energies

Article

Optimization of e-Mobility Service for Disabled People Using a Multistep Integrated Methodology †

Regina Lamedica, Marco Maccioni *, Alessandro Ruvio, Federico Carere, Nicola Mortelliti, Fabio Massimo Gatta and Alberto Geri

Deptartment of Astronautics, Electrical and Energy Engineering (DIAEE), Sapienza University of Rome, 00184 Rome, Italy; regina.lamedica@uniroma1.it (R.L.); alessandro.ruvio@uniroma1.it (A.R.); federico.carere@uniroma1.it (F.C.); mortelliti.1831574@studenti.uniroma1.it (N.M.); fabiomassimo.gatta@uniroma1.it (F.M.G.); alberto.geri@uniroma1.it (A.G.)

* Correspondence: marco.maccioni@uniroma1.it

† This paper is an extended version of our paper published in 2021 International Conference on Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE), Torino, Italy, 17–19 November 2021.

Abstract: The penetration of e-mobility is growing thanks to the European guidelines on climate preservation regarding the reduction in CO_2 emission. Governments are adapting their economic policies with the aim to incentivize e-mobility. At the same time, with a view to equality and accessibility, countries are working to introduce e-mobility services also for people with disabilities in order to improve the quality of their lives. The paper reports the deployment of an e-mobility service for persons with disabilities carried out in a project financed by Sapienza University of Rome. The project includes a feasibility study and a cost–benefit analysis in order to identify the optimal solution from a technical and environmental point of view for a sustainable e-mobility service for people with reduced mobility. A methodology to design a service based on optimal routes and electric vehicles with respect to energy consumption, time travel, energy and vehicle costs and quality of service is proposed. The 5-step methodology calculates the most energy-efficient routes and defines the optimal charging schedule, taking into account charging points dislocated along the routes and choosing vehicle typologies with the best performance based on economic evaluations. A software was developed to automatize the methodology.

Keywords: disabilities; electric vehicle; e-mobility service; energy efficiency; optimal planning

Citation: Lamedica, R.; Maccioni, M.; Ruvio, A.; Carere, F.; Mortelliti, N.; Gatta, F.M.; Geri, A. Optimization of e-Mobility Service for Disabled People Using a Multistep Integrated Methodology. *Energies* **2022**, *15*, 2751. https://doi.org/10.3390/en15082751

Academic Editor: Javier Contreras

Received: 28 February 2022
Accepted: 6 April 2022
Published: 8 April 2022

1. Introduction

The future urban mobility is a great challenge, in particular for large cities, in which the technological transition in the transportation system will require a deep infrastructure upgrade. Deloitte global forecast [1] reports that total EV sales will achieve 11.2 million in 2025 and 31.1 million by 2030. The total market share for new car sales will be characterized by EVs, accounting for approximately 32%. The growth of EVs penetration in the transportation sector is influenced by the worldwide environmental needs related to air pollution, GHG emissions, energy transition and new incomes due to the COVID-19 pandemic [2]. New technologies and services are investigated, such as autonomous vehicles and shared mobility services, which will be crucial for the expansion of EVs in urban mobility [3]. Mobility transformation is also interconnected with social needs, as is the case with the transport of people affected by disabilities. The recent European Accessibility Act [4] of April 2019 defines the accessibility requirements for products and services, with the aim to remove the barriers with respect to transport, education and labor. This paper investigates an e-mobility transport system for people with disabilities, describing a project financed by Sapienza University of Rome for the introduction of an e-mobility service to move people with disabilities among several departments of the university located in different areas of the city.

According to the principles of non-discrimination, equal opportunities and universal accessibility, many universities around the world are implementing solutions to ensure that people with disabilities are fully and effectively included as members of the university community. Cornell University (New York) provides free bus passes, the approval to purchase an accessible parking permit for campus, the use of Cornell paratransit service that provides pre-scheduled rides to on-campus classes, appointments and extra-curricular activities [5]. The University of Pittsburgh offers the "DisAbility Shuttle" [6], which ensures safe, convenient transportation for students, department and staff with temporary injuries or permanent disabilities. Similar services are also adopted in Europe, as in the University of Edinburgh [7] and University of Granada [8]. In Italy, the University of Pavia provides a service for the necessary movements for participation in lectures, laboratory or tutoring activities, as well as all examinations, meetings with teachers, dealing with bureaucratic and administrative practices. The collaboration with the local public transport company guarantees an accompanying service [9]. The University of Turin supports students with motor and/or visual disabilities with teaching activities by means of a physical accompaniment service for reaching the various university sites and departments. The routes and meeting places are selected according to university residences, bus terminals, train stations, and private homes located in the city of Turin. The service also supports the students not able to consume a meal independently at any lunch break. The accompanying service is carried out exclusively by students who have won a special scholarship [10]. A service for disabled students' transport among the classes is provided by Cattolica University [11] in its campuses located in Milan, Brescia, Piacenza and Rome. The University of Bologna offers accompanied activities to and from the facilities by walking with the help of civil protection volunteers for students with permanent or temporary motor disabilities, visual impairments or duly certified civil disability. Moreover, the university provides cash contributions as reimbursement for cab expenses incurred to attend classes and exams [12]. The mitigation actions to remove the social and infrastructural barriers for persons affected by disabilities meet the environmental and sustainable needs by means of e-mobility, which able to cut CO_2 emissions and guarantee high energetic and economic performance in people transport.

In the literature, many studies analyze e-mobility facing the vehicle routing problem, fundamental for delivery and collection of goods or people, integrated with the EVs charging needs [13–21]. In Ref. [16], a dynamic transit system with EVs is studied as an extended pickup and delivery problem, maximizing users' satisfaction (travel time and distance) and energy efficiency (fuel and charging cost). In Ref [14], a route scheduling optimization problem is proposed for centralized bus depots in the city of Hamburg in Germany. The model minimizes the necessary number of buses and the total cost of the fleet, defining the optimum composition of the fleet. However, these studies do not provide a fully automated procedure for implementing a transport service taking into account environmental, economic and social requirements.

Other studies [22–30] focus on the EVs charging sessions scheduling and charging infrastructure upgrade among the DNs. In Ref. [25], the public charging infrastructure is investigated according to a wide range of public and private stakeholders in the metropolitan areas, taking into account environmental, social and economic benefits and risks. In Ref. [23], an open-source smart charging algorithm is proposed and validated in a one-year field test; the algorithm schedules EVs heterogeneous fleets for charging, ensuring a fair share for each vehicle. Another crucial aspect analyzed in the literature is the driver assistance system, as in Refs. [31,32]. In Ref. [31], the driver assistance technology is used to evaluate an optimal speed profile suggested for the driver, according to the energy consumption prediction on the actual route. Many studies focus on the sustainable and environmental aspects in the new electric fleet definition, considering the carsharing services as a promising solution in future years [33–39]. In Ref. [33], an e-mobility service for an academic community is designed, identifying the locations of the vehicle pick-up/dropoff points and the composition of the electric fleet. Nevertheless, dynamic and cinematic simulations of EVs are not integrated in the analysis to identify the optimal energetic routes.

The present paper describes the feasibility study of an e-mobility service, funded by the Sapienza University of Rome, for transportation of people with disabilities among the departments of the Faculty of Civil and Industrial Engineering. Mobility impairments, which can be permanent or temporary, range from lower body impairments, which may require use of canes, walkers or wheelchairs, to upper body impairments that may include limited or no use of the upper extremities and hands. A broken bone or surgical procedure can temporarily impact a student's ability to walk independently and travel between department buildings in a timely manner. Some students may be ambulatory with a walker for short distances within a classroom but may need a wheelchair or scooter for longer distances. The study offers the university a possibility to remove the actual infrastructural barriers to inclusion of disabled people, suggesting an environmentally friendly and sustainable service based on the introduction of an electric fleet. The optimal routes between departments are selected among the existing routes, taking into account energy savings and ensuring at the same time high levels of service quality. EVs for disabled people available on the market are simulated along the routes, and the best ones are selected according to an investment plan.

The main contributions of this paper are summarized below:

- The paper presents a feasibility study for the deployment of an e-mobility service able to remove barriers for disabled people, reduce CO_2 emissions and achieve economic revenues.
- The vehicle routing problem is solved by simulating several EVs available on the market and considering the existing routes in the city of Rome, identifying the optimal energetic itineraries and taking into account the location of existing charging stations scattered in the city.
- A 5-step methodology is proposed to correctly design the e-mobility service from a technical and economic point of view. The methodology selects routes and EV typologies, as well as providing the scheduling of trips and charging sessions. The methodology is also automated by means of a software developed in the MATLAB environment, providing a robust and efficient tool for feasibility studies of e-mobility services.

The paper is organized as follows. Section 2 describes commercial EVs for people with disabilities presently available on the market; Section 3 illustrates the 5-step methodology for the feasibility study of the e-mobility service; Section 4 illustrates the software deployed in MATLAB for automating the methodology; Sections 5 and 6 present the case study and the results obtained by the methodology, respectively; conclusions are reported in Section 7.

2. EVs on Market for People Affected by Disabilities

Several EVs for disabled people are currently penetrating the market due to the widespread increasing requests to remove social and infrastructural barriers. International car manufacture companies are presenting new EVs models able to fulfill environmental and social needs and are implementing technological solutions to improve the mobility transport quality. For example, lowering the vehicle floor creates an equal head height for able-bodied and wheelchair-seated passengers alike. This enables easier conversation and promotes the feeling of inclusion for the wheelchair user. Locating the wheelchair in the middle of the rear passenger seats enables the wheelchair user to travel as part of the family [40]. Another relevant solution is represented by specific kits, characterized by a quick installation, able to transform a vehicle according to the needs of a wheelchair user [41]. Additionally, autonomous vehicles are attracting a great interest due to the possibility to enhance transport experience for people with disabilities [42].

In this paper, the EVs commercial models shown in Figure 1 are taken into account:

- EV—Type A: a single-seater vehicle that can be driven directly by people affected by mobility difficulties. The wheelchair is guided, locked and placed in an appropriate position through an automatic ramp so that the disabled driver can manage the various controls and commands. It may have a joystick on the steering wheel to simplify driving. This type of EV is useful for short journeys [43].

- EV—Type B: a two-seater EV allowing short journeys, possibly having a personal driver “on call” [44].
- EV—Type C: an electric minibus with transport capacity of six people (reduced to four in case of transport of a disabled person on a wheelchair) designed for long journeys. According to the European Directive 2007/46, this type of vehicle is homologated N1 and therefore has access to the traffic limit zone, as well as being able to take advantage of any incentives [45].
- EV—Type D: an eight-seater minivan with the possibility of transporting two open wheelchairs (transport capacity 4 + 2 in this case) for long journeys around the city [46].

Figure 1. EV typologies for transportation of people with disabilities.

The main technical and mechanical characteristics of the above-described EVs are reported in Table 1. Such characteristics are fundamental for the dynamic and cinematic simulation of the vehicles along the routes in the city.

Table 1. Main technical and mechanical characteristics of the simulated EVs.

EV Type	Type A	Type B	Type C	Type D
$n_{k,seats}$	1	2	6 (4 + 1)	8 (4 + 2)
P_k^{full} (kW)	4	1.2	10	100
F_k^{full} (Nm)	190	120	254	260
E_k^n (kWh)	1.2	2.4	15.3	50
M_k (t)	0.66	0.28	2	2.77
v_k^{full} (km/h)	40	18	40	130
S_k^{max} (%)	17	15	19	>25
A_k (km)	100	70	130	230
Size (m × m × m)	2.38 × 1.35 × 1.70	1.55 × 1.20 × 1.65	4.00 × 1.20 × 2.27	4.61 × 1.90 × 1.92

Type A and type B are EVs characterized by a lower number of seats, dimensions and total mass. Type C and type D are more expensive EVs but with a larger number of seats and a larger battery capacity.

3. Proposed 5-Step Methodology

The paper proposes a 5-step methodology for the feasibility study of an e-mobility service for people with disabilities. In the first two steps of the methodology, plano-altimetric characteristics of the existing routes between departments are obtained, and electro-mechanical models of the EV types are implemented. In the third step, dynamic and cinematic simulations of each point-to-point route allow identifying the best itineraries from an energetic point of view, as well as to maximize the e-mobility service quality for disabled people. In the fourth step of the methodology, the multi-point routes interconnecting all departments are analyzed from an energetic, sustainable and comfortable point of view. A final economic analysis in the last step selects the numbers and the typologies of the EVs, the optimal routes and the annual number of necessary charging sessions. The 5-step methodology, illustrated in Figure 2, is fully automated and implemented in a software deployed in the MATLAB environment. The software structure is discussed in Section 4, while the main inputs/outputs of each step are described below. The entire methodology consists of an upgrade and generalization of the work presented in Ref. [47].

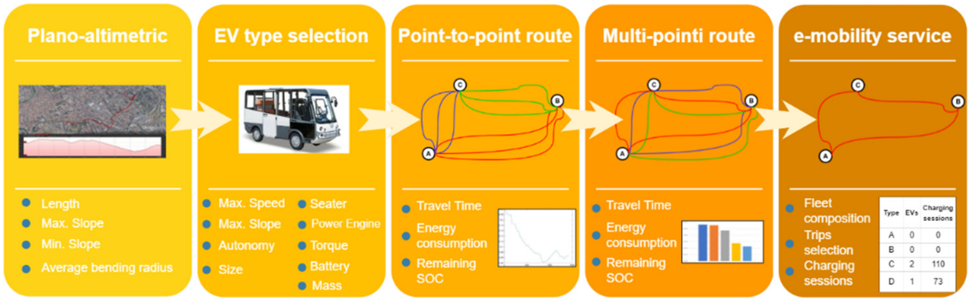


Figure 2. 5-step methodology for e-mobility service for people with disabilities; outputs of each step are reported in the relevant bulleted list.

3.1. Plano-Altimetric Step

The available existing routes between different departments are identified, minimizing the route length and considering the one-way roads. For this reason, in general, the routes are not reversible; therefore, two different routes are selected for each point-to-point connection. The plano-altimetric characteristics of the paths needed for dynamic and cinematic simulations of the EVs are:

- L_p (km);
- S_p^{max} (%);
- S_p^{min} (%);
- $br_p^{average}$ (m).

Data are acquired using a software (e.g., Google Earth 7.3.4.8248) that generates virtual images of the earth through satellite images obtained from terrestrial remote sensing, aerial photographs and topographic data stored in a geographic information system (GIS) platform.

3.2. EV Type Step

After the definition of point-to-point routes, the four EVs commercial models are analyzed to build up the electro-mechanical model of the vehicles. Mechanical characteristics are:

- M_k (kg);
- F_k^{full} (Nm);
- v_k^{full} (km/h);
- S_k^{max} (%).

The electrical characterization focuses on the capacity of the battery (kWh) and on the rated power of the electric motor (kW).

3.3. Point-to-Point Route Step

All possible combinations of routes and EV types are investigated, considering only point-to-point itineraries. In this way, for each route–EV combination the model provides the following outputs:

- Δt_p^{tot} (s);
- $E_{i,k}$ (kWh);
- $SOC_{i,k}^{fin}$ (%).

Naturally, a route with a smaller travel time, a smaller global energy consumption and a higher battery SOC at the end of the trip is preferable with respect to other routes that interconnect the same two points. The outputs of this phase allow selecting the energetic optimal routes that satisfy high levels of sustainability and service quality for people with disabilities. The selection of the optimal multi-point routes is performed in the next step.

3.4. Multi-Point Route Step

The multi-point routes interconnect different departments of Sapienza University of Rome by means of a combination of different point-to-point routes. The optimal multi-point routes are identified according to the criteria already defined for point-to-point routes (energetic, environmental, service quality criteria). The combinations of the point-to-point routes analyzed are the following:

- Circular clockwise transportation service interconnecting all departments.
- Circular anticlockwise transportation service interconnecting all departments.
- Round-route solutions interconnecting not all the departments.

The outputs of this step of the methodology are: global travel time (s), global energy consumption (kWh), global remaining SOC at the end of the multi-point route (%).

3.5. e-Mobility Service Step

The optimal multi-point routes are identified to provide an environmentally friendly and comfortable e-mobility service. In the last step, the methodology evaluates the number of vehicles and the number of annual charging sessions needed to activate and manage a feasible e-mobility service. In detail, the outputs of the last step, i.e., the outputs of the feasibility study, are:

- n_k;
- RC_k;
- Real environmentally friendly multi-point routes selection according to EV types.

The economic optimization takes into account the investment cost of each EV type and the electricity cost of the charging sessions. A MILP algorithm is implemented to find the optimal solution.

4. MATLAB-Based Software for 5-Step Methodology Automation

The 5-step methodology presented in Section 3 is automated in the MATLAB environment to provide a robust and user-friendly tool. The economic evaluation provides the economic impact of this type of service, ensuring the optimal solution in terms of sustainable and environmental requirements. The structure of the tool is summarized in the flowchart shown in Figure 3. At the beginning, the software gathers all inputs of the 5-step methodology: the plano-altimetric profiles of the real routes in the city of Rome, EVs commercial model information, economic costs related to vehicles and electricity, Sapienza University of Rome social requirements in terms of statistical information about people with disabilities in the university environment. The first loop (index k) starts by automating the procedure for each type of commercial EV model. The second loop (index p) carries out the dynamic and cinematic simulation of the vehicles for every point-to-point route. In this way, all possible combinations among the EV commercial models and point-to-point routes are simulated and analyzed to offer the best possible e-mobility service.

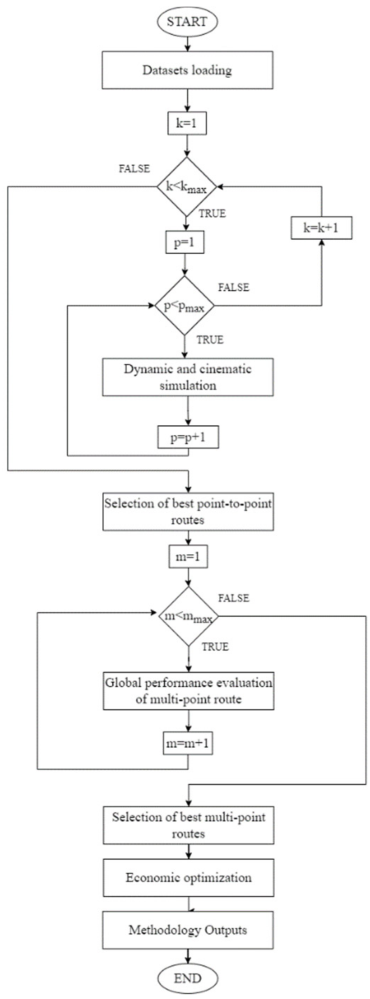


Figure 3. Flowchart of the tool for e-mobility service feasibility study, implemented in MATLAB environment.

4.1. Dynamic and Cinematic EVs Simulation

A separated flowchart is reported in Figure 4 to show how the dynamic and cinematic simulations are performed. EV commercial model and point-to-point route are selected according to indexes k and p. An electro-mechanical model describes the EV as a material point characterized by mass M_k, provided in the EV dataset loaded at the beginning of the tool, and the route is discretized in N_I sections.

The evaluation of EV performance on a route is conducted in two main loops. The first loop defines the EV speed profile without considering route speed limits, whereas the second one takes into account the speed limits, implementing the braking phase. At the end of the two loops, power and energy evaluations are carried out. The speed profile is influenced by the route characteristics; therefore, aerodynamic, bending and slope resistances are calculated with the following equations [48].

$$R_{i,k}^{ae} = g\cdot\left(b_1 + b_2\cdot c_i^{gal}\right)\cdot v_{i,k}^2\cdot M_k \tag{1}$$

$$M_{i,k}^{eq} = \left(1 + c_{i,k}^{rm}\right)\cdot M_k \tag{2}$$

$$R_{i,k}^{bending} = \frac{b_3}{br_i - b_4}\cdot M_k \tag{3}$$

$$R_{i,k}^{slope} = -\frac{g\cdot S_i}{1 + c_{i,k}^{rm}} \tag{4}$$

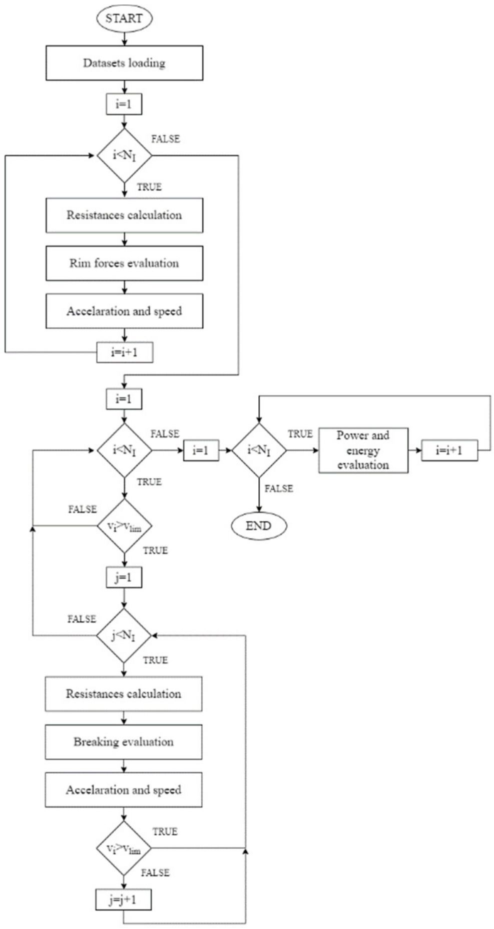


Figure 4. Flowchart of the dynamic and cinematic simulation of EVs on real point-to-point routes.

The resistances evaluation allows computing the tractive force, which depends on the vehicle speed. In case of a vehicle speed lower than the full speed v_k^{full}, the tractive force is

$$F_{i,k}^{t} = \left(\frac{F_k^{start} - F_k^{full}}{v_k^{full}}\right) \cdot v_{i,k} + F_k^{start} \tag{5}$$

Otherwise, the available tractive force is calculated considering a constant power operation by Equation (6):

$$F_{i,k}^{t} = \frac{P_{i,k}}{v_{i,k}} \tag{6}$$

The applied tractive force corresponds to the available tractive force if the speed is lower than the speed limit, as in Equation (7), otherwise it is calculated with Equation (8):

$$F_{i,k}^{a} = F_{i,k}^{t} \tag{7}$$

$$F_{i,k}^{a} = R_i^{ae} + R_i^{bending} + g \cdot S_i \cdot M_k \tag{8}$$

The calculation of the applied tractive force allows evaluating the EV acceleration by means of Equations (9) and (10):

$$a_{i,k} = \frac{F_{i,k}^{a}}{M_{i,k}^{eq}} + R_i^{ae} + R_i^{bending} \tag{9}$$

$$a_{i,k}^{TOT} = a_{i,k} + R_i^{slope} \tag{10}$$

In each i-th route section, the motion is considered as uniformly accelerated, and thus, the EV speed, $v_{i,k}$, is calculated with Equation (11):

$$v_{i,k} = \sqrt{v_{i-1,k}^2 + 2 \cdot a_{i,k}^{TOT} \cdot (x_{i,k} - x_{i-1,k})} \tag{11}$$

An "ideal" driving style was considered in the simulations, in which both acceleration and braking motion phases are conducted according to EV rated performance. Indeed, drivers could apply a coasting phase before braking. When the full speed is achieved, the motion becomes uniform.

The time duration $\Delta t_{i,k}$ to overcome the i-th route section is calculated considering the uniformly accelerated motion equations. The speed in each route section is then compared with the attendant speed limit. In case the limit is exceeded, the braking phase is carried out. The applied tractive force is thus calculated with Equation (12):

$$F_{i,k}^{a} = R_{i}^{ae} + R_{i}^{bending} - \frac{M_{i,k}^{eq}}{2} \tag{12}$$

For each route section, the braking ends when the speed fulfills the limit, and during this phase, the EV battery can be charged by the braking energy. EV battery is simply modeled by the efficiency η_{batt}.

The power profile $P_{i,k}$ of the EV storage system in each i-th route section is calculated with Equations (13) and (14), respectively, in case of braking or not:

$$P_{i,k} = F_{i,k}^{a} \cdot v_{i,k} \cdot \eta_{k} + P_{i,k}^{aux} \tag{13}$$

$$P_{i,k} = \frac{F_{i,k}^{a} \cdot v_{i,k}}{\eta_{k}} + P_{i,k}^{aux} \tag{14}$$

The energy stored in the EV battery may thus be updated with Equation (15):

$$E_{i,k} = E_{k}^{0} + \sum_{j=1}^{i} P_{j,k} \cdot \Delta t_{j,k} \tag{15}$$

where a negative energy value is consumption, and a positive energy value corresponds to an increase in the stored energy due to the braking process. The EV SOC per unit of the rated energy is lastly computed with Equation (16):

$$SOC_{i,k} = SOC_{k}^{ini} + \sum_{j=1}^{i} \frac{E_{j,k}}{E_{k}^{n}} \tag{16}$$

At the end of the dynamic and cinematic simulations, the best point-to-point routes are thus selected according to the environmental (plano-altimetric profiles), energetic (energy consumption, remaining SOC) and quality (travel duration, speed profile) criteria.

4.2. Multi-Point Route Selection

Multi-point routes are evaluated in the loop indexed with m in the flowchart in Figure 3. Clockwise, anticlockwise and round-trip solutions, obtained as combinations of all possible point-to-point routes, are analyzed with the same environmental, energetic and quality criteria listed above to obtain the best e-mobility service where interconnections between different departments must be guaranteed.

4.3. Optimization Procedure and Economic Evaluation

The number and type of EVs to be operated in the e-mobility service, as well as the daily scheduling of charging sessions, are optimally defined by an economic evaluation, modeled as a MILP problem. The problem formulation was implemented in the MATLAB environment, interfaced by YALMIP [49] with the CPLEX 12.9 solver [50]. The global cost of the service is composed of the CAPEX, related to EVs purchase, and the OPEX, related to the electricity cost of charging sessions. Assuming 10 h of service activation every working day of the year, the total number of charging sessions is identified considering the energy consumption, as in Equation (17).

$$RC_k = n_h \cdot n_d \cdot s \cdot \Delta SOC_k \quad (17)$$

The solver optimizes the number of vehicles operating the service for each EV type so as to guarantee the hourly request of the service. The multi-point route considered is the one in output pf step 4.

The objective function to minimize is

$$F = \sum_{k=1}^{4} n_k \cdot (CAPEX_k + c_{EE} \cdot RC_k) \quad (18)$$

The constraints of the MILP problem are

$$0 \le n_k \le n_{k,max}, \ \forall k \quad (19)$$

$$\sum_{k=1}^{4} n_k \cdot n_{k,seats} \ge s \quad (20)$$

Constraint (19) would not be strictly required and is used only to reduce execution times. The maximum number of type k EVs, $n_{k,max}$, is posed equal to s. Constraint (20), ensuring that the number of EVs is sufficient for the service requirements.

5. Case Study: Sapienza University of Rome

The 5-step methodology proposed in this paper is used for the feasibility study of an e-mobility service for the departments of the Faculty of Civil and Industrial Engineering of Sapienza University of Rome. Sapienza was founded in 1303 and is the oldest university in Rome and the largest in Europe. According to the ranking published in 2021 by the University of New South Wales, Sydney, Sapienza is ranked 1st in Italy and 155th globally [51]. The impact of the university on the transportation system is very high in the city of Rome due to the very large number of people involved: 117,000 students, 3300 professors, 2700 adjunct professors, 2100 employees (technicians and librarians), 1500 administrative staff in university hospitals [52]. Over 30,000 students come from other Italian cities, nearly 10,000 are international students, and over 4000 students a year take part in international mobility programs. The university is trying to enhance a sustainable management, in particular with respect to students and personnel transport. Car and bike sharing services are supported by means of new special offers for the Sapienza community interested in car sharing and shared mobility services [53].

A service for the transportation of disabled people is not directly managed by Sapienza. It relies on the public transport or on the possibility for people with disabilities to use parking areas reserved for employees. For this reason, Sapienza founded the feasibility study of an e-mobility service for the movement of the disabled by means of a sustainable and environmentally friendly service.

- The study reported in this paper mainly focuses on movements within and between: the secondary headquarter of the Faculty of Civil and Industrial Engineering, located at Scarpa street (point A in Figure 5);

- the main headquarter of the Faculty of Civil and Industrial Engineering, located at Eudossiana street (point B in Figure 5);
- the Department of Computer, Control and Management Engineering, located at Ariosto street (point C in Figure 5).

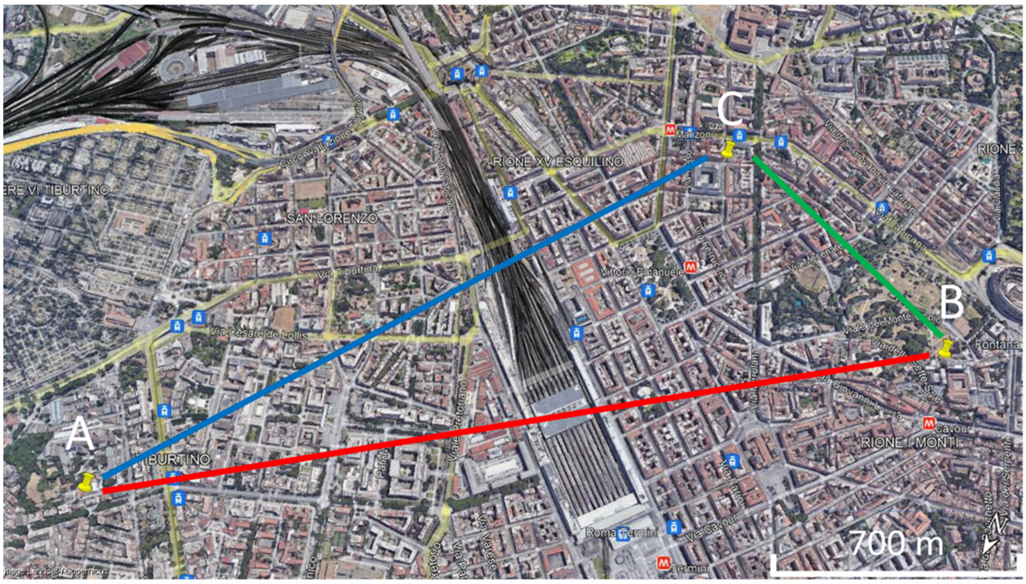


Figure 5. Location of the three departments under study from Google Earth.

In Figure 5, the distances (as the crow flies) among the three departments are, respectively: 5 km for the red line (A-B), 1.5 km for the green line (B-C), 3.5 km for the blue line (A-C). The feasibility of the activation of an e-mobility service between the three locations A, B and C is investigated. Sapienza University does not provide updated statistics about persons (employees and students) affected by disabilities presence. From an internal document [54], in the academic year 2012–2013, students with disabilities were about 1% of the overall enrolled students. Starting from this datum, an hourly transportation request for 10 people/hour has been estimated for the e-mobility service. A 20-year service operation is analyzed.

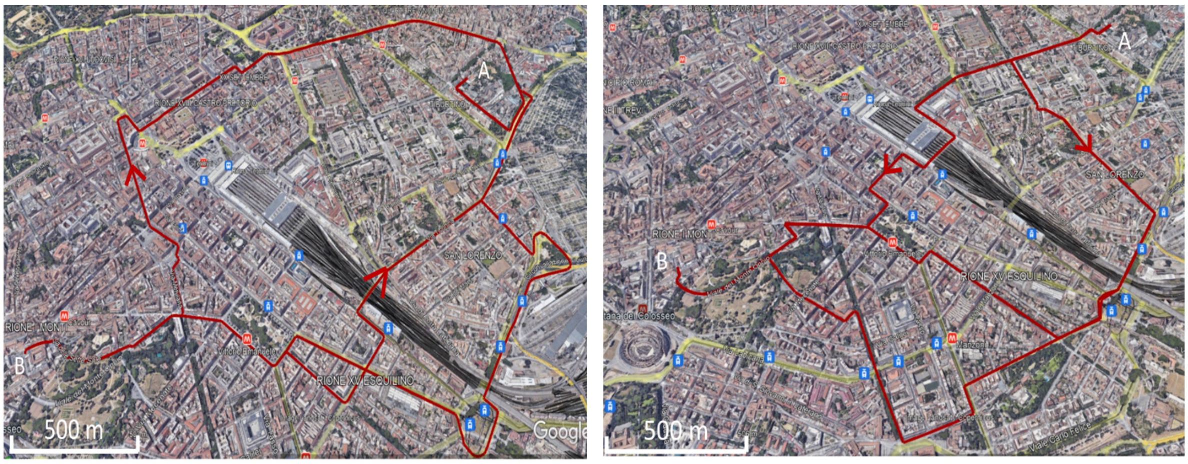
6. Simulation Results

At first, the developed software acquires relevant data of the infrastructure in the area of Rome object of the study and acquires the plano-altimetric profiles of point-to-point routes. A total of 14 routes connecting the three Engineering departments are identified:

- 3 routes between points B and A (route 1, route 2, route 3);
- 3 routes between A and B (route 4, route 5, route 6);
- 2 routes between A and C (route 7, route 8);
- 2 routes between C and A (route 9, route 10);
- 3 routes between B and C (route 11, route 12, route 13);
- 1 route between C and B (route 14).

Google Earth maps of the routes, distinguished according to the two points that interconnect and according to the running direction, are shown in Figures 6–8.

The main data of the plano-altimetric profiles, i.e., length, maximum and minimum slope, average bending radius, are summarized in Table 2. The lengths are in the range between 1.4 km and 5.7 km, with maximum and minimum slope ranging from 3.8% to 7.6% and from −8.1% to −3.5%, respectively. The average bending radius varies between 30 m and 276 m.



(**a**) (**b**)

Figure 6. Google Earth maps of point-to-point routes: (**a**) Routes between points B and A (route 1, route 2 and route 3); (**b**) Routes between points A and B (route 4, route 5 and route 6).

(**a**) (**b**)

Figure 7. Google Earth maps of point-to-point routes: (**a**) Routes between points A and C (route 4 and route 8); (**b**) Routes between points C and A (route 9 and route 10).

(**a**) (**b**)

Figure 8. Google Earth maps of point-to-point routes: (**a**) Routes between points B and C (route 11, route 12 and route 13); (**b**) Routes between points C and B (route 14).

Table 2. Main data of the plano-altimetric profiles.

Route ID	1 (B-A)	2 (B-A)	3 (B-A)	4 (A-B)	5 (A-B)	6 (A-B)	7 (A-C)
Length (km)	4.5	5.7	5.5	4.8	3.6	5	2.9
Max. Slope (%)	3.9	5.2	4.7	9	7.1	7.1	7.6
Min. Slope (%)	−4	−8.1	−5.5	−6.2	6.5	−5.9	−6.5
Average Bending Radius (m)	88	100	110	67	55	276	30
Route ID	**8 (A-C)**	**9 (C-A)**	**10 (C-A)**	**11 (B-C)**	**12 (B-C)**	**13 (B-C)**	**14 (C-B)**
Length (m)	3.7	3.7	5	1.5	1.4	1.5	1.4
Max. Slope (%)	7.1	3.8	4.7	3.9	3.9	5.5	4.9
Min. Slope (%)	−5.4	−3.5	−4.2	−4.4	−4.7	−6.3	−5.9
Average Bending Radius (m)	58	98	130	62	35	65	137

The tool then evaluates the dynamic and cinematic performances of all possible combinations of the four EV models along the 14 identified routes, calculating the relevant performance indicators (travel time, energy consumption, remaining SOC and energy). The best performances are obtained for EV—type C, whose performance indicators on all routes are reported in Table 3.

Table 3. Performance indicators of EV—type C.

Route ID	1 (B-A)	2 (B-A)	3 (B-A)	4 (A-B)	5 (A-B)	6 (A-B)	7 (A-C)
Travel Time (mm:ss)	18:55	21:18	21:27	15:53	15:05	23:25	13:41
Energy Consumption (kWh)	0.3502	0.4550	0.4311	0.4447	0.3574	0.5388	0.3401
Remaining SOC (%)	11.8133	11.6804	11.7072	11.6958	11.8069	11.5954	11.8333
Remaining Stored Energy (kWh)	77.21	76.34	76,52	76.44	77.17	75.79	77.34
Route ID	**8 (A-C)**	**9 (C-A)**	**10 (C-A)**	**11 (B-C)**	**12 (B-C)**	**13 (B-C)**	**14 (C-B)**
Travel Time (mm:ss)	13:35	16:10	15:39	08:35	08:33	09:23	07:51
Energy Consumption (kWh)	0.3662	0.2691	0.4312	0.1594	0.1427	0.1756	0.1595
Remaining SOC (%)	11.7965	11.9158	11.7162	12.0462	12.0663	12.0299	12.0521
Remaining Stored Energy (kWh)	77.10	77.88	76.58	78.73	78.86	78.63	78.77

According to the performance indicators, the software selects the optimal point-to-point routes. Naturally, routes characterized by lower travel time, energy consumption and a major remaining SOC at the end of the simulation are preferred to others. In the case of EV—type C, the optimal point-to-point routes are:

- A-B: routes 5 and 1;
- B-C: routes 12 and 14;
- A-C: routes 7 and 9.

For each connection, two routes are selected (one for each direction of travel) due to different road traffic. Some results of the dynamic and cinematic simulations for EV—type C are shown in Figures 9–11, which report speed, power, stored energy and remaining SOC profiles along routes 5, 12 and 9, respectively.

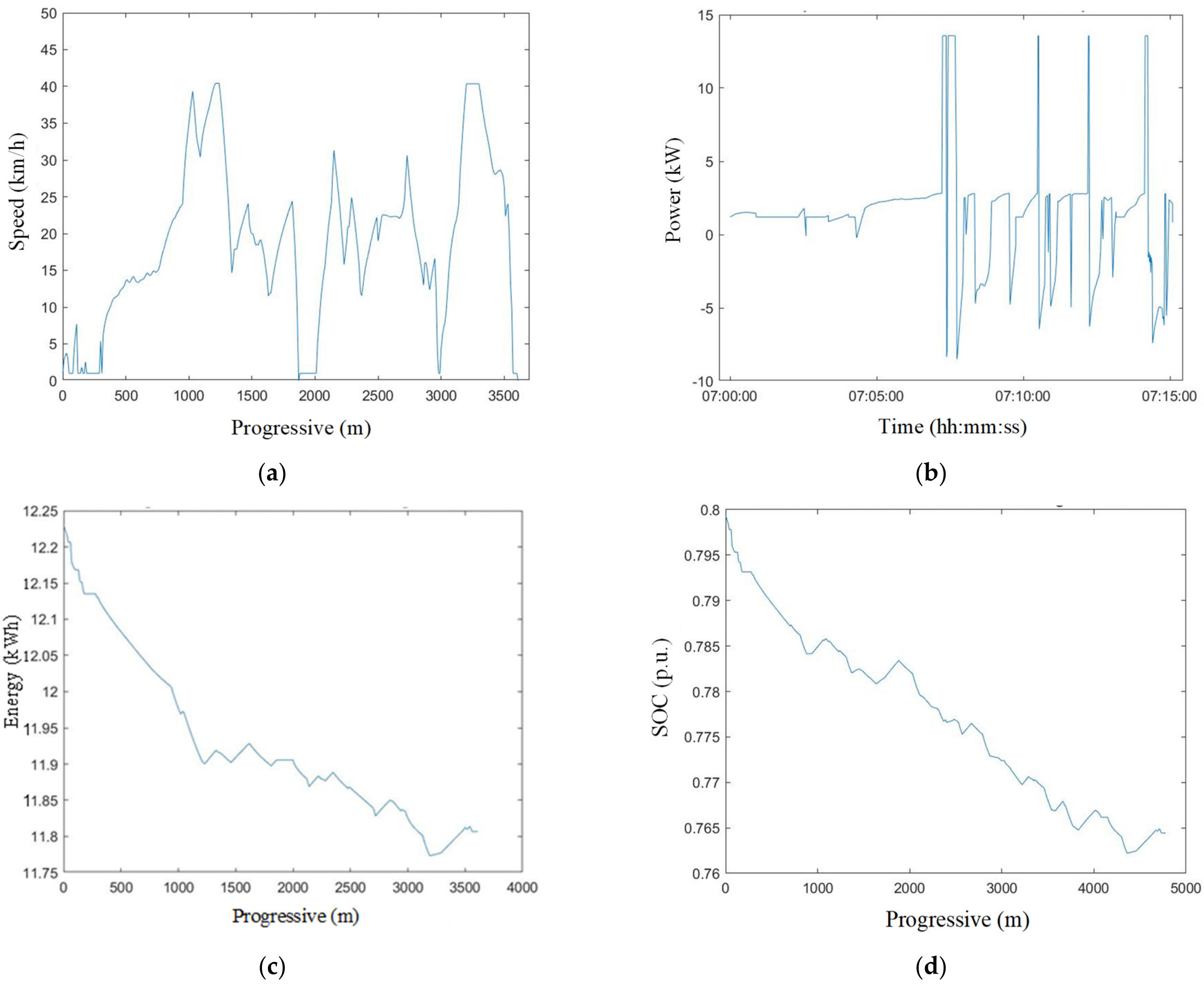


Figure 9. EV-type C performance along route 5: (**a**) Speed profile; (**b**) Power profile; (**c**) Energy profile; (**d**) SOC profile.

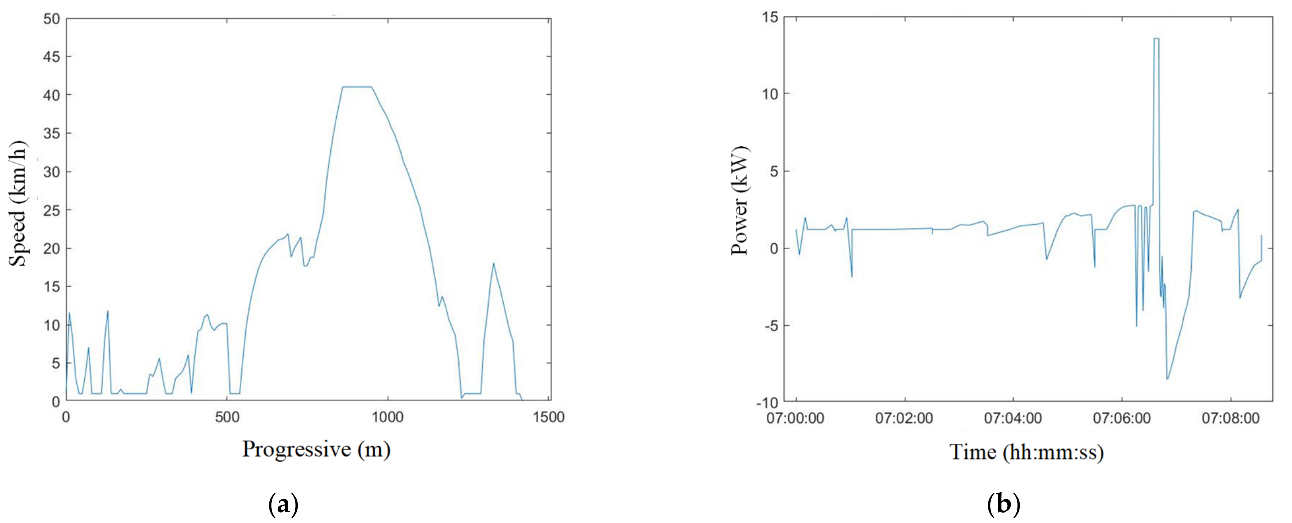
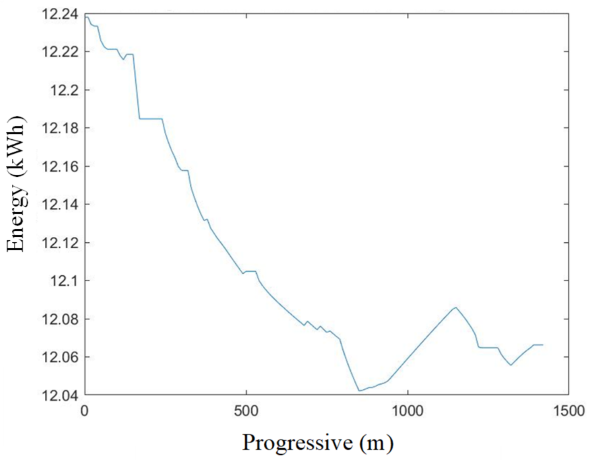
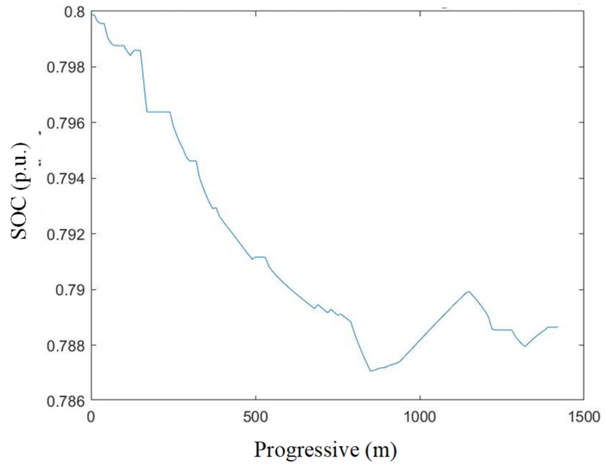


Figure 10. *Cont*.

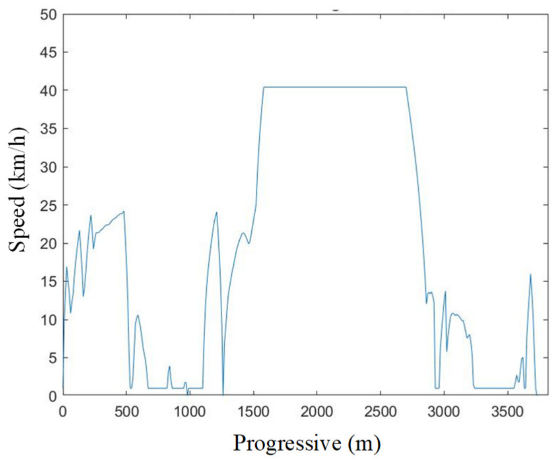


(**c**)

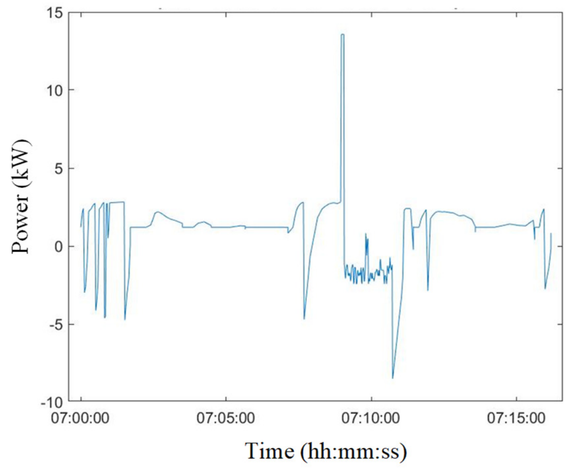


(**d**)

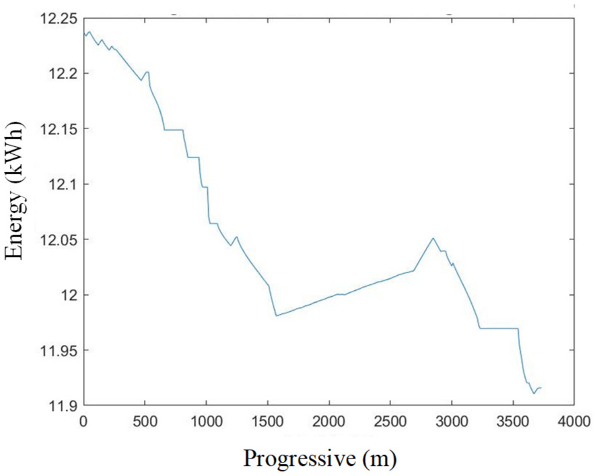
Figure 10. EV-type C performance along route 12: (**a**) Speed profile; (**b**) Power profile; (**c**) Energy profile; (**d**) SOC profile.



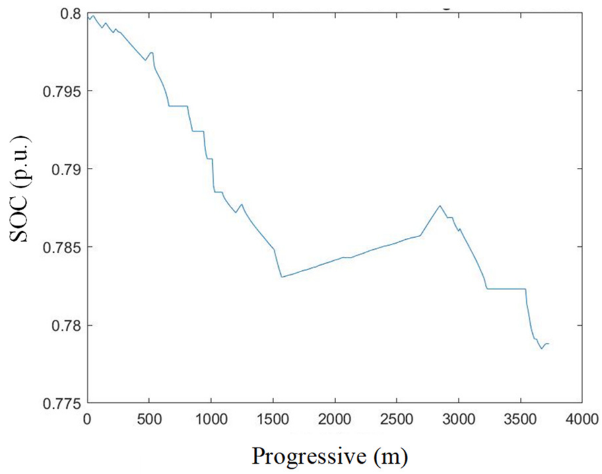
(**a**)



(**b**)



(**c**)



(**d**)

Figure 11. EV-type C performance along route 9: (**a**) Speed profile; (**b**) Power profile; (**c**) Energy profile; (**d**) SOC profile.

The profiles in Figures 9–11 seem reasonable; moreover, it is clear how the plano-altimetric characteristics of the routes influence dynamic and cinematic performances of the EV, as can be inferred from peaks and valleys of speed and power consumption profiles.

Three different possibilities for multi-point routes are then considered by the software:

- Clockwise solution, with a circular transportation service interconnecting points A, C, B;
- Anticlockwise solution, with a circular transportation service interconnecting points A, B, C;
- Round-route solutions, interconnecting only two locations.

The performance indicators of the point-to-point routes are used by the procedure to calculate global indicators of the multi-point routes in terms of travel time, energy consumption and remaining SOC. Figures 12–14 compare global indicators of each multi-point route in the case of EV—type C.

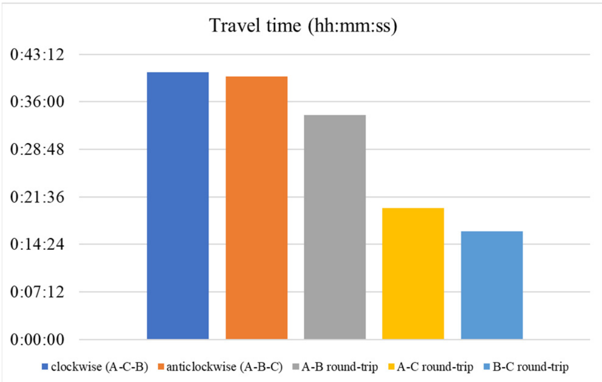


Figure 12. Travel time comparison of the multi-point routes.

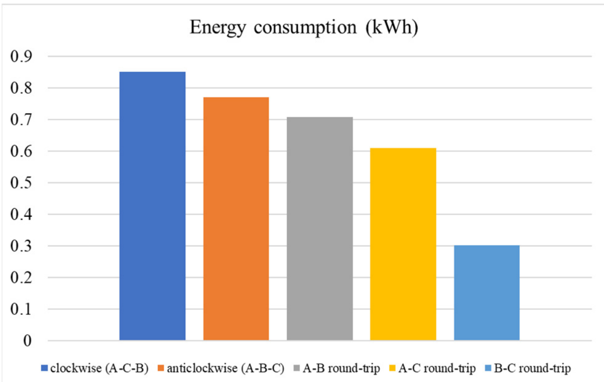


Figure 13. Energy consumption comparison of the multi-point routes.

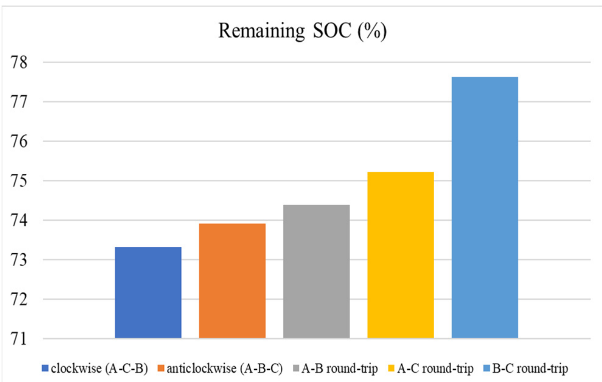


Figure 14. Remaining SOC comparison of the multi-point routes.

The comparisons highlight that the round-route solutions should be rejected. In fact, travel time of route A-B (about 34 min) is comparable to travel times of both clockwise and anticlockwise solutions (about 40 and 39 min, respectively). The energy consumption is also very similar: 0.71 kWh for route A-B, 0.85 kWh and 0.77 kWh for the clockwise and anticlockwise route, respectively. Similar considerations hold for the remaining SOC, which is 74.4% for A-B round route, and 73.3% and 73.9% for the other two solutions. Due to the fact that the point-to-point route A-B should be associated with the A-C and B-C point-to-point routes to provide the interconnections among the three departments, the round-trip solutions are rejected, considering the global performances. In summary, the anticlockwise solution, consisting of routes 5 (A-B), 12 (B-C) and 9 (C-A), is the optimal multi-point route for EV—type C.

In the last step of the methodology, the type and number of EVs to be purchased, as well as the number of annual charging sessions required for the service, are obtained. For the economic optimization, we considered the following CAPEX values: EUR 20,000 for EV—type A, EUR 6950 for EV—type B, EUR 39,000 for EV—type C, EUR 48,000 for EV—type D. The cost of electricity c_{EE} is EUR 0.25 /kWh for charging sessions, h = 10 and d = 305. The allowable SOC range of EV batteries is between 20 and 80%, with the aim to maintain a more reliable battery operation during the 20-year lifetime. The optimal solution found by the procedure consists of the operation of two EVs—type C and 305 charging sessions per year for each EV, i.e., one charging session every working day.

The choice to use only type C EVs is reasonable. Type A and type B EVs are indeed very limited regarding the number of seats and, therefore, are more adequate for a transportation service internal to a single faculty, whereas type C and type D EVs are naturally more suited for an hourly transportation service. The e-mobility service takes advantage of some charging stations already installed along or near the routes. Figure 15 depicts the optimal multi-point route and the location of such charging stations. The possibility to install additional EV charging points, for instance, on the premises of the Faculty, is another solution to be considered by Sapienza University.

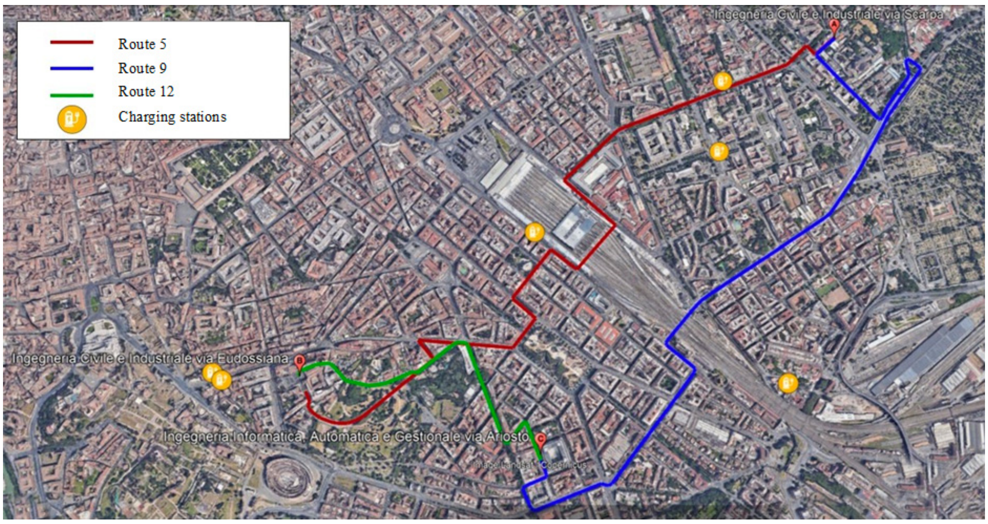


Figure 15. Google Earth map of the multi-point route selected by the software: route 5 in red; route 12 in green; route 9 in blue; charging stations installed near the route in yellow.

The summary of the feasibility study funded by Sapienza University of Rome is reported in Table 4.

The e-mobility service with two type C EVs has a total travel time of about 40 min, with the possibility to stop in each department at least for 5 min in order to take passengers on board. The energy consumption along the optimal multi-point route is about 0.79 kWh, with a SOC decrease of about 6%. In this regard, if the battery storage system of type C EV is fully charged at the beginning of the day (i.e., SOC = 80%), the daily operation is performed without interruptions until the end of the daily service (SOC = 20%), and the battery is recharged after the end of the service.

Table 4. e-mobility service results.

e-Mobility Service			
Hourly Number of Persons Affected by Disabilities	10	**Travel Time (mm:ss)**	39:48
Energy Consumption (kWh)	0.79	**SOC Decrease (%)**	6.1
EV Type	C	**CAPEX (EUR)**	78,000
Number of EVs	2	**OPEX (EUR/year)**	504.9
Optimal Multi-Point Route	Anticlockwise Solution		
Optimal Point-to-Point Routes	5 (A-B) 12 (B-C) 9 (C-A)		

7. Conclusions

This paper proposes a 5-step methodology for the feasibility study of an e-mobility service for people with disabilities, taking into account sustainable and environmental requirements. The methodology is the result of a research project, funded by the Sapienza University of Rome, with the aim to remove social and infrastructural barriers for disabled people, while at the same time promoting energy transition to electric mobility development. In the paper, the case study of three departments of the Faculty of Civil and Industrial Engineering, located in different areas of the city of Rome, is presented and discussed. Starting from all possible existing routes interconnecting the departments, the optimal ones are selected in order to reduce energy consumption and CO_2 emissions. Different commercial models of EVs for disabled people are simulated from a dynamic and cinematic point of view along the routes. A MATLAB-based tool is deployed to automate the methodology, thus ensuring the possibility to apply the proposed methodology to other case studies. An optimization problem, modeled as a MILP problem, is also solved to identify the number and type of EVs needed for the operation. The feasibility study shows that two EVs are able to guarantee an hourly service line between the three departments, with only one charging session every day for each EV. The service ensures the transport of 10 disabled people each hour, with a global travel time of about 40 min (excluding the stop delays) and a total energy consumption of about 0.79 kWh. From a business plan point of view, an investment of EUR 78,000 is required, with an annual operative cost of about EUR 505.

Many universities and cities around the world are facing the increasing requirements aimed at removing social and infrastructural barriers for ensuring disabled people have the proper support; at the same time, the environmental needs call for a revolution in the transport sector. The integration of energetic optimization tools with electric mobility could be a very attractive solution, both from a political and a social point of view.

Author Contributions: Conceptualization, F.C. and A.G.; Data curation, N.M.; Funding acquisition, M.M.; Investigation, A.R. and F.M.G.; Methodology, M.M., F.C., F.M.G. and A.G.; Software, M.M., F.C. and N.M.; Supervision, F.M.G. and A.G.; Validation, R.L. and A.R.; Writing—original draft, R.L. and A.R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Sapienza University of Rome, grant number RM11916B4744828C.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

Acronyms	
CS	Charging Stations
DN	Distribution Network
EV	Electric Vehicle
GHG	Greenhouse Gas
SOC	State of Charge
Indices	
i	Index of progress of the route
j	Index of braking phase
k	Index of EV type
m	Index of multi-point route
p	Index of point-to-point route
Variables	
$a_{i,k}$	Acceleration
$a_{i,k}^{TOT}$	Total acceleration
br_i	Bending radius
c_i^{gal}	Gallery coefficient
$c_{i,k}^{rm}$	Rotating mass coefficient
$E_{i,k}$	Energy consumption
$F_{i,k}^t$	Available tractive force
$F_{i,k}^a$	Applied tractive force
$M_{i,k}^{eq}$	Vehicle equivalent mass
n_k	Number of type k vehicles
$P_{i,k}$	Power consumption
$P_{i,k}^{aux}$	Auxiliaries' power
$R_{i,k}^{ae}$	Aerodynamic resistance
$R_{i,k}^{bending}$	Bending resistance
$R_{i,k}^{slope}$	Slope resistance
RC_k	Number of charging sessions of type k vehicle in 20 years
S_i	Slope
$SOC_{i,k}$	Vehicle SOC
SOC_k^{ini}	Vehicle initial SOC
$SOC_{i,k}^{fin}$	Vehicle final SOC
$v_{i,k}$	Vehicle speed
$x_{i,k}$	Progress of the route
ΔSOC_k	SOC decrease in EV type k
$\Delta t_{i,k}$	Time interval to move from section $i-1$ to section i
Δt_p^{tot}	Travel time of point-to-point route p
Constants	
A_k	Autonomy of type k vehicle
b_1, b_2	Empirical coefficients for aerodynamic resistance
b_3, b_4	Empirical coefficients for bending resistance
$br_p^{average}$	Average bending resistance of point-to-point route p
$CAPEX_k$	CAPEX of type k vehicle
c_{EE}	Cost of electricity (EUR /kWh)
d	Number of days of service activation per one year
h	Number of daily hours of service activation
η_k	Vehicle efficiency
E_k^n	Rated capacity of the vehicle battery storage system
E_k^0	Initial energy stored in the vehicle battery storage system
F_k^{start}	Vehicle start-up tractive force
F_k^{full}	Vehicle full tractive force
L_p	Point-to-point route p length

M_k	Vehicle mass
$n_{k,seats}$	Number of available seats of type k vehicle
P_k^{full}	Vehicle rated engine power
s	Hourly number of people with disabilities to be transported
S_k^{max}	Vehicle maximum slop
S_p^{max}	Point-to-point route maximum slop
S_p^{min}	Point-to-point route minimum slop
v_k^{full}	Vehicle full speed

References

1. Deloitte Electric Vehicles—Setting a Course for 2030. Available online: https://www2.deloitte.com/uk/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html (accessed on 11 March 2022).
2. Carere, F.; Bragatto, T.; Santori, F. A Distribution Network during the 2020 COVID-19 Pandemic. In Proceedings of the 2020 AEIT International Annual Conference (AEIT), Catania, Italy, 23–25 September 2020; pp. 1–6. [CrossRef]
3. Miskolczi, M.; Földes, D.; Munkácsy, A.; Jászberényi, M. Urban mobility scenarios until the 2030s. *Sustain. Cities Soc.* **2021**, *72*, 103029. [CrossRef]
4. European Parliament. Directive (EU) 2019/882 of the European Parliament and of the Council of 17 April 2019 on the Accessibility Requirements for Products and Services. 2019. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0882&from=EN (accessed on 11 March 2022).
5. Cornell University. Transportation Accommodations. Available online: https://sds.cornell.edu/accommodations-services/transportation (accessed on 11 March 2022).
6. University of Pittsburgh. DisAbility Shuttle. Available online: https://www.pts.pitt.edu/mobility/shuttle-services/disability-shuttle (accessed on 11 March 2022).
7. University of Edinburgh. Disabled Users. Available online: https://www.ed.ac.uk/transport/parking/disabledusers (accessed on 11 March 2022).
8. University of Granada. Disability Support. Available online: https://www.ugr.university/pages/campuslife_outreach/disabilityservices (accessed on 11 March 2022).
9. University of Pavia. Linee Guida per il Servizio di Accompagnamento e Trasporto Degli Studenti con Disabilità (In Italian). Available online: https://saisd.unipv.it/wp-content/uploads/linee-guida-.pdf (accessed on 11 March 2022).
10. University of Turin. Accompagnamento Fisico Presso le Strutture Universitarie. Available online: https://www.unito.it/servizi/lo-studio/studenti-con-disabilita/servizi-offerti-agli-studenti-con-disabilita-0 (accessed on 11 March 2022).
11. Cattolica University. Services for the Integration of Students with Disabilities and DSA. Available online: https://studenticattolica.unicatt.it/studenti-campus-life-copia-di-servizi-per-l-integrazione-degli-studenti-con-disabilita-e-con-dsa (accessed on 11 March 2022).
12. University of Bologna. Servizio per gli Studenti con Disabilità e con DSA. Available online: http://www.studentidisabili.unibo.it/servizi-agli-studenti/frequentare (accessed on 11 March 2022).
13. Cordeau, J.-F.; Laporte, G.; Savelsbergh, M.W.; Vigo, D. Chapter 6 Vehicle Routing. In *Handbooks in Operations Research and Management Science*; Cynthia, B., Gilbert, L., Eds.; Elsevier: Amsterdam, The Netherlands, 2007; Volume 14, pp. 367–428. ISSN 0927-0507/9780444513465. [CrossRef]
14. Jahic, A.; Plenz, M.; Eskander, M.; Schulz, D. Route Scheduling for Centralized Electric Bus Depots. *IEEE Open J. Intell. Transp. Syst.* **2021**, *2*, 149–159. [CrossRef]
15. Yang, H.; Yang, S.; Xu, Y.; Cao, E.; Lai, M.; Dong, Z.Y. Electric Vehicle Route Optimization Considering Time-of-Use Electricity Price by Learnable Partheno-Genetic Algorithm. *IEEE Trans. Smart Grid* **2015**, *6*, 657–666. [CrossRef]
16. Chen, T.; Zhang, B.; Pourbabak, H.; Kavousi-Fard, A.; Su, W. Optimal Routing and Charging of an Electric Vehicle Fleet for High-Efficiency Dynamic Transit Systems. *IEEE Trans. Smart Grid* **2016**, *9*, 3563–3572. [CrossRef]
17. Li, H.; Li, Z.; Cao, L.; Wang, R.; Muren, M. Research on Optimization of Electric Vehicle Routing Problem with Time Window. *IEEE Access* **2020**, *8*, 146707–146718. [CrossRef]
18. Bac, U.; Erdem, M. Optimization of electric vehicle recharge schedule and routing problem with time windows and partial recharge: A comparative study for an urban logistics fleet. *Sustain. Cities Soc.* **2021**, *70*, 102883. [CrossRef]
19. Yang, H.; Deng, Y.; Qiu, J.; Li, M.; Lai, M.; Dong, Z.Y. Electric Vehicle Route Selection and Charging Navigation Strategy Based on Crowd Sensing. *IEEE Trans. Ind. Inform.* **2017**, *13*, 2214–2226. [CrossRef]
20. Kasani, V.S.; Tiwari, D.; Khalghani, M.R.; Solanki, S.K.; Solanki, J. Optimal Coordinated Charging and Routing Scheme of Electric Vehicles in Distribution Grids: Real Grid Cases. *Sustain. Cities Soc.* **2021**, *73*, 103081. [CrossRef]
21. Shahkamrani, A.; Askarian-Abyaneh, H.; Nafisi, H.; Khorsandi, A.; Marzband, M. An Innovative Method for Route Mapping of Battery Electric Vehicles. In Proceedings of the 2019 Smart Grid Conference (SGC), Tehran, Iran, 18–19 December 2019; pp. 1–5. [CrossRef]
22. Yang, Z.; Guo, T.; You, P.; Hou, Y.; Qin, S.J. Distributed Approach for Temporal–Spatial Charging Coordination of Plug-in Electric Taxi Fleet. *IEEE Trans. Ind. Inform.* **2019**, *15*, 3185–3195. [CrossRef]
23. Frendo, O.; Gaertner, N.; Stuckenschmidt, H. Open Source Algorithm for Smart Charging of Electric Vehicle Fleets. *IEEE Trans. Ind. Inform.* **2021**, *17*, 6014–6022. [CrossRef]

24. Li, Z.; Guo, Q.; Sun, H.; Xin, S.; Wang, J. A New Real-Time Smart-Charging Method Considering Expected Electric Vehicle Fleet Connections. *IEEE Trans. Power Syst.* **2014**, *29*, 3114–3115. [CrossRef]
25. Pardo-Bosch, F.; Pujadas, P.; Morton, C.; Cervera, C. Sustainable deployment of an electric vehicle public charging infrastructure network from a city business model perspective. *Sustain. Cities Soc.* **2021**, *71*, 102957. [CrossRef]
26. Gatta, F.M.; Geri, A.; Maccioni, M.; Carere, F.; Abbafati, M.; Paulucci, M.; Bragatto, T. E-mobility Hosting Capacity assessment in Terni distribution network. In Proceedings of the 2021 IEEE International Conference on Environment and Electrical Engineering and 2021 IEEE Industrial and Commercial Power Systems Europe (EEEIC/I&CPS Europe), Bari, Italy, 7–10 September 2021; pp. 1–6. [CrossRef]
27. Carere, F.; Gatta, F.; Geri, A.; Maccioni, M.; Bragatto, T.; Cresta, M.; Paulucci, M.; Santori, F. Electric Vehicle Charging Rescheduling to Mitigate Local Congestions in the Distribution System. In Proceedings of the 2021 IEEE Madrid PowerTech, Madrid, Spain, 28 June–2 July 2021; pp. 1–6. [CrossRef]
28. Lamedica, R.; Maccioni, M.; Ruvio, A.; Ribeiro, P.F. EVs recharging management to maintain high PQ levels in LV islanded networks. In Proceedings of the 2018 18th International Conference on Harmonics and Quality of Power (ICHQP), Ljubljana, Slovenia, 13–16 May 2018; pp. 1–6. [CrossRef]
29. Gatta, F.M.; Geri, A.; Lamedica, R.; Maccioni, M.; Ruvio, A. PQ and hosting capacity issues for EV charging systems penetration in real MV/LV networks. In Proceedings of the 2016 Power Systems Computation Conference (PSCC), Genoa, Italy, 20–24 June 2016; pp. 1–7. [CrossRef]
30. LaMedica, R.; Geri, A.; Gatta, F.M.; SanGiovanni, S.; Maccioni, M.; Ruvio, A. Integrating Electric Vehicles in Microgrids: Overview on Hosting Capacity and New Controls. *IEEE Trans. Ind. Appl.* **2019**, *55*, 7338–7346. [CrossRef]
31. Thibault, L.; De Nunzio, G.; Sciarretta, A. A Unified Approach for Electric Vehicles Range Maximization via Eco-Routing, Eco-Driving, and Energy Consumption Prediction. *IEEE Trans. Intell. Veh.* **2018**, *3*, 463–475. [CrossRef]
32. ABozorgi, A.M.; Farasat, M.; Mahmoud, A. A Time and Energy Efficient Routing Algorithm for Electric Vehicles Based on Historical Driving Data. *IEEE Trans. Intell. Veh.* **2017**, *2*, 308–320. [CrossRef]
33. Galatoulas, N.-F.; Genikomsakis, K.N.; Ioakimidis, C.S. Analysis of potential demand and costs for the business development of an electric vehicle sharing service. *Sustain. Cities Soc.* **2018**, *42*, 148–161. [CrossRef]
34. Shi, J.; Gao, Y.; Wang, W.; Yu, N.; Ioannou, P.A. Operating Electric Vehicle Fleet for Ride-Hailing Services with Reinforcement Learning. *IEEE Trans. Intell. Transp. Syst.* **2019**, *21*, 4822–4834. [CrossRef]
35. Mehar, S.; Zeadally, S.; Remy, G.; Senouci, S.M. Sustainable Transportation Management System for a Fleet of Electric Vehicles. *IEEE Trans. Intell. Transp. Syst.* **2014**, *16*, 1401–1414. [CrossRef]
36. Peres, L.A.P.; Pessanha, J.F.M.; Particelli, F.D.M.F.; Caldas, A.C.I.L.; Serra, J.V. Analysis of the Use of Electric Vehicles by Electric Utility Companies Fleet in Brazil. *IEEE Lat. Am. Trans.* **2011**, *9*, 1032–1039. [CrossRef]
37. Fanti, M.P.; Mangini, A.M.; Pedroncelli, G.; Ukovich, W. Fleet Sizing for Electric Car Sharing Systems in Discrete Event System Frameworks. *IEEE Trans. Syst. Man, Cybern. Syst.* **2017**, *50*, 1161–1177. [CrossRef]
38. Calise, F.; Fabozzi, S.; Vanoli, L.; Vicidomini, M. A sustainable mobility strategy based on electric vehicles and photovoltaic panels for shopping centers. *Sustain. Cities Soc.* **2021**, *70*, 102891. [CrossRef]
39. Liberto, C.; Valenti, G.; Orchi, S.; Lelli, M.; Nigro, M.; Ferrara, M. The Impact of Electric Mobility Scenarios in Large Urban Areas: The Rome Case Study. *IEEE Trans. Intell. Transp. Syst.* **2018**, *99*, 3540–3549. [CrossRef]
40. Nissan eNV-200, More Details. Available online: https://www.brotherwood.com/wheelchair-accessible-vehicles/electric-wheelchair-accessible-vehicle-nissan-env-200/ (accessed on 11 March 2022).
41. Volkswagen Caddy Maxi Disability Car. Available online: https://www.b-style.eu/disability-car-wav/volkswagen/caddy-maxi (accessed on 11 March 2022).
42. Automated and Electric Vehicles Act 2018, UK. Available online: https://www.legislation.gov.uk/ukpga/2018/18/contents/enacted (accessed on 11 March 2022).
43. Video-Kenguru Yellow: L'auto che può Cambiare la vita dei Disabili. Available online: www.napolitan.it/2017/08/17/67704/kenguruyellow/ (accessed on 11 March 2022).
44. Scooter Elettrico Tandem. Available online: www.mobilitycenter.it/ausili-disabili/scooter-per-disabilianziani/scooter-elettrico-tandem-due-posti/ (accessed on 11 March 2022).
45. GECO BB Navetta. Available online: https://esagonoenergia.com/home-page-v7/navetta-geco/ (accessed on 11 March 2022).
46. Allestimento Veicoli per Trasporto Disabili. Available online: https://www.imobility.eu/trasporto-disabili/ (accessed on 11 March 2022).
47. Lamedica, R.; Gatta, F.M.; Maccioni, M.; Mortelliti, N.; Ruvio, A. E-mobility for persons with disabilities: A project for the Sapienza University of Rome. In Proceedings of the International Conference on Electrical and Electronic Technologies for Automotive, Torino, Italy, 17–19 November 2021.
48. Lamedica, R.; Ruvio, A.; Palagi, L.; Mortelliti, N. Optimal Siting and Sizing of Wayside Energy Storage Systems in a D.C. Railway Line. *Energies* **2020**, *13*, 6271. [CrossRef]
49. YALMIP Package. Documentation. Available online: https://yalmip.github.io/ (accessed on 11 March 2022).
50. IBM ILOG CPLEX Optimization Studio V12.10. Documentation. Available online: https://www.ibm.com/uk-en/products/ilog-cplex-optimization-studio (accessed on 11 March 2022).

51. ARTU Top 400 Ranked Global Universities in 2021. Available online: https://research.unsw.edu.au/artu/artu-results (accessed on 11 March 2022).
52. Sapienza University of Rome. Information. Available online: https://www.uniroma1.it/en/pagina/about-us (accessed on 11 March 2022).
53. "Share Now" Car Sharing: Special Offers for Sapienza Students. More Information. Available online: https://www.uniroma1.it/en/notizia/bonus-studenti-il-car-sharing-share-now-0 (accessed on 11 March 2022).
54. Servizi per gli Studenti Disabili—Relazione del Nucleo di Valutazione d'Ateneo (In Italian). Available online: www.uniroma1.it/sites/default/files/estratti/presaattostudenti11_2_05_12_2013.pdf (accessed on 11 March 2022).