Smart Transportation Alliance

Deploying light electric vehicles (EL-Vs) in transportation infrastructures

Data analysis and conclusions from the EU-funded ELVITEN R&D project

DISCUSSION PAPER 1/2020

December 2020

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Author

Friederike Lena Kühl
Operations Manager, Etelätär Innovation OÜ
STA Programmes Coordinator

Francisco Aletta
Innovation Manager, Etelätär Innovation OÜ
STA Technical Coordinator

Contributors

Mr. José F. Papí
Founder & Chief Executive Officer, Etelätär Innovation OÜ
STA President

1. Introduction

The **ELVITEN**[1] project is an EU-funded research and development project, which has spanned from November 2017 to October 2020.

The project's objectives were to enhance user's awareness about **light electric vehicles (EL-Vs),** generate guidelines for vehicles manufacturers and authorities for the better integration of such vehicles in the transportation and electricity networks and thus ensure their wider market uptake. Although EL-Vs are relatively common in the United States and many Asian countries, their wide market uptake in Europe has been held off. The ELVITEN partners explored, wherever EL-Vs could represent a suitable alternative to established modes of transportation for urban environments in Europe, and furthermore, how they could be best integrated into existing infrastructures.

For this purpose, the 21 ELVITEN partners completed a series of demonstrations with 223 EL-Vs of different categories in six European cities: Berlin (Germany), Trikala (Greece), Málaga (Spain), and Genoa, Roma and Bari (Italy). The ELVITEN demonstrations started in April 2019 and were completed on 30 June 2020. A consortium of 21 partners participated in the project, coordinated by ICCS (Greece).

Electric light vehicles are defined as L Category according to Directives of the European Parliament and of the Council 2002/24/EC[2] of 18 March 2002 and 2007/46/EC[3] of 5 September 2007. EL-Vs support the user with more electric power than common small electric vehicles such as "regular" e-scooters or e-bikes (limited at 250 W) but weighs far less than an electric car, placing them into a unique position with few competitors on the market.

The ELVITEN project focused on 4 types of EL-Vs:

- L1e-A (electric powered cycle)
- L1e-B (two-wheeled moped)
- L5e-A (tricycle)
- L6e-B (light four-wheelers)

Figure 1 ELVITEN EL-Vs and e-hubs

[1] https://www.elviten-project.eu/en/
[2] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32002L0024
[3] https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32007L0046

During the project, the consortium has analysed the users' behaviour and opinions by means of data collection from multiple sources:

- User's background questionnaires (user age, type, gender, occupation)
- ICT tools (duration, purpose of the trip, type of EL-V)
- Vehicle telemetry collected by "Black Box" devices (speed, trip distance, geolocation)
- Charging behaviour (State of Charge, SoC)

The aim was to get a clear indication on the general acceptance of these vehicles in order to identify current shortcomings in the current offerings on the market and propose crucial improvements to infrastructures and the overall promotion of EL-Vs to increase the general uptake and acceptance of EL-Vs. The ELVITEN project represents the largest amount of data collected on EL-Vs, since past research and investigations have been but singular and focussed snapshots and did not include long-term observations. The partners were able to collect 1.5 Gb of detailed data of a total of **38,866 trips** and concluded with a comprehensive report and dashboard cross-matching the following data sets together:

- **9,712** values from background data (age, gender occupation)
- **660,722** different trip values (user, trip time, trip purpose, trip distance, etc.)
- **219.8** million telemetry values from "Black Boxes"

This Discussion Paper presents and overview and key conclusions of this project. Section 2 briefly describes the methodology followed. Sections 3-5 of the present Discussion Paper documents the key findings on the different aspects of the project while section 6 provides some insight into the consequential conclusions.

Annex 1 contains a selection of the most relevant and resounding graphs resulting from the demonstrations.

2. Methodology

The large quantity of data accumulated required a potent tool in order to successfully perform an analysis. Data from different sources had to be integrated, unified and cross-matched (data from trips and questionnaires). The partners used both the server and desktop version of the data visualisation platform *Tableau*. This methodology guaranteed that data quality and analysis were the best possible taking into account the means available within this project.

In order to eliminate faulty data, which could affect the final analysis, a process to clear the available data has been applied. This cleaning process differed according to the data source. A **z-scores analysis** has been performed to identify and eliminate data, which deviated too highly from reasonable results, and therefore had to be considered irregular. A **map-matching algorithm** has been applied to correct the recorded trip routes of the Black Boxes' GPS signals. The Map-Matching consists of pinning GNSS positions to a digital road map and align the line-string with the most probable path that the vehicle has followed (e.g. existing road).

The main tool used by the project partners to share and monitor the collected data is the **ELVITEN Dashboard**. This dashboard collected all of the existing data in the Data Warehouse and is available to all partners to download in different file format such as Excel, json or csv text files. The dashboard has been particularly helpful during the implementation period of the project and in order to execute the final analysis of all data.

Simultaneously to the city demonstrations, the partners downloaded and verified all data collected on a regular basis to make sure that the data collection process was conducted correctly and to check the data's quality.

This monitoring led to the early identification and correction of several issues, both technical and operational, which was crucial to ensure the high quality and consistency of the data collected.

Figure 2 Tableau Dashboard used in ELVITEN

3. User types and -behaviours

Cross-matching the available data resulted in several impressive insights on the behaviour of EL-V users.

One important characteristic of the ELVITEN demonstrations is that most trips (**93.83%**) were undertaken by **regular users**, which was also the group which delivered the most valuable insights into day-to-day patterns in real life. On the other hand, occasional users (05.60%) and testers (00.57%) tend to display irregular behaviours due to their unfamiliarity with the use of the vehicles.

Table 1 Trip distribution by user type

User type	Total trips %	Av. Distance (Km)	User Count	Trip Count	Average
Type User Regular	93.83%	4.93	267	37,312	89.6
Type User Occasional	5.60%	4.95	135	1,739	10.6
Type User Tester	0.57%	9.07	110	175	1.3

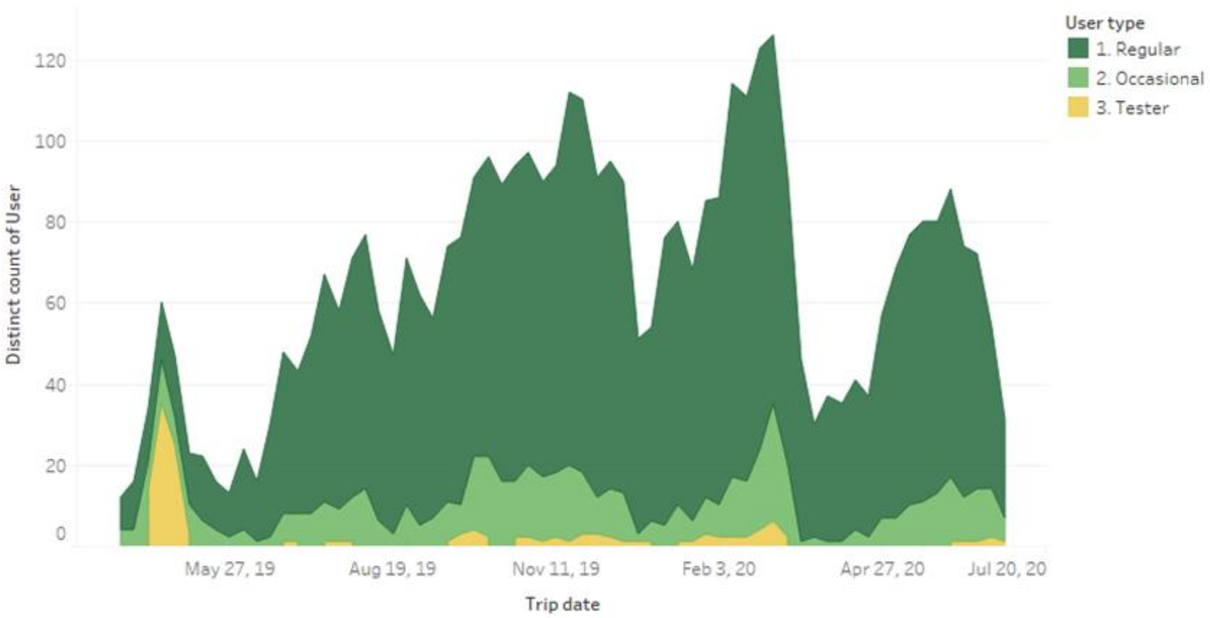

Figure 3 Type of user's activity during the demonstrations

It should also be noted that most of the users (71.26%) were between 30 and 59 years of age, followed by the age group of 18-29-year olds.

Table 2 Trip by user age group

Age	Trip Distribution	AV. Distance	Count (users)	Count (trips)	Average
Age 18-29	23.58%	4.84	141	6,012	42.6
Age 30-59	71.26%	4.54	347	18,173	52.4
Age 60+	4.96%	4.89	25	1,265	50.6
Under 18	0.20%	2.26	3	51	17.0

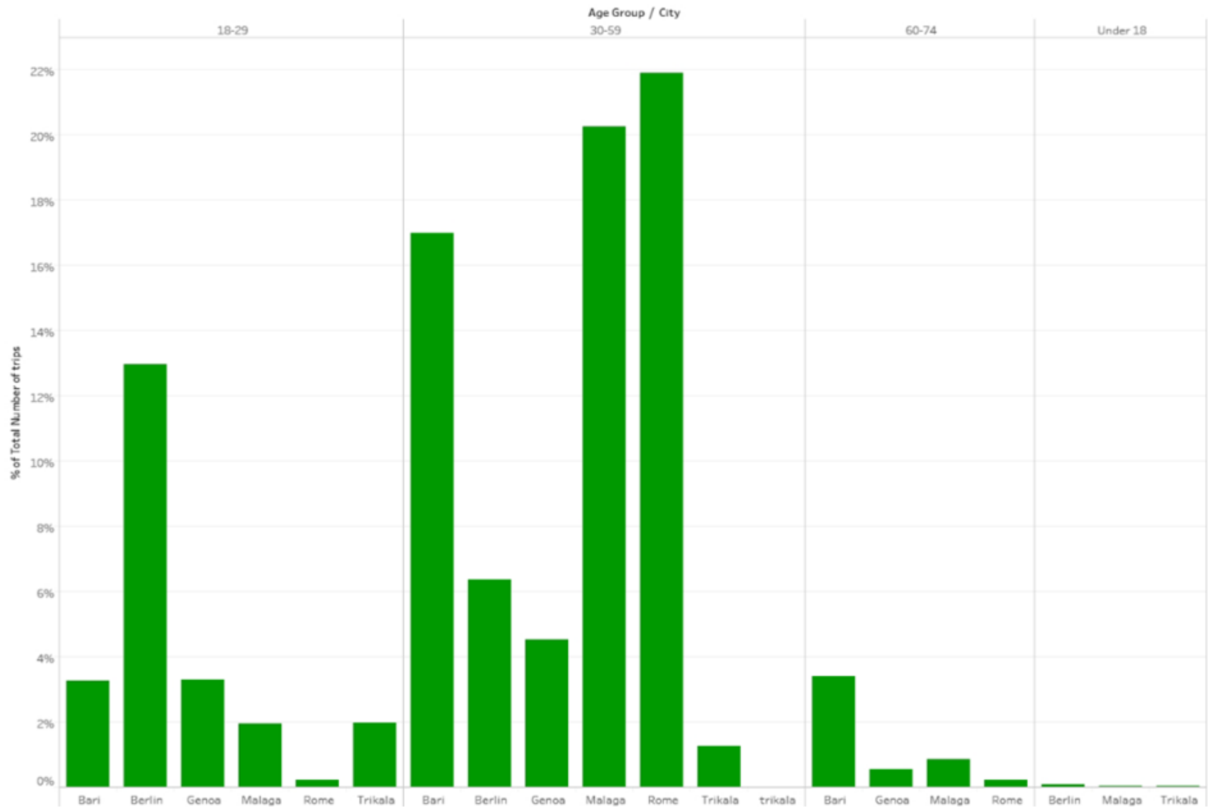

Figure 4 Trips by age group and city

Finally, most of the users were **full-time employees**. These users performed **75.07%** of all trips recorded, which leads to the assumption that they mainly used the EL-Vs to commute to their place of work. Other types of employment included students (11.18%), part-time employed, unemployed and retired.

ELVITEN project also introduced two indicators that have not been studied before in similar projects: **user gender** and **trip purpose**. This allowed the consortium to enlarge the scope of the analysis and obtain some interesting insights.

Table 3 Trip distribution by gender

User Gender	Total trips %	AV. Distance (Km)	User Count	Trip Count	Average
Female	16.37%	4.93	165	4,174	25.3
Male	82.78%	4.95	347	21,110	60.8
Prefer not to say	0.85%	3.86	5	219	43.4

Male users recorded the majority of trips (82.78% of total trips), with a higher average of trips per user than female users (60.8 and 25.3 respectively). The average distance of trips taken by men and women is very similar across any gender. A small percentage of ELVITEN users preferred not to specify their gender. These users performed trips with a much shorter average distance.

Table 4 Trip distribution by purpose

Trip Purpose	Total trips %	AV. Distance (Km)	Trip Count
Charging the vehicle	0.20%	9.039	13
Delivering goods	0.29%	4.818	19
Just to try the shared EL-V curiosity	1.01%	5.880	65
Leisure/entertainment or visit (family/friends)	23.03%	6.526	1,486
Shopping	9.19%	3.774	593
Work/education	66.27%	4.990	4,276

The information of the purpose of each trip is crucial to understand the trip behaviour. Most trips recorded in ELVITEN (66.27%) are related to work and education purposes such as attending to work, university, etc. This information is consistent with the use cases observed in most demonstration cities. Leisure trips have a longest average distance, of around 6.5 Km. It is worth noticing that trips for leisure were completed more frequently during and after the COVID-19 lockdown than during the rest of the demonstrations.

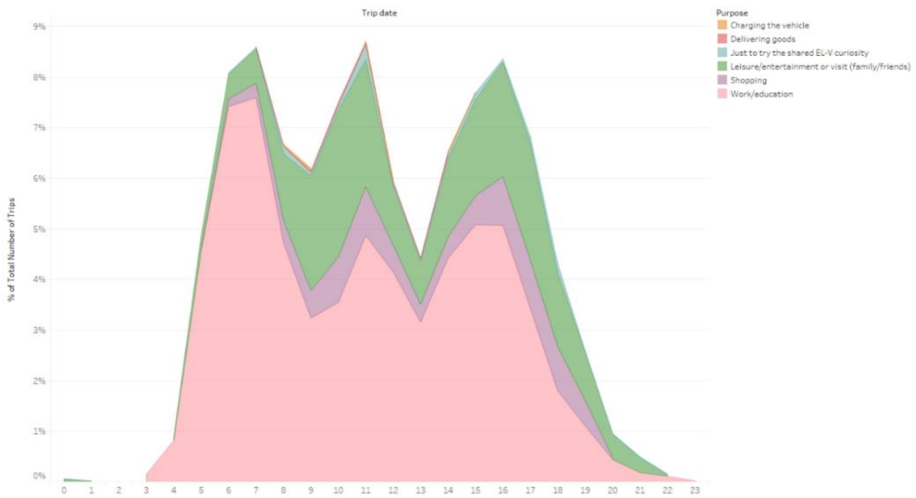

Figure 5 Trip purpose by hour

4. Vehicle types and charging behaviour

The average distance travelled differed between the various types of vehicles, rendering them viable for different kinds of transportation modes and commuting distances. Other factors such as comfort, affordability, status or environmental friendliness also played a considerable role.

Table 5 Daily distance travelled per vehicle type

Vehicle type / Vehicle code-name	EL-V				Electric Car
	L1e-A	L1e-B	L5e-A	L6e-B	E-V
Daily distance travelled (Km)	20.37	16.37	16.5	17.42	15.67

The **average trip distance** was **18.87 Km**, which is quite far in comparison to other light vehicles. The partners found that this is probably due to the low operation cost (keeping in mind parking fees as well as the high cost of fossil fuels).

Interestingly, charging patterns revealed useful insight into the infrastructural requirements for EL-Vs: most of the vehicles were charged at night at the user's home using their private electricity outlets as well as during the day at their place of work. This indicates that opposite to previous belief**, no specific and dedicated charging stations are needed** to ensure the wider uptake of EL-Vs.

Most of the cities peaked in October-November 2019 and in February 2020. Other remarkable anomalies can be explained by the usual decrease in activity for short-distance mobility activities during the Christmas holidays and a stark increase of usage in May 2020 as a consequence of the lifted lockdown restrictions.

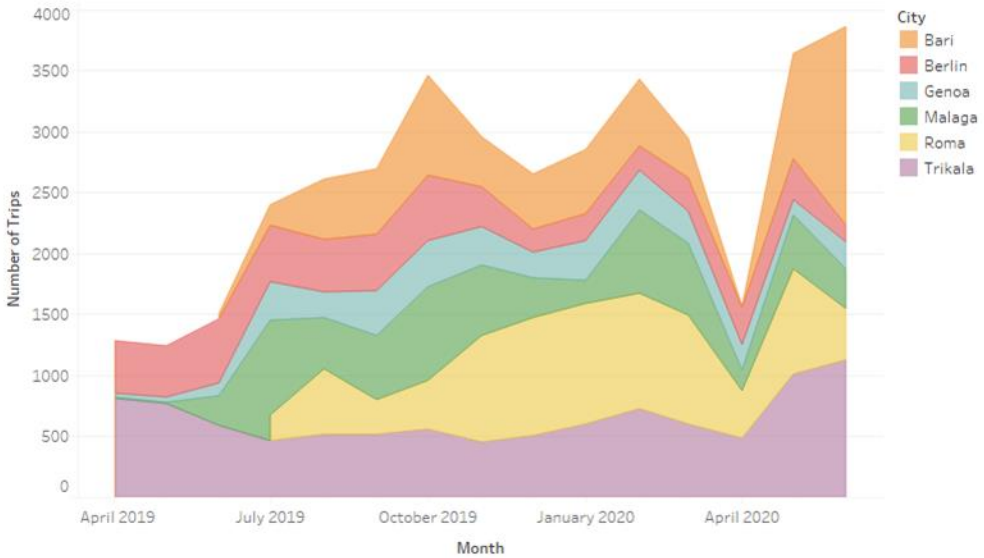

Figure 6 Number of trips by month and city

One of the parameters, which were logged by the black boxes is the battery voltage, which reveals valuable information on the State of Charge (SoC) of the vehicle at any time. For all 6 demonstration cities, the partners observed similar charging patterns. In general, most vehicles are charged during the evening and night, with some recharging periods during business hours.

Figure 7 Average state of charge (SoC) per hour for all cities

The collected data demonstrates that the EL-Vs, contrary to some initial hypotheses, do not need an extensive charging infrastructure for individual use in most urban use cases. Several so-called e-hubs have been installed in the demonstration cities to ensure safe storage and charging.

Some of the vehicles, in particular L1e-As and L1e-Bs, allow batteries to be removed from the vehicles and carried into the user's home or office building for charging using the regular grid. In general, the vehicle's range is sufficient for most use cases and batteries and chargers are designed for charging at home, at the office or at the school using a standard socket. This design renders them particularly convenient for individual usage.

The e-hubs added to the convenience of charging and security of parking at different points within the city. No issues in the usage of the e-hubs have been encountered. The e-hubs usage data documents an important aspect of the project and demonstrates extensive usage of the EL-Vs. However, they could not be installed next to any transport node to provide last mile commuting because no appropriate space could be provided by the cities.

5. Specific challenges of the project

The teams faced several legal, regulatory, technical and circumstantial issues, which delayed the deployment of demonstrations in some cities:

- Regulations in Spain consider L1e-A as "mopeds" which implies that these are not allowed to use cycle lanes or sidewalks. Many users considered that the speed limit of 25 Km/h was not enough for on-road trips and refused to participate in the demonstration.
- Registration and insurance of the vehicles in the Italian deployments caused long red-tape related delays that needed to be resolved.
- Several national lockdowns due to the COVID-19 pandemic shut down freedom of mobility.

The latter case led to a particular and novel situation: luck and misfortunate hit at the same time. Due to the lockdowns, the pilots could not proceed as planned and led to the necessity of restructuring the overall project timeline. At the same time, ELVITEN delivered invaluable insight on the changed mobility patterns during and after the lockdown.

Although the number of trips halted dramatically during the months of March and April 2020, the uptake of EL-Vs increased substantially after the restrictions had been lifted.

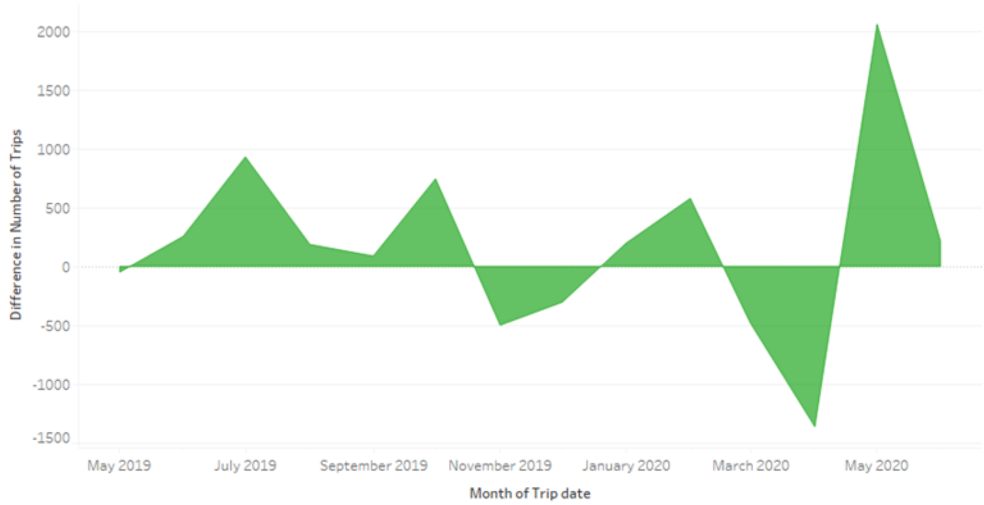

Figure 6 Trips difference per month

The partners believe that EL-Vs are an adequate mobility mode even during long pandemics or health crises. The vehicles not only provide an inherent distance between individual users by design, but they are also easier to disinfect before and after each use than common public and shared transportations (such as buses or trains).

6. Conclusions

Overall, the data collected has clearly demonstrated that **EL-Vs perform very well in urban traffic** and serve especially the purposes of daily commuting of employees. The average speed, trip distance and daily number of trips are quite high compared to the average traffic data of the demonstration cities. It is also important to notice that **male and female users demonstrated very similar trip distances**. The partners were also able to observe a very high trip density following main streets and avenues with higher speed and capacity, which is unusual for bicycles and light vehicles. This indicates that users feel safer using EL-Vs than common bicycles or scooters along high-traffic routes.

Probably the most important conclusion from the ELVITEN demonstrations is that contrary to common assumptions and user's perceptions (as shown in the questionnaires), **EL-Vs performed very well without the need of an extensive charging infrastructure**. During the demonstrations, 36 e-hubs (closed parking/charging stations) were deployed in 3 different cities. However, most users were able to charge the vehicles at home or in their office.

Although they only made up 20.35% of all Km travelled during the project, L1e-As (the least-powered type of EL-Vs) made up 78.83% of the number of trips recorded. This points to the conclusion that inhabitants of denser urban areas need to take **short but frequent trips** and prefer the convenience of a light and portable vehicle over the inconvenience of parking a car or the necessity of storing heavy vehicles. Instead, these vehicles are locked quickly and safely and can be parked anywhere for short amounts of time and with easy access.

During the project, **integration with other transport infrastructures could not be achieved**. Namely, the seamless integration is hindered by the lack of security surrounding popular transportation nodes and the prohibition to carry EL-Vs or comparable vehicles onto buses, trains or trams. It was not possible to install the e-hubs (closed parking/charging stations) in the transport nodes surroundings, as initially intended, due to regulatory and procurement issues.

One of the main concerns of users is the low security of the EL-Vs, especially if they need to leave the vehicles unattended for a longer period of time. Theft and vandalism are the two major concerns, due to the light construction of these vehicles and their relatively high value. When the vehicle needs to stay parked, and the user cannot take the battery with him for any given reason, the risk of theft and the anxiety users experience is very high. This needs to be addressed by both manufacturers and public transportation offices.

Overall, the ELVITEN partners found that there is not one standardised solution to register and import EL-Vs. For instance, some countries consider them as “regular” electric bikes, with no need of registration and insurance, while others consider them as “mopeds”. It is necessary to find one **common shared European legislation** for this kind of vehicle and define clear guidelines on the operation and registration of all parts.

The usage of EL-Vs should be recommended on a European, national and local level in order to battle congestion, pollution and decreasing productivity in cities. An excellent encouragement could be the installation of e-hubs for safe storage and charging. It is also important to allow EL-Vs to safely travel on separated bicycling lanes.

One key aspect of the project is the fact, that EL-Vs **attracted a high number of conventional engine vehicle users**. In particular, 23.7% of trips were recorded by regular petrol-powered 2-wheeled vehicle users, and 17.54% of trips by diesel, petrol or hybrid car users. The common assumption that EL-Vs will only “steal” users from public transport or other sustainable transport means has been proven incorrect. This means that it will be important for future projects to focus on the dedicated effort to persuade these users of switching to electric mobility. It is necessary to **enlarge the pool of e-Mobility users instead of shifting users within this same pool**.

Table 6 Trips by user usual transport mode

User usual transport mode	% of trips in ELVITEN
Diesel, petrol or hybrid can or van	17.54%
Electric bicycle	5.46%
Electric power 3-wheel vehicle	0.16%
Electric powered 2-wheel vehicle	6.52%
Electric powered 4-wheel light vehicle	0.55%
Fully electric (plug-in)	0.45%
Other (to specify)	2.00%
Pedal bicycle	16.21%
Petrol powered 2-wheel vehicle	23.70%
Petrol powered 3-wheel vehicle	0.80%
Power powered 4-wheel light vehicle	1.21%
Public transportation	17.49%
Taxi or ride-sharing	0.00%
Walking	7.90%

7. Annex I

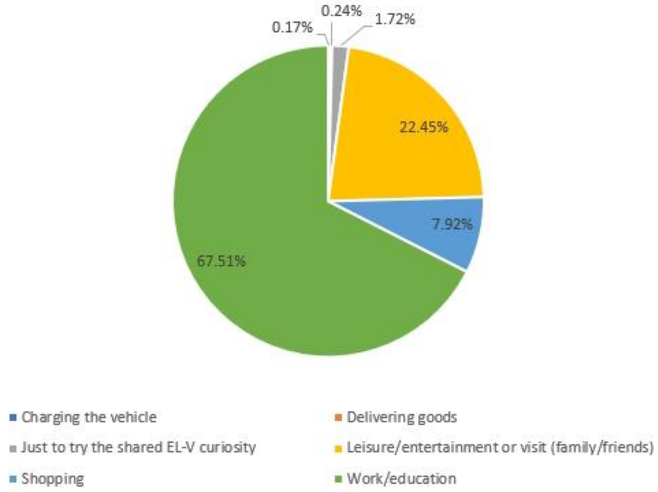

Figure 8 Trips by purpose

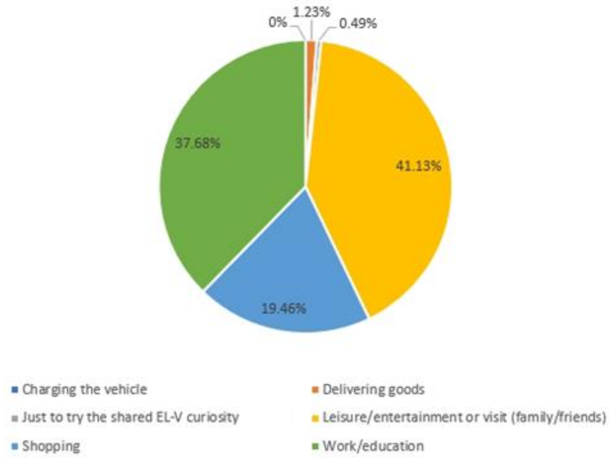

Figure 9 Trips by purpose during COVID-19 lockdown (15 March - 3 May)

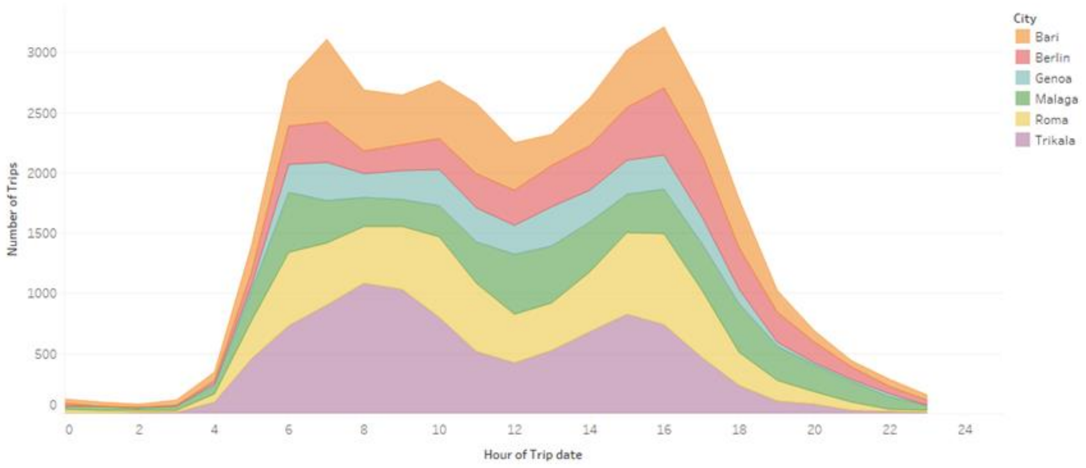

Figure 10 Trip by hour

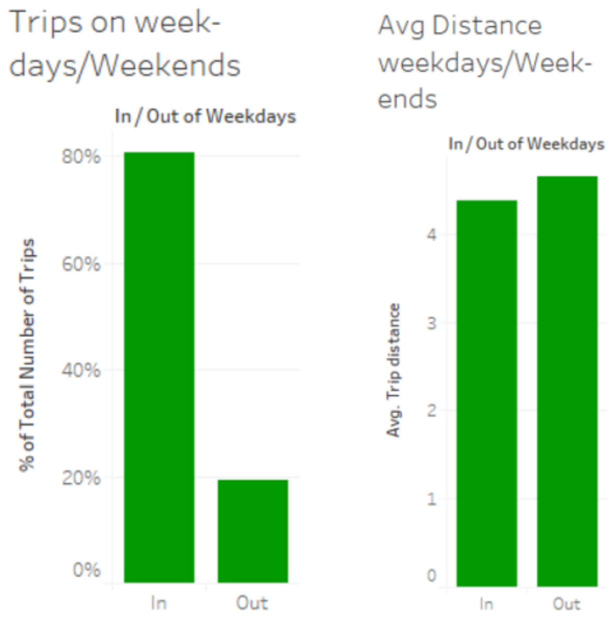

Figure 11 Number of trips and average distance by weekdays/weekends

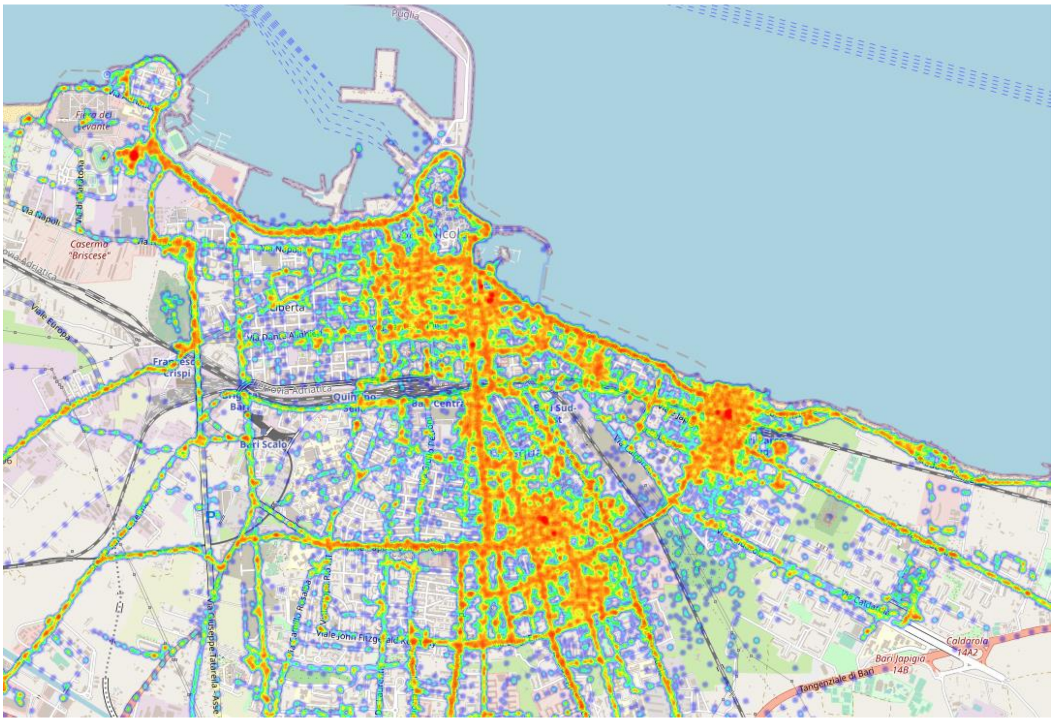

Figure 12 Trip density heatmap (Bari)

Figure 13 Average SoC per hour for all cities

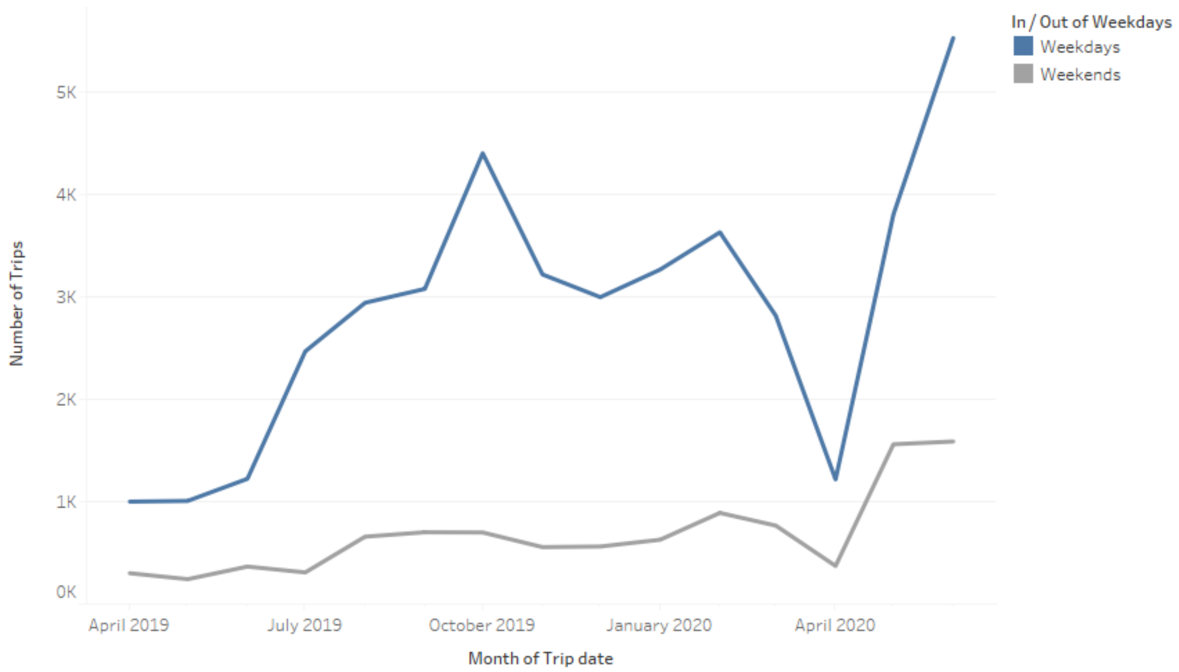

Figure 14 Variation in frequency of trip by EL-V by day of the week