5	a024	52,855	10.00	67.00	8.32
r_20	6	a041	57,774	10.21	18.00	2.38
r_20	7	a210	62,368	10.42	95.00	2.20
r_20	8	a046	66,913	10.62	16.00	4.99
r_20	9	a273	77,858	10.94	632.00	4.20
r_20	10	a298	79,634	11.10	18.00	0.82
r_20	11	a105	85,613	11.33	58.00	5.44
r_20	12	a065	90,922	11.54	20.00	4.75
r_20	13	a061	90,967	11.68	43.00	0.04
r_20	14	a063	102,601	12.00	16.00	3.42
r_20	15	a045	104,468	12.16	8.00	1.63
r_20	16	a023	107,270	12.34	32.00	2.44
r_20	17	a263	108,912	12.49	62.00	0.83
r_20	18	a219	109,107	12.63	88.00	0.16
r_20	19	t01	120,497	12.82	-	5.12
r_21	0	t01	-	8.12	-	-
r_21	1	a296	12,118	9.32	74.00	4.84
r_21	2	a267	14,694	9.49	59.00	3.68
r_21	3	a314	16,003	9.64	5.00	0.66
r_21	4	a317	21,009	9.86	899.00	3.51
r_21	5	a064	21,855	10.00	20.00	0.98
r_21	6	a009	23,396	10.16	52.00	1.78
r_21	7	a307	25,237	10.32	46.00	1.08
r_21	8	a053	26,708	10.47	16.00	1.66
r_21	9	a246	27,793	10.62	55.00	0.35
r_21	10	a159	29,036	10.77	38.00	1.37
r_21	11	a231	29,630	10.91	99.00	0.24
r_21	12	a093	30,231	11.05	15.00	0.64
r_21	13	a158	30,983	11.19	625.00	0.24
r_21	14	a281	32,592	11.35	109.00	0.70
r_21	15	a026	33,954	11.50	28.00	1.17
r_21	16	a235	35,381	11.66	29.00	0.80
r_21	17	a052	36,113	11.80	15.00	0.62
r_21	18	a100	38,907	11.97	57.00	1.15
r_21	19	t01	49,283	12.15	-	5.37
r_22	0	t01	-	8.09	-	-
r_22	1	a304	8,453	9.23	412.00	3.53
r_22	2	a282	8,453	9.36	146.00	-
r_22	3	a308	8,645	9.50	151.00	0.13
r_22	4	a289	11,895	9.68	555.00	3.52
r_22	5	a111	13,507	9.84	629.00	1.50
r_22	6	a010	15,360	10.00	50.00	1.39
r_22	7	t01	24,316	10.15	-	3.92
r_23	0	t01	0	8.03	-	-
r_23	1	a318	8,422	9.17	308.00	3.56
r_23	2	a247	12,312	9.36	151.00	6.38
r_23	3	a301	12,971	9.50	112.00	0.19
r_23	4	a221	16,190	9.69	94.00	5.04
r_23	5	a185	18,866	9.86	70.00	4.12
r_23	6	a198	19,391	10.00	73.00	0.28
r_23	7	a156	22,689	10.18	328.00	4.95
r_23	8	a211	26,685	10.38	85.00	3.39
r_23	9	a051	29,756	10.56	15.00	4.25
r_23	10	a014	43,137	10.92	14.00	18.46
r_23	11	a264	50,120	11.16	127.00	2.10
r_23	12	a233	50,590	11.30	201.00	0.63
r_23	13	a311	52,520	11.46	98.00	0.81
r_23	14	a106	53,523	11.61	60.00	1.26
r_23	15	a173	54,170	11.75	713.00	0.44

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_23	16	a183	54,662	11.89	253.00	0.26
r_23	17	a032	55,024	12.02	32.00	0.35
r_23	18	t01	64,283	12.18	-	4.71
r_24	0	t01	-	6.72	-	-
r_24	1	a205	16,541	8.00	150.00	7.23
r_24	2	a146	46,012	8.62	71.00	47.55
r_24	3	a140	57,690	8.95	644.00	18.61
r_24	4	a162	57,690	9.08	49.00	-
r_24	5	a154	57,690	9.21	18.00	-
r_24	6	a164	61,126	9.39	37.00	2.53
r_24	7	a113	64,218	9.57	1,040.00	4.28
r_24	8	a006	69,929	9.80	242.00	6.23
r_24	9	a151	107,082	10.55	208.00	17.66
r_24	10	a294	146,989	11.34	44.00	16.80
r_24	11	a025	154,510	11.60	75.00	7.16
r_24	12	a309	186,346	12.26	29.00	13.93
r_24	13	t01	192,070	12.36	-	2.31
r_25	0	t01	-	11.52	-	-
r_25	1	a297	20,168	12.85	71.00	8.67
r_25	2	a137	21,322	13.00	124.00	1.28
r_25	3	a134	46,104	13.54	839.00	26.69
r_25	4	a160	52,298	13.78	79.00	2.42
r_25	5	a171	58,307	14.01	213.00	2.77
r_25	6	a040	99,517	14.82	26.00	31.28
r_25	7	a276	102,251	15.00	323.00	1.11
r_25	8	t01	105,041	15.05	-	0.98
r_26	0	t01	-	8.51	-	-
r_26	1	a186	5,734	9.60	11.00	2.68
r_26	2	a292	8,130	9.77	18.00	1.07
r_26	3	a241	14,081	10.00	137.00	8.23
r_26	4	a112	21,244	10.25	83.00	9.63
r_26	5	a070	26,847	10.47	38.00	7.40
r_26	6	a286	52,177	11.02	199.00	11.62
r_26	7	a030	80,206	11.62	72.00	35.16
r_26	8	a007	87,452	11.87	40.00	8.94
r_26	9	a031	100,810	12.23	47.00	4.71
r_26	10	a138	103,547	12.40	793.00	1.09
r_26	11	a194	105,705	12.57	258.00	1.03
r_26	12	a207	112,612	12.81	364.00	2.97
r_26	13	a262	122,124	13.10	64.00	4.26
r_26	14	a049	135,528	13.45	12.00	10.64
r_26	15	t01	165,964	13.96	-	13.39
r_27	0	t01	-	7.83	-	-
r_27	1	a315	15,121	9.08	80.00	6.55
r_27	2	a284	22,203	9.33	254.00	12.03
r_27	3	a280	24,418	9.50	88.00	3.60
r_27	4	a169	26,325	9.66	213.00	3.05
r_27	5	a295	27,446	9.81	889.00	0.09
r_27	6	a259	31,300	10.00	149.00	4.98
r_27	7	a232	53,940	10.51	141.00	28.31
r_27	8	a055	60,787	10.75	20.00	8.29
r_27	9	a204	63,632	10.93	314.00	0.88
r_27	10	a058	81,707	11.36	16.00	20.19
r_27	11	a047	85,948	11.56	66.00	4.72
r_27	12	a245	90,888	11.77	156.00	3.02
r_27	13	a109	91,677	11.92	44.00	0.83
r_27	14	a019	97,183	12.14	19.00	5.71
r_27	15	a057	100,220	12.32	6.00	0.49
r_27	16	a201	101,351	12.47	133.00	0.43

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_27	17	a060	102,153	12.61	50.00	0.80
r_27	18	a050	107,558	12.83	16.00	5.29
r_27	19	a072	112,261	13.04	36.00	1.69
r_27	20	a037	113,515	13.19	16.00	1.21
r_27	21	a043	116,425	13.37	2.00	1.45
r_27	22	a069	116,508	13.50	2.00	0.01
r_27	23	a073	117,130	13.64	13.00	0.31
r_27	24	t01	128,102	13.82	-	5.24
r_28	0	t01	-	6.63	-	-
r_28	1	a114	35,652	8.22	397.00	15.53
r_28	2	a074	42,286	8.46	24.00	8.49
r_28	3	a147	48,921	8.70	147.00	3.60
r_28	4	a033	48,926	8.83	46.00	0.01
r_28	5	a324	76,607	9.42	508.00	11.59
r_28	6	a327	76,607	9.55	152.00	-
r_28	7	a300	79,238	9.73	94.00	2.72
r_28	8	a165	79,638	9.86	174.00	0.40
r_28	9	a163	80,009	10.00	594.00	0.36
r_28	10	t01	90,657	10.18	-	5.54
r_29	0	t01	-	7.96	-	-
r_29	1	a313	13,952	9.20	118.00	5.74
r_29	2	a255	14,398	9.33	70.00	0.71
r_29	3	a290	14,967	9.47	188.00	0.31
r_29	4	a172	16,436	9.63	848.00	2.23
r_29	5	a021	19,516	9.81	30.00	3.95
r_29	6	a034	23,104	10.00	55.00	1.63
r_29	7	a042	27,131	10.20	18.00	2.02
r_29	8	a184	27,651	10.34	65.00	0.30
r_29	9	a001	28,884	10.49	80.00	1.52
r_29	10	a310	29,528	10.63	51.00	0.36
r_29	11	a258	30,306	10.77	173.00	0.93
r_29	12	a215	30,775	10.91	29.00	0.54
r_29	13	a320	33,122	11.08	232.00	1.17
r_29	14	a209	34,594	11.23	232.00	1.58
r_29	15	a022	35,482	11.38	60.00	0.90
r_29	16	a261	36,384	11.52	84.00	0.39
r_29	17	a274	37,798	11.67	124.00	0.44
r_29	18	a266	39,223	11.83	61.00	1.33
r_29	19	a076	42,248	12.01	3.00	2.78
r_29	20	a048	47,994	12.23	34.00	5.27
r_29	21	t01	54,336	12.34	-	2.91
r_30	0	t01	-	8.14	-	-
r_30	1	a202	12,094	9.34	182.00	4.97
r_30	2	a299	14,403	9.51	157.00	1.42
r_30	3	a325	16,929	9.68	107.00	1.35
r_30	4	a288	19,041	9.85	375.00	3.12
r_30	5	a141	20,388	10.00	149.00	1.85
r_30	6	a252	24,455	10.20	102.00	1.10
r_30	7	a089	25,278	10.34	30.00	1.07
r_30	8	a095	25,475	10.47	609.00	0.09
r_30	9	a094	25,475	10.60	107.00	-
r_30	10	a271	26,183	10.75	128.00	0.18
r_30	11	a260	26,478	10.88	131.00	0.31
r_30	12	a062	26,944	11.02	30.00	0.48
r_30	13	a269	27,367	11.16	150.00	0.24
r_30	14	a217	28,124	11.30	112.00	0.73
r_30	15	a002	30,110	11.46	30.00	1.86
r_30	16	a008	30,564	11.60	93.00	0.26
r_30	17	a039	31,370	11.74	5.00	0.48

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_30	18	a054	32,083	11.88	19.00	0.38
r_30	19	t01	40,937	12.03	-	4.17
r_31	0	t01	-	8.29	-	-
r_31	1	a085	7,213	9.41	16.00	3.44
r_31	2	a099	34,698	10.00	27.00	12.32
r_31	3	a148	62,623	10.60	322.00	13.28
r_31	4	a161	70,816	10.86	1,226.00	3.95
r_31	5	a029	95,322	11.40	90.00	22.49
r_31	6	a166	108,274	11.75	118.00	5.50
r_31	7	a149	113,468	11.96	119.00	4.46
r_31	8	a082	129,217	12.36	14.00	13.01
r_31	9	a005	133,475	12.56	74.00	3.50
r_31	10	a011	143,516	12.85	84.00	4.44
r_31	11	t01	148,568	12.94	-	2.09
r_32	0	t01	-	8.10	-	-
r_32	1	a116	10,633	9.28	108.00	4.90
r_32	2	a277	11,642	9.42	184.00	0.62
r_32	3	a213	20,954	9.71	149.00	14.03
r_32	4	a283	21,855	9.85	180.00	0.40
r_32	5	a220	22,755	10.00	148.00	1.27
r_32	6	a131	25,823	10.18	274.00	4.21
r_32	7	a257	28,397	10.35	72.00	1.26
r_32	8	a016	29,939	10.51	197.00	1.97
r_32	9	a003	32,662	10.69	54.00	3.32
r_32	10	a015	34,692	10.85	46.00	1.09
r_32	11	a182	35,968	11.00	186.00	0.86
r_32	12	a020	36,928	11.15	50.00	1.09
r_32	13	a018	38,829	11.31	47.00	2.14
r_32	14	a080	41,128	11.48	793.00	1.05
r_32	15	t01	47,650	11.58	-	2.68
r_33	0	t01	-	8.14	-	-
r_33	1	a187	14,609	9.38	164.00	6.52
r_33	2	a268	16,619	9.54	170.00	0.51
r_33	3	a092	18,775	9.71	481.00	2.84
r_33	4	a256	19,267	9.85	70.00	0.20
r_33	5	a004	20,604	10.00	74.00	1.55
r_33	6	a044	20,754	10.13	26.00	0.07
r_33	7	a250	25,061	10.33	149.00	2.33
r_33	8	a272	26,053	10.48	251.00	0.48
r_33	9	a068	26,229	10.61	52.00	0.18
r_33	10	a067	26,618	10.75	43.00	0.39
r_33	11	a196	28,336	10.91	691.00	0.99
r_33	12	t01	36,758	11.05	-	4.02

C.VI Worst case S_{Diesel}

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_01	0	t01	-	0.27	-	-
r_01	1	a250	10,597	1.45	31.00	4.72
r_01	2	a218	11,318	1.59	25.00	1.35
r_01	3	a195	11,517	1.73	22.00	0.37
r_01	4	a306	11,927	1.86	23.00	0.15
r_01	5	a303	12,337	2.00	34.00	0.76
r_01	6	a446	12,933	2.14	52.00	0.31
r_01	7	a194	13,691	2.28	25.00	1.39
r_01	8	a339	14,183	2.42	415.00	0.23
r_01	9	a462	14,408	2.55	48.00	0.03
r_01	10	a197	15,273	2.70	25.00	1.46
r_01	11	a236	16,181	2.84	22.00	0.37
r_01	12	a298	18,997	3.02	40.00	0.96
r_01	13	a587	60,217	3.84	351.00	20.71
r_01	14	a091	61,271	3.99	99.00	1.64
r_01	15	a159	63,612	4.15	75.00	0.77
r_01	16	a629	68,498	4.37	22.00	3.29
r_01	17	a360	73,771	4.58	640.00	7.91
r_01	18	a579	75,985	4.75	96.00	1.01
r_01	19	a269	78,028	4.91	24.00	2.62
r_01	20	a163	78,631	5.05	60.00	0.77
r_01	21	a420	112,762	5.75	114.00	16.30
r_01	22	a476	124,321	6.08	380.00	5.75
r_01	23	a488	128,584	6.28	193.00	2.26
r_01	24	a016	129,564	6.42	29.00	1.03
r_01	25	a253	130,078	6.56	4.00	0.31
r_01	26	t01	141,090	6.75	-	5.59
r_02	0	t01	-	0.31	-	-
r_02	1	a214	12,304	1.51	31.00	5.23
r_02	2	a108	12,782	1.65	20.00	0.91
r_02	3	a351	13,263	1.79	437.00	0.21
r_02	4	a232	13,691	1.93	22.00	0.76
r_02	5	a457	18,420	2.14	68.00	4.10
r_02	6	a181	20,088	2.29	31.00	2.92
r_02	7	a345	23,345	2.48	327.00	0.31
r_02	8	a627	23,690	2.61	22.00	0.12
r_02	9	a442	23,963	2.75	59.00	0.45
r_02	10	a359	27,052	2.93	7.00	5.00
r_02	11	a571	27,485	3.07	196.00	0.21
r_02	12	a365	28,605	3.22	40.00	1.75
r_02	13	a210	29,304	3.36	39.00	1.08
r_02	14	a328	84,868	4.41	968.00	28.67
r_02	15	a361	87,749	4.59	56.00	1.18
r_02	16	a325	103,765	4.99	38.00	19.73
r_02	17	a401	142,314	5.76	86.00	18.01
r_02	18	a008	148,874	6.00	80.00	7.84
r_02	19	a527	152,672	6.19	44.00	1.93
r_02	20	a499	157,185	6.40	74.00	5.23
r_02	21	a620	160,627	6.59	148.00	1.59
r_02	22	a522	160,852	6.72	48.00	0.25
r_02	23	a300	164,648	6.91	1.00	4.09
r_02	24	a256	165,014	7.05	28.00	0.39
r_02	25	a291	167,459	7.22	12.00	1.00
r_02	26	a238	167,822	7.36	22.00	0.39
r_02	27	t01	178,336	7.53	-	5.29
r_03	0	t01	-	3.43	-	-
r_03	1	a378	24,238	4.84	254.00	10.89

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_03	2	a237	24,249	4.97	31.00	0.02
r_03	3	a059	26,787	5.14	134.00	3.59
r_03	4	a097	36,071	5.42	86.00	5.10
r_03	5	a078	37,936	5.59	30.00	2.51
r_03	6	a409	47,024	5.87	187.00	4.24
r_03	7	a018	47,197	6.00	36.00	0.22
r_03	8	a517	54,898	6.26	415.00	4.42
r_03	9	a478	61,843	6.50	693.00	7.99
r_03	10	a433	64,374	6.68	325.00	2.39
r_03	11	t01	81,820	6.97	-	8.26
r_04	0	t01	-	3.19	-	-
r_04	1	a319	8,300	4.33	40.00	4.01
r_04	2	a310	8,835	4.47	18.00	0.69
r_04	3	a117	10,488	4.63	85.00	2.13
r_04	4	a643	12,593	4.79	65.00	0.63
r_04	5	a185	18,461	5.02	29.00	7.30
r_04	6	a264	19,675	5.17	39.00	0.37
r_04	7	a193	24,397	5.38	31.00	5.78
r_04	8	a168	25,934	5.54	101.00	1.87
r_04	9	a169	27,062	5.69	184.00	0.19
r_04	10	a387	29,401	5.85	599.00	0.93
r_04	11	a115	30,336	6.00	105.00	0.89
r_04	12	a530	32,174	6.16	61.00	0.92
r_04	13	a116	35,194	6.34	56.00	2.73
r_04	14	a622	37,102	6.50	138.00	1.11
r_04	15	a521	43,943	6.75	50.00	5.79
r_04	16	a349	45,563	6.90	265.00	1.35
r_04	17	t01	51,853	7.01	-	2.77
r_05	0	t01	-	0.17	-	-
r_05	1	a183	12,938	1.38	23.00	6.41
r_05	2	a244	15,590	1.56	31.00	0.34
r_05	3	a606	102,654	3.14	129.00	46.78
r_05	4	a608	102,828	3.27	34.00	0.18
r_05	5	a029	175,632	4.61	102.00	136.11
r_05	6	a600	188,580	4.96	63.00	5.81
r_05	7	a090	252,699	6.16	98.00	116.74
r_05	8	a294	255,935	6.34	10.00	1.35
r_05	9	a483	265,237	6.63	271.00	5.38
r_05	10	a022	271,719	6.87	26.00	11.08
r_05	11	a096	280,233	7.14	86.00	5.52
r_05	12	a093	288,007	7.40	102.00	13.02
r_05	13	a586	290,964	7.58	108.00	0.43
r_05	14	a590	300,880	7.87	61.00	3.59
r_05	15	a497	346,838	8.77	87.00	73.31
r_05	16	a489	347,371	8.91	73.00	0.84
r_05	17	a072	347,758	9.04	10.00	0.60
r_05	18	a171	349,010	9.19	80.00	0.83
r_05	19	a505	349,664	9.33	167.00	0.31
r_05	20	a520	350,389	9.48	58.00	0.39
r_05	21	a036	351,678	9.63	57.00	1.88
r_05	22	a204	352,750	9.78	22.00	0.29
r_05	23	a020	358,365	10.00	67.00	8.04
r_05	24	t01	371,793	10.22	-	6.46
r_06	0	t01	-	1.68	-	-
r_06	1	a005	18,496	2.99	25.00	7.98
r_06	2	a060	22,807	3.19	30.00	2.00
r_06	3	a209	23,392	3.33	26.00	0.26
r_06	4	a068	26,067	3.50	27.00	1.72
r_06	5	a456	26,746	3.65	132.00	0.28

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_06	6	a302	27,593	3.79	8.00	0.51
r_06	7	a612	72,110	4.66	111.00	19.70
r_06	8	a594	75,088	4.84	96.00	1.67
r_06	9	a099	83,188	5.11	93.00	4.32
r_06	10	a166	118,316	5.82	36.00	15.28
r_06	11	a318	121,183	6.00	18.00	1.26
r_06	12	a357	125,881	6.21	188.00	2.07
r_06	13	t01	145,072	6.53	-	9.11
r_07	0	t01	-	3.00	-	-
r_07	1	a032	5,645	4.10	110.00	2.93
r_07	2	a429	13,870	4.37	101.00	3.53
r_07	3	a247	14,391	4.50	27.00	0.81
r_07	4	a002	17,859	4.69	49.00	5.36
r_07	5	a245	19,786	4.85	31.00	1.07
r_07	6	a076	19,874	4.99	10.00	0.13
r_07	7	a186	20,930	5.13	25.00	0.23
r_07	8	a202	21,735	5.28	26.00	0.43
r_07	9	a405	22,161	5.41	147.00	0.27
r_07	10	a423	28,803	5.66	131.00	3.50
r_07	11	a015	32,602	5.85	27.00	5.40
r_07	12	a368	33,903	6.00	293.00	0.33
r_07	13	a465	36,062	6.17	143.00	0.13
r_07	14	a480	40,938	6.38	52.00	2.12
r_07	15	a040	44,148	6.56	45.00	4.08
r_07	16	a241	46,950	6.74	44.00	1.64
r_07	17	a216	48,511	6.89	11.00	1.94
r_07	18	a511	51,803	7.08	42.00	0.91
r_07	19	a388	52,732	7.22	138.00	1.14
r_07	20	a317	56,350	7.41	50.00	4.29
r_07	21	a327	56,605	7.55	60.00	0.08
r_07	22	a346	56,806	7.68	745.00	0.13
r_07	23	a026	58,197	7.83	48.00	1.30
r_07	24	a281	61,199	8.01	37.00	1.22
r_07	25	t01	67,123	8.11	-	2.46
r_08	0	t01	-	3.60	-	-
r_08	1	a102	16,553	4.88	70.00	7.46
r_08	2	a342	17,218	5.02	672.00	0.22
r_08	3	a187	18,309	5.17	40.00	1.01
r_08	4	a399	18,666	5.30	232.00	0.15
r_08	5	a150	19,725	5.45	30.00	0.89
r_08	6	a201	19,956	5.58	39.00	0.10
r_08	7	a374	26,771	5.83	122.00	3.26
r_08	8	a179	29,348	6.00	31.00	2.03
r_08	9	a284	41,532	6.33	45.00	5.14
r_08	10	a170	46,099	6.54	25.00	3.50
r_08	11	a033	69,978	7.07	40.00	18.10
r_08	12	a498	71,064	7.22	98.00	0.61
r_08	13	a400	71,520	7.35	10.00	0.33
r_08	14	a470	72,255	7.50	141.00	0.32
r_08	15	t01	88,193	7.76	-	7.39
r_09	0	t01	-	4.33	-	-
r_09	1	a267	6,153	5.44	8.00	2.90
r_09	2	a362	10,239	5.63	1,287.00	2.28
r_09	3	a436	13,326	5.82	226.00	1.30
r_09	4	a455	16,620	6.00	163.00	1.44
r_09	5	a528	18,578	6.16	113.00	0.88
r_09	6	t01	22,668	6.23	-	1.72
r_10	0	t01	-	3.21	-	-
r_10	1	a001	8,367	4.35	82.00	3.62

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_10	2	a180	10,715	4.52	24.00	0.87
r_10	3	a227	11,062	4.66	29.00	0.16
r_10	4	a437	11,432	4.79	60.00	0.16
r_10	5	a273	11,669	4.93	23.00	0.21
r_10	6	a233	11,879	5.06	31.00	0.18
r_10	7	a364	14,147	5.23	40.00	1.22
r_10	8	a461	16,252	5.39	65.00	1.00
r_10	9	a410	18,382	5.56	102.00	1.77
r_10	10	a408	19,378	5.70	90.00	0.80
r_10	11	a391	20,732	5.86	524.00	1.05
r_10	12	a509	21,560	6.00	94.00	0.41
r_10	13	a500	23,217	6.16	80.00	0.98
r_10	14	t01	32,427	6.31	-	4.74
r_11	0	t01	-	4.03	-	-
r_11	1	a440	11,341	5.22	64.00	5.75
r_11	2	a414	30,192	5.66	74.00	25.44
r_11	3	a223	36,012	5.89	28.00	7.73
r_11	4	a248	37,458	6.05	31.00	0.88
r_11	5	a392	52,512	6.43	24.00	7.94
r_11	6	a504	54,979	6.60	239.00	1.46
r_11	7	a320	56,159	6.75	60.00	1.45
r_11	8	t01	68,474	6.95	-	5.67
r_12	0	t01	-	4.47	-	-
r_12	1	a460	23,588	5.86	41.00	10.18
r_12	2	a007	24,223	6.00	36.00	0.43
r_12	3	a031	65,166	6.81	110.00	18.44
r_12	4	a105	65,788	6.95	50.00	0.25
r_12	5	a588	66,753	7.10	170.00	0.40
r_12	6	a321	94,837	7.70	55.00	15.80
r_12	7	a471	95,668	7.84	119.00	0.36
r_12	8	a380	95,976	7.98	201.00	0.16
r_12	9	a231	105,858	8.27	33.00	4.46
r_12	10	t01	131,028	8.69	-	12.73
r_13	0	t01	-	3.69	-	-
r_13	1	a203	3,893	4.76	44.00	1.83
r_13	2	a304	31,485	5.35	25.00	12.58
r_13	3	a104	31,501	5.48	50.00	0.01
r_13	4	a369	54,923	6.00	142.00	11.19
r_13	5	a515	58,915	6.20	140.00	1.33
r_13	6	a582	68,852	6.49	878.00	4.94
r_13	7	t01	73,691	6.57	-	1.63
r_14	0	t01	-	1.19	-	-
r_14	1	a213	24,233	2.60	27.00	10.66
r_14	2	a354	53,307	3.21	173.00	16.92
r_14	3	a610	58,812	3.43	38.00	0.90
r_14	4	a630	79,521	3.91	125.00	12.35
r_14	5	a176	85,402	4.14	90.00	9.38
r_14	6	a088	93,161	4.40	73.00	12.16
r_14	7	a039	96,506	4.58	45.00	5.17
r_14	8	a581	106,327	4.88	191.00	3.91
r_14	9	a589	109,710	5.06	51.00	1.00
r_14	10	a142	134,599	5.61	46.00	36.36
r_14	11	a254	139,866	5.83	61.00	2.86
r_14	12	a382	142,556	6.00	182.00	1.31
r_14	13	a623	177,880	6.72	261.00	16.27
r_14	14	a599	185,521	6.98	893.00	9.92
r_14	15	a601	188,119	7.15	56.00	1.19
r_14	16	a569	194,811	7.39	168.00	6.81
r_14	17	a598	205,952	7.71	56.00	4.59

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_14	18	t01	205,951	7.71	-	-,,,,,,,,,,,,,,0.00
r_15	0	t01	-	3.25	-	-
r_15	1	a295	30,028	4.75	50.00	13.36
r_15	2	a189	34,136	4.95	31.00	5.04
r_15	3	a071	36,645	5.12	31.00	3.06
r_15	4	a454	39,150	5.29	186.00	1.23
r_15	5	a421	41,169	5.46	530.00	2.33
r_15	6	a184	41,426	5.59	8.00	0.26
r_15	7	a205	42,381	5.74	39.00	0.45
r_15	8	a452	42,381	5.87	480.00	-
r_15	9	a496	42,639	6.00	198.00	0.10
r_15	10	a109	47,144	6.21	32.00	3.52
r_15	11	a518	47,270	6.34	174.00	0.07
r_15	12	t01	81,563	6.91	-	16.10
r_16	0	t01	-	0.56	-	-
r_16	1	a239	14,316	1.79	44.00	6.24
r_16	2	a066	18,818	2.00	27.00	7.83
r_16	3	a463	37,101	2.43	387.00	11.60
r_16	4	a278	64,988	3.03	22.00	45.10
r_16	5	a044	65,767	3.17	162.00	1.25
r_16	6	a258	86,548	3.65	28.00	11.05
r_16	7	a074	92,253	3.87	32.00	8.87
r_16	8	a242	112,600	4.34	35.00	10.41
r_16	9	a173	114,379	4.50	80.00	2.73
r_16	10	a411	138,344	5.03	130.00	10.72
r_16	11	a416	147,660	5.32	91.00	4.94
r_16	12	a402	166,014	5.75	72.00	26.53
r_16	13	a133	173,040	6.00	200.00	10.01
r_16	14	a494	179,593	6.24	74.00	3.26
r_16	15	a513	193,377	6.60	70.00	6.80
r_16	16	a621	195,365	6.76	130.00	0.79
r_16	17	a143	196,624	6.91	46.00	1.62
r_16	18	a266	198,381	7.07	1.00	0.75
r_16	19	a370	199,109	7.21	534.00	0.33
r_16	20	a396	199,182	7.35	457.00	0.03
r_16	21	t01	210,893	7.54	-	6.10
r_17	0	t01	-	0.60	-	-
r_17	1	a145	9,017	1.76	20.00	3.88
r_17	2	a287	9,065	1.89	63.00	0.04
r_17	3	a331	96,116	3.47	5.00	43.19
r_17	4	a235	150,026	4.50	61.00	71.60
r_17	5	a086	184,838	5.21	433.00	45.61
r_17	6	a013	187,008	5.37	27.00	2.56
r_17	7	a230	189,842	5.55	26.00	0.67
r_17	8	a178	192,331	5.72	31.00	2.90
r_17	9	a024	193,052	5.86	76.00	0.83
r_17	10	a484	193,516	6.00	524.00	0.14
r_17	11	a479	194,964	6.15	366.00	1.42
r_17	12	a495	196,458	6.31	126.00	0.40
r_17	13	a014	197,302	6.45	76.00	0.70
r_17	14	a514	198,602	6.60	36.00	0.65
r_17	15	a041	198,813	6.74	39.00	0.17
r_17	16	a477	201,741	6.92	40.00	1.61
r_17	17	t01	210,194	7.06	-	4.24
r_18	0	t01	-	0.52	-	-
r_18	1	a276	10,880	1.70	44.00	5.06
r_18	2	a123	12,225	1.86	40.00	2.17
r_18	3	a153	14,001	2.01	76.00	0.79
r_18	4	a286	61,221	2.93	22.00	24.48

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_18	5	a638	69,583	3.20	145.00	4.93
r_18	6	a647	73,101	3.39	58.00	1.24
r_18	7	a464	123,350	4.36	96.00	75.83
r_18	8	a449	131,498	4.62	279.00	12.06
r_18	9	a453	132,049	4.76	92.00	0.23
r_18	10	a422	132,645	4.90	38.00	0.82
r_18	11	a280	137,961	5.12	28.00	7.23
r_18	12	a229	139,497	5.28	31.00	2.08
r_18	13	a191	150,198	5.58	31.00	14.36
r_18	14	a438	158,611	5.85	40.00	4.65
r_18	15	a583	159,516	6.00	175.00	0.47
r_18	16	a519	165,034	6.22	738.00	7.00
r_18	17	a432	165,742	6.36	128.00	0.74
r_18	18	a047	177,968	6.70	32.00	12.39
r_18	19	a523	181,167	6.88	78.00	1.31
r_18	20	a042	181,419	7.02	232.00	0.25
r_18	21	t01	188,337	7.13	-	3.23
r_19	0	t01	-	2.83	-	-
r_19	1	a338	11,817	4.03	826.00	5.24
r_19	2	a635	12,221	4.17	101.00	0.16
r_19	3	a459	13,613	4.32	69.00	1.85
r_19	4	a279	17,944	4.52	7.00	5.65
r_19	5	a418	23,640	4.75	95.00	5.15
r_19	6	a118	28,458	4.96	40.00	6.14
r_19	7	a263	36,037	5.22	57.00	2.39
r_19	8	a445	37,796	5.37	59.00	0.78
r_19	9	a314	43,243	5.60	45.00	6.69
r_19	10	a243	43,243	5.73	19.00	-
r_19	11	a419	44,113	5.87	181.00	0.16
r_19	12	a337	44,113	6.00	607.00	-
r_19	13	a283	44,891	6.14	136.00	0.76
r_19	14	a290	47,305	6.31	25.00	1.16
r_19	15	a503	50,118	6.49	46.00	2.02
r_19	16	a448	56,782	6.73	50.00	6.10
r_19	17	t01	73,823	7.02	-	8.34
r_20	0	t01	-	2.08	-	-
r_20	1	a435	9,121	3.23	155.00	4.01
r_20	2	a417	9,999	3.38	94.00	1.58
r_20	3	a252	11,469	3.53	28.00	2.60
r_20	4	a404	12,726	3.68	342.00	0.59
r_20	5	a226	13,145	3.82	31.00	0.70
r_20	6	a251	16,704	4.01	9.00	1.75
r_20	7	a367	21,781	4.22	53.00	3.09
r_20	8	a397	26,838	4.44	64.00	2.01
r_20	9	a434	33,184	4.67	62.00	3.43
r_20	10	a212	34,230	4.82	22.00	1.67
r_20	11	a006	35,256	4.97	28.00	1.63
r_20	12	a057	36,075	5.11	4.00	0.67
r_20	13	a207	38,478	5.28	31.00	1.17
r_20	14	a450	39,190	5.42	364.00	0.29
r_20	15	a430	50,354	5.74	136.00	16.29
r_20	16	a493	58,252	6.00	147.00	4.64
r_20	17	a468	58,269	6.13	114.00	0.02
r_20	18	a129	67,624	6.42	140.00	12.55
r_20	19	a215	67,897	6.55	76.00	0.14
r_20	20	a512	68,679	6.69	68.00	0.45
r_20	21	a516	69,515	6.84	107.00	0.34
r_20	22	a466	72,316	7.01	255.00	3.43
r_20	23	a224	74,691	7.18	25.00	2.73

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_20	24	a473	76,648	7.35	207.00	1.16
r_20	25	a481	80,201	7.54	62.00	1.81
r_20	26	a424	82,196	7.70	145.00	2.12
r_20	27	t01	92,685	7.87	-	5.66
r_21	0	t01	-	0.99	-	-
r_21	1	a228	16,217	2.26	31.00	8.19
r_21	2	a379	29,600	2.61	200.00	5.58
r_21	3	a642	30,020	2.75	104.00	0.22
r_21	4	a632	42,341	3.09	121.00	19.52
r_21	5	a297	44,350	3.25	40.00	3.11
r_21	6	a644	47,309	3.43	651.00	1.51
r_21	7	a130	48,947	3.59	100.00	2.20
r_21	8	a646	49,472	3.73	200.00	0.26
r_21	9	a645	50,586	3.87	130.00	1.40
r_21	10	a639	52,640	4.04	146.00	2.50
r_21	11	a637	60,427	4.30	40.00	9.14
r_21	12	a648	68,090	4.56	116.00	3.76
r_21	13	a177	71,655	4.75	60.00	4.02
r_21	14	a221	81,435	5.04	30.00	4.61
r_21	15	a075	86,337	5.25	11.00	5.40
r_21	16	a311	89,136	5.43	51.00	0.86
r_21	17	a172	93,267	5.63	29.00	4.47
r_21	18	a246	97,623	5.83	8.00	1.90
r_21	19	a458	100,118	6.00	109.00	1.47
r_21	20	a525	101,475	6.15	45.00	0.51
r_21	21	a309	106,878	6.37	18.00	5.54
r_21	22	a443	107,641	6.52	183.00	0.30
r_21	23	a487	109,378	6.67	82.00	1.16
r_21	24	t01	120,771	6.86	-	4.94
r_22	0	t01	-	-	-	-
r_22	1	a249	12,513	1.21	31.00	5.05
r_22	2	a425	13,925	1.36	52.00	0.68
r_22	3	t01	25,609	1.56	-	5.24
r_23	0	t01	-	4.08	-	-
r_23	1	a426	18,970	5.40	164.00	8.75
r_23	2	a398	20,197	5.55	800.00	2.34
r_23	3	a386	23,323	5.73	750.00	5.22
r_23	4	a003	23,800	5.87	65.00	0.69
r_23	5	a526	23,953	6.00	117.00	0.03
r_23	6	a366	23,953	6.13	788.00	-
r_23	7	a508	27,601	6.32	278.00	1.33
r_23	8	t01	45,598	6.62	-	8.79
r_24	0	t01	-	0.17	-	-
r_24	1	a070	22,319	1.54	40.00	9.77
r_24	2	a077	43,174	2.02	56.00	11.17
r_24	3	a447	44,613	2.17	48.00	0.84
r_24	4	a618	60,799	2.57	193.00	11.16
r_24	5	a624	63,409	2.74	199.00	0.59
r_24	6	a330	75,455	3.08	1,348.00	19.83
r_24	7	a052	86,376	3.39	137.00	13.62
r_24	8	a609	108,964	3.89	48.00	9.95
r_24	9	a636	109,226	4.03	175.00	0.12
r_24	10	a053	114,394	4.24	50.00	5.89
r_24	11	a584	156,761	5.08	74.00	19.65
r_24	12	a307	156,825	5.21	49.00	0.07
r_24	13	a585	158,238	5.37	114.00	0.69
r_24	14	a167	179,972	5.86	117.00	22.94
r_24	15	a316	180,727	6.00	14.00	0.42
r_24	16	a486	197,747	6.41	48.00	7.61

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_24	17	t01	220,808	6.80	-	11.77
r_25	0	t01	-	4.18	-	-
r_25	1	a009	10,337	5.35	48.00	4.82
r_25	2	a384	11,307	5.50	435.00	0.39
r_25	3	a011	25,219	5.86	38.00	15.72
r_25	4	a431	25,809	6.00	165.00	0.30
r_25	5	a510	26,656	6.14	124.00	0.33
r_25	6	a485	30,060	6.33	86.00	3.52
r_25	7	a502	32,876	6.51	119.00	1.57
r_25	8	a333	39,342	6.75	6.00	6.29
r_25	9	a376	40,171	6.89	88.00	0.34
r_25	10	a492	52,139	7.22	702.00	5.58
r_25	11	t01	54,954	7.27	-	0.93
r_26	0	t01	-	0.17	-	-
r_26	1	a240	15,465	1.42	31.00	6.43
r_26	2	a272	16,078	1.57	30.00	0.31
r_26	3	a255	16,419	1.70	57.00	0.71
r_26	4	a274	30,715	2.07	8.00	8.32
r_26	5	a069	31,969	2.22	23.00	2.59
r_26	6	a293	61,857	2.85	4.00	16.97
r_26	7	a067	63,655	3.01	190.00	3.69
r_26	8	a208	78,196	3.38	39.00	7.07
r_26	9	a592	80,460	3.55	472.00	1.34
r_26	10	a348	118,017	4.30	1,046.00	69.37
r_26	11	a344	133,774	4.70	416.00	24.23
r_26	12	a190	135,136	4.85	10.00	1.93
r_26	13	t01	150,302	5.10	-	7.98
r_27	0	t01	-	4.03	-	-
r_27	1	a141	12,435	5.24	36.00	6.01
r_27	2	a340	13,906	5.39	902.00	0.43
r_27	3	a439	26,892	5.74	58.00	6.34
r_27	4	a441	34,727	6.00	47.00	3.20
r_27	5	a506	35,394	6.14	770.00	0.25
r_27	6	a371	47,799	6.48	1,093.00	19.08
r_27	7	t01	62,783	6.73	-	7.24
r_28	0	t01	-	4.36	-	-
r_28	1	a085	163,886	8.09	208.00	74.17
r_28	2	a027	175,280	8.41	73.00	14.39
r_28	3	a285	190,894	8.80	144.00	8.83
r_28	4	a028	245,770	9.85	21.00	65.79
r_28	5	a373	267,963	10.35	307.00	10.55
r_28	6	a341	280,520	10.69	177.00	13.84
r_28	7	a087	321,168	11.49	73.00	42.66
r_28	8	a393	369,291	12.43	354.00	20.63
r_28	9	a138	370,956	12.58	42.00	1.54
r_28	10	a045	377,216	12.82	147.00	5.70
r_28	11	a383	380,387	13.00	353.00	1.48
r_28	12	t01	380,386	13.00	-	-
r_29	0	t01	-	7.93	-	-
r_29	1	a352	221,096	12.61	81.00	91.43
r_29	2	a353	221,096	12.74	5.00	-
r_29	3	a046	228,596	13.00	96.00	2.12
r_29	4	t01	265,983	13.62	-	14.17
r_30	0	t01	-	6.75	-	-
r_30	1	a625	15,266	8.00	93.00	6.68
r_30	2	a196	15,328	8.13	31.00	0.05
r_30	3	a631	15,691	8.27	706.00	0.13
r_30	4	a591	16,100	8.40	143.00	0.22
r_30	5	t01	31,027	8.65	-	6.93

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_31	0	t01	-	6.72	-	-
r_31	1	a597	16,825	8.00	41.00	7.01
r_31	2	a602	19,059	8.17	357.00	0.96
r_31	3	t01	34,554	8.43	-	6.78
r_32	0	t01	-	5.80	-	-
r_32	1	a021	72,213	8.00	81.00	30.55
r_32	2	a146	77,782	8.22	36.00	2.28
r_32	3	a605	80,039	8.39	81.00	1.00
r_32	4	t01	146,847	9.50	-	32.34
r_33	0	t01	-	6.12	-	-
r_33	1	a475	52,865	8.00	97.00	23.55
r_33	2	a406	58,536	8.22	92.00	7.62
r_33	3	a064	73,987	8.61	51.00	20.35
r_33	4	a149	75,472	8.77	72.00	1.10
r_33	5	a155	77,395	8.93	42.00	0.13
r_33	6	a611	85,772	9.20	73.00	3.69
r_33	7	a616	92,036	9.43	490.00	2.76
r_33	8	a596	98,267	9.67	99.00	6.86
r_33	9	a089	110,922	10.01	98.00	13.57
r_33	10	a010	126,569	10.40	48.00	16.33
r_33	11	a128	134,891	10.67	40.00	4.30
r_33	12	a139	138,506	10.86	42.00	1.65
r_33	13	a296	140,030	11.01	10.00	0.71
r_33	14	a037	141,410	11.17	43.00	1.38
r_33	15	a103	143,510	11.33	155.00	0.82
r_33	16	a324	147,043	11.52	131.00	1.39
r_33	17	a023	148,732	11.68	33.00	1.53
r_33	18	a157	150,193	11.83	82.00	0.77
r_33	19	a152	151,308	11.98	82.00	0.97
r_33	20	a120	153,657	12.15	28.00	1.99
r_33	21	a199	158,796	12.37	39.00	2.10
r_33	22	a188	160,622	12.53	18.00	1.51
r_33	23	a114	161,965	12.68	116.00	1.10
r_33	24	t01	187,319	13.10	-	12.69
r_34	0	t01	-	5.96	-	-
r_34	1	a626	62,360	8.00	129.00	26.26
r_34	2	a081	63,301	8.15	23.00	0.33
r_34	3	a094	71,729	8.42	165.00	3.62
r_34	4	t01	125,110	9.31	-	25.00
r_35	0	t01	-	12.25	-	-
r_35	1	a607	40,424	13.93	71.00	17.26
r_35	2	a372	57,061	14.33	119.00	8.86
r_35	3	a640	72,106	14.71	54.00	6.54
r_35	4	a641	81,427	15.00	352.00	4.04
r_35	5	t01	102,980	15.36	-	10.06
r_36	0	t01	-	6.26	-	-
r_36	1	a595	44,498	8.00	79.00	19.99
r_36	2	a615	45,979	8.15	85.00	0.44
r_36	3	a358	49,997	8.35	196.00	5.72
r_36	4	a617	53,067	8.53	69.00	2.15
r_36	5	a593	53,377	8.67	699.00	0.42
r_36	6	a101	55,078	8.83	91.00	1.94
r_36	7	a061	56,993	8.99	514.00	2.13
r_36	8	a136	57,429	9.13	90.00	0.22
r_36	9	a628	62,600	9.34	50.00	2.62
r_36	10	a603	68,699	9.57	41.00	5.60
r_36	11	a030	76,724	9.84	45.00	7.27
r_36	12	a161	83,893	10.09	154.00	3.43
r_36	13	a289	86,082	10.25	35.00	0.74

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_36	14	t01	133,394	11.04	-	22.59
r_37	0	t01	-	5.83	-	-
r_37	1	a614	70,298	8.00	41.00	29.59
r_37	2	a261	83,539	8.35	27.00	3.03
r_37	3	t01	149,552	9.45	-	31.53
r_38	0	t01	-	8.90	-	-
r_38	1	a125	5,973	10.00	120.00	2.49
r_38	2	a012	5,990	10.13	46.00	0.00
r_38	3	t01	11,936	10.23	-	2.74
r_39	0	t01	-	10.44	-	-
r_39	1	a211	16,171	11.71	1.00	6.85
r_39	2	a034	18,978	11.89	60.00	4.87
r_39	3	a570	21,090	12.06	50.00	1.54
r_39	4	a552	21,565	12.19	405.00	0.81
r_39	5	a551	22,186	12.33	93.00	0.98
r_39	6	a054	24,289	12.50	48.00	3.27
r_39	7	a403	24,965	12.64	667.00	0.28
r_39	8	a554	25,426	12.78	650.00	0.17
r_39	9	a198	25,832	12.91	28.00	0.47
r_39	10	a082	34,194	13.18	14.00	9.57
r_39	11	a574	35,554	13.34	142.00	0.65
r_39	12	a305	46,737	13.65	24.00	12.28
r_39	13	a575	47,916	13.80	186.00	0.45
r_39	14	a553	53,047	14.02	59.00	5.31
r_39	15	a395	75,403	14.52	82.00	22.76
r_39	16	a098	96,375	15.00	86.00	20.85
r_39	17	t01	131,021	15.58	-	16.89
r_40	0	t01	-	7.30	-	-
r_40	1	a329	113,397	10.19	40.00	50.05
r_40	2	a106	126,893	10.55	88.00	12.97
r_40	3	a282	152,262	11.10	154.00	11.71
r_40	4	a335	182,485	11.74	37.00	13.98
r_40	5	a532	237,008	12.77	61.00	24.48
r_40	6	a572	240,679	12.97	140.00	2.01
r_40	7	a049	246,616	13.19	92.00	4.86
r_40	8	a084	250,458	13.39	40.00	1.93
r_40	9	a533	251,265	13.53	88.00	0.50
r_40	10	a079	252,202	13.68	20.00	0.71
r_40	11	a268	261,535	13.96	28.00	3.90
r_40	12	a056	266,155	14.17	106.00	3.42
r_40	13	a322	271,428	14.39	23.00	2.37
r_40	14	a062	272,398	14.53	154.00	0.68
r_40	15	a162	274,165	14.69	76.00	0.83
r_40	16	a063	275,688	14.85	153.00	0.96
r_40	17	a323	276,973	15.00	5.00	0.58
r_40	18	t01	299,174	15.37	-	10.68
r_41	0	t01	-	5.95	-	-
r_41	1	a111	63,199	8.00	52.00	29.91
r_41	2	a137	95,352	8.67	44.00	16.06
r_41	3	a562	117,613	9.17	155.00	10.07
r_41	4	a580	124,789	9.42	45.00	3.59
r_41	5	a633	128,819	9.61	198.00	2.21
r_41	6	a634	129,986	9.76	146.00	0.83
r_41	7	a313	132,793	9.94	9.00	3.98
r_41	8	a134	133,311	10.08	66.00	0.73
r_41	9	a200	134,678	10.23	54.00	0.52
r_41	10	a619	137,362	10.41	1,067.00	1.14
r_41	11	a356	139,175	10.57	38.00	1.93
r_41	12	a095	141,935	10.74	86.00	2.91

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_41	13	a035	181,752	11.54	20.00	40.91
r_41	14	a164	183,823	11.70	144.00	0.93
r_41	15	a182	190,979	11.95	17.00	3.70
r_41	16	a271	198,296	12.20	37.00	3.22
r_41	17	a259	199,925	12.36	27.00	1.57
r_41	18	a080	202,618	12.53	10.00	2.57
r_41	19	a140	205,992	12.72	46.00	1.08
r_41	20	a126	206,971	12.87	40.00	0.92
r_41	21	a151	210,349	13.05	76.00	1.59
r_41	22	t01	215,018	13.13	-	1.99
r_42	0	t01	-	8.95	-	-
r_42	1	a308	2,897	10.00	42.00	1.22
r_42	2	a534	7,127	10.20	235.00	1.85
r_42	3	a444	12,160	10.41	220.00	2.08
r_42	4	t01	18,837	10.53	-	3.21
r_43	0	t01	-	13.51	-	-
r_43	1	a390	20,405	14.85	223.00	8.97
r_43	2	a334	21,663	15.00	737.00	0.88
r_43	3	t01	41,812	15.34	-	8.44
r_44	0	t01	-	8.64	-	-
r_44	1	a537	21,783	10.00	33.00	9.21
r_44	2	a222	23,755	10.16	39.00	0.81
r_44	3	a565	27,782	10.36	216.00	1.73
r_44	4	a469	30,275	10.53	55.00	0.83
r_44	5	a262	31,733	10.69	28.00	0.46
r_44	6	t01	50,757	11.00	-	8.93
r_45	0	t01	-	8.85	-	-
r_45	1	a407	9,178	10.00	181.00	3.95
r_45	2	a567	9,842	10.14	52.00	0.58
r_45	3	a555	10,770	10.29	84.00	1.76
r_45	4	a491	12,482	10.45	179.00	3.20
r_45	5	a467	13,131	10.59	128.00	1.18
r_45	6	a507	14,544	10.74	67.00	0.61
r_45	7	a542	17,178	10.91	62.00	1.94
r_45	8	a038	17,354	11.05	51.00	0.31
r_45	9	a412	21,654	11.25	84.00	2.09
r_45	10	a385	22,405	11.39	6.00	1.28
r_45	11	a381	23,129	11.53	84.00	1.23
r_45	12	a559	24,381	11.68	280.00	0.55
r_45	13	a556	25,377	11.83	154.00	1.58
r_45	14	a065	26,408	11.98	50.00	1.59
r_45	15	a299	26,408	12.11	30.00	-
r_45	16	a025	28,536	12.27	58.00	3.24
r_45	17	a113	28,967	12.41	78.00	0.19
r_45	18	a144	29,968	12.56	55.00	0.71
r_45	19	a548	30,305	12.69	228.00	0.19
r_45	20	a132	31,154	12.84	107.00	1.19
r_45	21	a472	32,021	12.98	338.00	0.32
r_45	22	a265	34,852	13.16	7.00	3.58
r_45	23	a092	36,669	13.32	102.00	2.29
r_45	24	a004	42,226	13.54	29.00	6.85
r_45	25	a112	44,703	13.71	48.00	1.36
r_45	26	a048	48,401	13.90	69.00	4.47
r_45	27	a578	48,970	14.04	47.00	0.19
r_45	28	a206	49,491	14.18	40.00	0.61
r_45	29	a545	50,010	14.32	278.00	0.27
r_45	30	t01	61,614	14.51	-	5.95
r_46	0	t01	-	8.69	-	-
r_46	1	a540	18,532	10.00	118.00	7.99

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_46	2	a217	20,681	10.17	39.00	1.83
r_46	3	a119	21,330	10.31	70.00	0.55
r_46	4	a100	24,430	10.49	91.00	2.55
r_46	5	a394	26,536	10.65	58.00	0.94
r_46	6	a043	35,721	10.94	93.00	7.14
r_46	7	a156	42,272	11.18	54.00	3.04
r_46	8	a558	43,478	11.33	94.00	0.53
r_46	9	a107	46,533	11.51	100.00	2.16
r_46	10	a538	47,819	11.66	224.00	0.58
r_46	11	a158	49,188	11.81	82.00	0.83
r_46	12	a257	53,538	12.01	27.00	2.00
r_46	13	a292	56,107	12.19	12.00	1.08
r_46	14	a127	58,740	12.36	100.00	1.51
r_46	15	t01	77,585	12.67	-	9.54
r_47	0	t01	-	8.38	-	-
r_47	1	a524	36,966	10.00	234.00	15.64
r_47	2	a270	37,260	10.13	78.00	0.10
r_47	3	a415	39,220	10.30	60.00	0.82
r_47	4	t01	76,429	10.92	-	17.57
r_48	0	t01	-	8.40	-	-
r_48	1	a543	35,913	10.00	166.00	15.19
r_48	2	a332	36,202	10.13	194.00	0.11
r_48	3	t01	71,852	10.73	-	16.80
r_49	0	t01	-	8.86	-	-
r_49	1	a225	11,631	10.06	31.00	5.15
r_49	2	a375	14,064	10.23	165.00	1.30
r_49	3	a529	15,055	10.38	463.00	0.02
r_49	4	a355	16,707	10.53	842.00	3.11
r_49	5	a389	17,680	10.68	510.00	0.49
r_49	6	a451	19,487	10.84	24.00	0.47
r_49	7	a531	21,245	11.00	530.00	1.25
r_49	8	a277	22,940	11.16	23.00	2.24
r_49	9	t01	31,149	11.29	-	4.05
r_50	0	t01	-	8.85	-	-
r_50	1	a544	8,771	10.00	57.00	3.99
r_50	2	a535	31,149	10.50	46.00	44.75
r_50	3	a154	41,831	10.81	46.00	21.22
r_50	4	a547	44,509	10.99	396.00	1.65
r_50	5	a413	51,449	11.23	150.00	12.88
r_50	6	a564	68,363	11.64	224.00	8.02
r_50	7	a219	70,884	11.82	1.00	4.40
r_50	8	a234	87,480	12.22	31.00	7.88
r_50	9	a073	88,145	12.36	11.00	1.15
r_50	10	a482	89,990	12.52	285.00	0.54
r_50	11	a604	93,445	12.71	158.00	1.36
r_50	12	a122	94,652	12.86	60.00	1.93
r_50	13	a336	96,050	13.01	865.00	0.57
r_50	14	a568	97,076	13.16	580.00	0.52
r_50	15	a121	97,883	13.31	75.00	0.93
r_50	16	a550	99,562	13.46	83.00	1.00
r_50	17	t01	108,223	13.61	-	4.41
r_51	0	t01	-	8.81	-	-
r_51	1	a055	11,529	10.00	106.00	4.91
r_51	2	a165	11,529	10.13	51.00	-
r_51	3	a560	13,022	10.28	218.00	0.39
r_51	4	a301	13,341	10.42	45.00	0.46
r_51	5	a474	14,916	10.58	122.00	1.14
r_51	6	a110	15,937	10.72	18.00	1.43
r_51	7	a347	16,397	10.86	971.00	0.06

Route ID	Route stop	Node ID	Distance (m)	Total time (h)	Weight (kg)	Energy consumption (kWh)
r_51	8	a260	16,871	11.00	28.00	0.52
r_51	9	a557	19,108	11.17	190.00	0.93
r_51	10	a577	20,613	11.32	128.00	0.69
r_51	11	a546	32,809	11.65	155.00	12.24
r_51	12	a174	35,197	11.82	35.00	2.29
r_51	13	a573	38,342	12.01	228.00	1.28
r_51	14	t01	64,529	12.44	-	12.58
r_52	0	t01	-	12.13	-	-
r_52	1	a501	2,317	13.17	71.00	1.05
r_52	2	a536	6,279	13.37	175.00	2.14
r_52	3	a175	8,601	13.54	20.00	1.75
r_52	4	a549	12,919	13.74	363.00	1.99
r_52	5	a490	16,409	13.93	123.00	2.24
r_52	6	a541	21,698	14.15	116.00	2.33
r_52	7	a147	29,113	14.40	20.00	4.23
r_52	8	a275	31,903	14.58	22.00	1.22
r_52	9	a561	39,236	14.83	102.00	3.21
r_52	10	a566	41,777	15.00	47.00	1.10
r_52	11	t01	52,836	15.18	-	5.23
r_53	0	t01	-	7.60	-	-
r_53	1	a613	18,870	8.91	64.00	8.01
r_53	2	a051	25,612	9.16	66.00	2.90
r_53	3	a148	29,508	9.35	30.00	1.67
r_53	4	a050	34,133	9.56	60.00	1.86
r_53	5	a017	37,642	9.75	76.00	1.35
r_53	6	a539	44,984	10.00	125.00	3.09
r_53	7	t01	54,866	10.16	-	4.20
r_54	0	t01	-	8.86	-	-
r_54	1	a563	8,337	10.00	278.00	3.64
r_54	2	a326	8,434	10.13	30.00	0.10
r_54	3	a576	8,938	10.27	505.00	0.25
r_54	4	a131	16,405	10.52	100.00	6.90
r_54	5	a058	18,587	10.69	92.00	1.95
r_54	6	a315	21,647	10.87	15.00	1.00
r_54	7	a192	22,311	11.01	31.00	0.57
r_54	8	a288	22,910	11.15	12.00	0.28
r_54	9	a083	25,794	11.33	162.00	2.45
r_54	10	a312	28,280	11.50	8.00	1.00
r_54	11	a427	29,455	11.65	34.00	0.52
r_54	12	a377	30,067	11.79	361.00	0.48
r_54	13	t01	39,727	11.95	-	4.91
r_55	0	t01	-	8.79	-	-
r_55	1	a363	12,789	10.00	66.00	5.46
r_55	2	a343	13,299	10.14	376.00	0.23
r_55	3	t01	25,675	10.34	-	6.07
r_56	0	t01	-	8.73	-	-
r_56	1	a428	16,206	10.00	145.00	6.61
r_56	2	a135	23,319	10.25	30.00	2.07
r_56	3	a220	27,028	10.44	10.00	1.61
r_56	4	a160	32,687	10.66	40.00	1.58
r_56	5	t01	44,561	10.86	-	5.19
r_57	0	t01	-	8.63	-	-
r_57	1	a019	22,193	10.00	77.00	9.26
r_57	2	a124	22,966	10.14	60.00	0.31
r_57	3	t01	44,671	10.50	-	10.06
r_58	0	t01	-	8.86	-	-
r_58	1	a350	8,126	10.00	1,175.00	3.74
r_58	2	t01	16,252	10.14	-	4.03

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