D1.6 IMPACT ASSESSMENT RESULTS

VOLUME 8: MONTEVIDEO, URUGUAY

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EXECUTIVE SUMMARY

The Uruguayan capital Montevideo is the country's largest city with a metropolitan population of approximately 1.8 million people and an area of 201 km2. The city is facing an economic growth and a population growth in areas outside of the city centre, which leads to growing motorization rates and CO2 emissions from both personal and freight transport. In Montevideo, especially freight transport services suffer from several problems, including lack of space to unload cargo, difficulties in scheduling cargo activities, local commerce concentrating on the central area of the city, as well as long waiting times and delays in cargo operations.
Based on the mapping of local stakeholder needs, the most important aims for the SolutionsPlus project were to assess the financial feasibility of e-vehicles, and to increase the amount of trips conducted with e-vehicles instead of internal combustion engine (ICE) vehicles. Additionally, emission reductions in terms of CO2 and local air pollutants were deemed an important goal among stakeholders. Regarding potential use cases, particularly first and last mile cargo deliveries were deemed relevant.
To tackle these issues, and meet the local user needs, the SolutionsPlus demonstration involved manufacturing and piloting of e-cargo bikes in delivery services. The duration of the pilot was 2 weeks, during which a total of 156 delivery trips were conducted, covering 187 km and a total of 90 package deliveries. Two different models (i.e., Long-John e-cargo bike and an e-3-wheeler) were manufactured and tested to accommodate the pilot.
Based on the pilot demonstration, with the income tax rate of 25%, and depreciation rate of 12%, the after-tax NPV is 2,521 USD, after- tax IRR 47.0%, and after-tax payback period is 1.8 years for the Long-John e-cargo bike model. For the e-3-wheeler, With the income tax rate of 25%, and depreciation rate of 12%, the after-tax NPV is 2,605 USD, after tax IRR 41.6%, and after-tax payback period 1.9 years.

Based on the assumption that the SolutionsPlus vehicles replaced ICE 2-wheelers (0.04 kg CO2/km), the deployment of two e-cargo bikes during the pilot for a total distance of 187 km decreased CO2 emissions by 7.48 kg. The yearly extrapolated CO2 savings per vehicle, considering the distance of 16,992 km is 670 kg.

Several hurdles hindered realizing the full potential of the e-cargo bikes in the pilot demonstration. Firstly, pilot participants were unfamiliar with e-cargo bikes and the short duration of the pilot did not allow participants to become familiar with the new types of vehicles. This led to shortcomings in terms of how the vehicles were perceived and how efficiently they were operated. Secondly, the business and operational model that focused on direct deliveries from business to customer did not take full advantage of e-cargo bike benefits, such as their capacity to carry more cargo than conventional ICE motorbikes.

To mitigate the problems faced during the pilot implementation, future efforts should be dedicated to finding and refining the use cases to allow taking advantage of the potential of e-cargo bikes. Additionally, efforts should be made to profoundly familiarize the users with the new types of vehicles to avoid unnecessary troubles in day-to-day operations.

CONTENTS

1 BACKGROUND AND CONTEXT

1.1.GEOGRAPHY AND THE SOCIAL/URBAN CONTEXT

Uruguay (Figure 1) is located in the southeastern region of South America. It borders Argentina to its west and southwest and Brazil to its north and northeast, with the Río de la Plata (the Silver River) to the south and the Atlantic Ocean to the southeast. Uruguay is home to an estimated 3.51 million people, of whom 1.8 million live in the metropolitan area of its capital and largest city, Montevideo. With an area of approximately 176,000 square kilometers (68,000 sq mi), Uruguay is geographically the second-smallest nation in South America.

Figure 1. Location of Uruguay in South America and distribution of its main cities.

The country's economy is tied to agro-industrial chains and services. Its geographic location in the continent and the Río de la Plata basin exposes the population, infrastructures, and services to different climate-related threats, making Uruguay particularly vulnerable to the adverse effects of climate change. Uruguay's contribution of 0.05% to global greenhouse gas (GHG) emissions in 2016 explains the political priority given to the implementation of measures that seek to increase the adoption of emission mitigation actions. Also, a Gini index of 0.38 positioned Uruguay as the most equitable country in Latin America. The widespread availability of public education across the country, a literacy rate of 98.7%, and high nationwide coverage of health systems provide an opportunity to incorporate sustainable practices with low-emission levels and to adopt behaviours to prevent climate-related risk and build resilience to climate change and climate variability (NATCOM 5, 2019).

The main extreme climate events in the country are floods and droughts, which have had different adverse effects on the country's society and economy. They have affected the population and infrastructure of the most vulnerable communities and climate-dependent essential services and economic activities.

Uruguay has undergone a structural transformation of its electricity system, and more than 95% of electricity currently comes from renewable sources. Transportation is the sector with the second highest energy consumption in Uruguay and is the main consumer of petroleum derivatives and the largest emitter of CO_2 (BEN, 2019). The contribution of transport to the energy sector emissions has increased, at a small pace between 2006 (39%) and 2012 (40%), and more significantly afterward, reaching a share of 58% in 2018 and with prospects to account for more than 60% of energy emissions in the next decade (BEN, 2018a).

Economy

Uruguay's GDP per capita is USD 16,245 which is the highest in South America. The Uruguayan economy has experienced positive growth rates since 2003, with an annual average of 4.1% between 2003 and 2018. Although with a marked slowdown, economic growth continued to be positive even in 2017 and 2018 despite the recessions experienced by Argentina and Brazil.

Moderate poverty decreased from 32.5% in 2006 to 8.1% in 2018, while indigence or extreme poverty has practically disappeared: reducing from 2.5% to 0.1% during the same period. In terms of equity, the income of the poorest 40% of the Uruguayan population has increased faster than the average income growth of the entire population. However, important disparities persist: the percentage of the population below the national poverty line is significantly higher in the north of the country; among children and young people (17.2% for children under 6 years old and 15.0% and 13.9% for the groups between 6 and 12 years old and 13 and 17 years old, respectively).

Inclusive social policies have focused on expanding the coverage of programs, for example, around 90% of the population over the age of 65 is covered by the pension system: this is one of the highest shares in Latin America and the Caribbean, along with Argentina and Brazil.

Ethnicity

Uruguayans are of predominantly European origin, with over 87.7% of the population claiming European descent in the 2011 census. Most Uruguayans of European ancestry are descendants of 19th and 20th century immigrants from Spain and Italy, and to a lesser degree Germany, France and Britain.

Population distribution profile according to age group:

Uruguay's rate of population growth is much lower than in other Latin American countries. Its median age is 35.3 years, which is higher than the global average due to its low birth rate, high life expectancy, and relatively high rate of emigration among younger people. A quarter of the population is less than 15 years old and about a sixth are aged 60 and older. In 2017 the average total fertility rate (TFR) across Uruguay was 1.70 children born per woman, below the replacement rate of 2.1. The results of the last census (INE, 2011) are summarised in Figure 2.

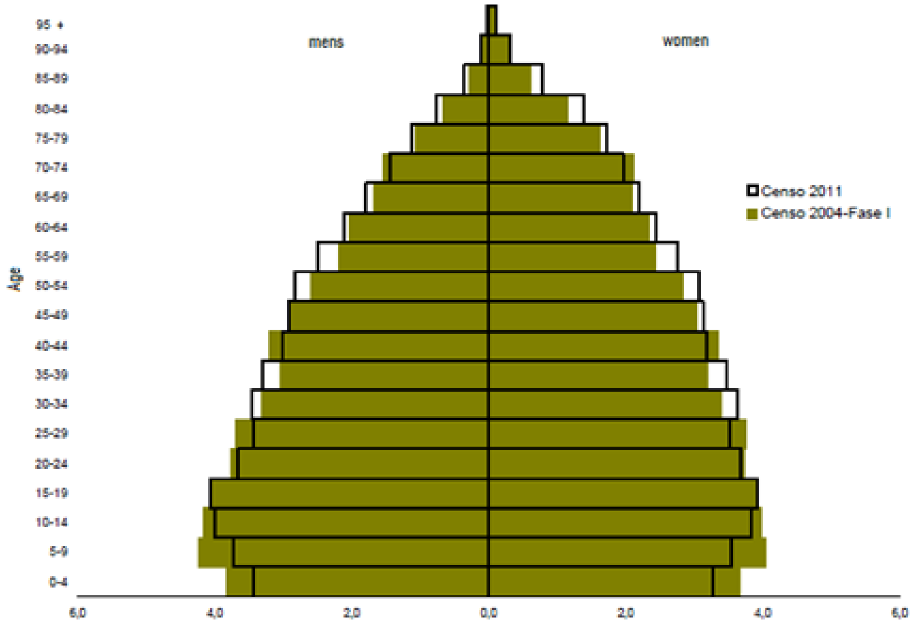

Figure 2. Population pyramids of Uruguay
(INE, 2011)

Compared to the previous census in 2004, there is a decrease in the percentage of children under 10 years of age, as a result of the decrease in the birth rate observed in the intercensal periods. In contrast to the decline in the child population, in 2011 there was an increase in the proportion of people over 50 years of age compared to 2004 (a widening of the upper part of the population pyramid). This phenomenon is associated with the lengthening of life as a result of the increased probability of survival at different ages (increase in life expectancy at birth).

Montevideo City

The city of Montevideo is situated on the southern coast of the country, on the northeastern bank of the Río de la Plata. It has a population of 1.3 million which represents more than 30% of the country's population. The Metropolitan area, composed of several small cities, surrounds the capital and the area gathers a population of near 1.8 million people in total. Montevideo has an area of 201 km2. Although population growth is estimated to be rather low (0.4% annually), it will take place in areas outside the city center, thus leading to more potential travel. Also, the expected economic growth (annual growth rate of 1.6% in 2017, 2.5% in 2018, and 3.7% in 2019) is a further driver of motorization rates and thus higher CO2 emissions from urban mobility in Montevideo. During 2007 and 2008 the use of public transportation increased by about 30%, when a policy of subsidies was introduced, keeping prices low. However, cheap ticket prices were unable to curb steady car-use growth and since 2014 the ticket sales have even decreased slightly. Not even the Sustainable Urban Mobility Plan (SUMP) of Montevideo, implementing a new pricing system and priority corridors has led to an increase in public transport ridership.

1.2. URBAN TRANSPORT

Public Transport

The public transport system in Montevideo City is based on buses operated by four private operators (PTOs), remises and taxis and ride hailing services such as Uber and Cabify. Multimodal transport is challenging in the city and the metropolitan area except for some combinations of train, bus, taxi and active transport. However, Montevideo is aiming to advance the transition to an inclusive, adaptable, efficient and low carbon transport system. Therefore, within the MOVES project (which shares the aforementioned aims), the Municipality of Montevideo in cooperation with different national ministries aims at the integration of 100 e-buses, e-cargo-vehicles, e-taxis and e-Ubers as well as the promotion of active mobility. It will begin in the metropolitan area of Montevideo and is planned to serve as a model for replication in other cities of Uruguay. It is expected that this project will result in direct CO2 emissions savings of at least 115,000 tons and indirect savings of at least 165,000 tons 10 years after the completion of the project.

The public transport system, Metropolitan Transportation System (STM), covers the entire metropolitan area of Montevideo. The system aims to incorporate the use of new technology, which allows more efficient, rational and safe public transport enabling greater practicality for users through routes and costs according to their needs.

Montevideo city accommodates 140 bus lines that have 107 destinations and 4,721 stops covered by 1,528 buses. Every bus is equipped with a GPS satellite control system that allows tracking the route and location of all units, adjusting routes and schedules. This technological integration enables information on the number of users of the different lines at all times in order to optimize the system.

There are currently 31 electric buses (e-buses) in the region. Figure 3 shows the main corridors, terminals and the main structure of the STM at the Ciudadela terminal.

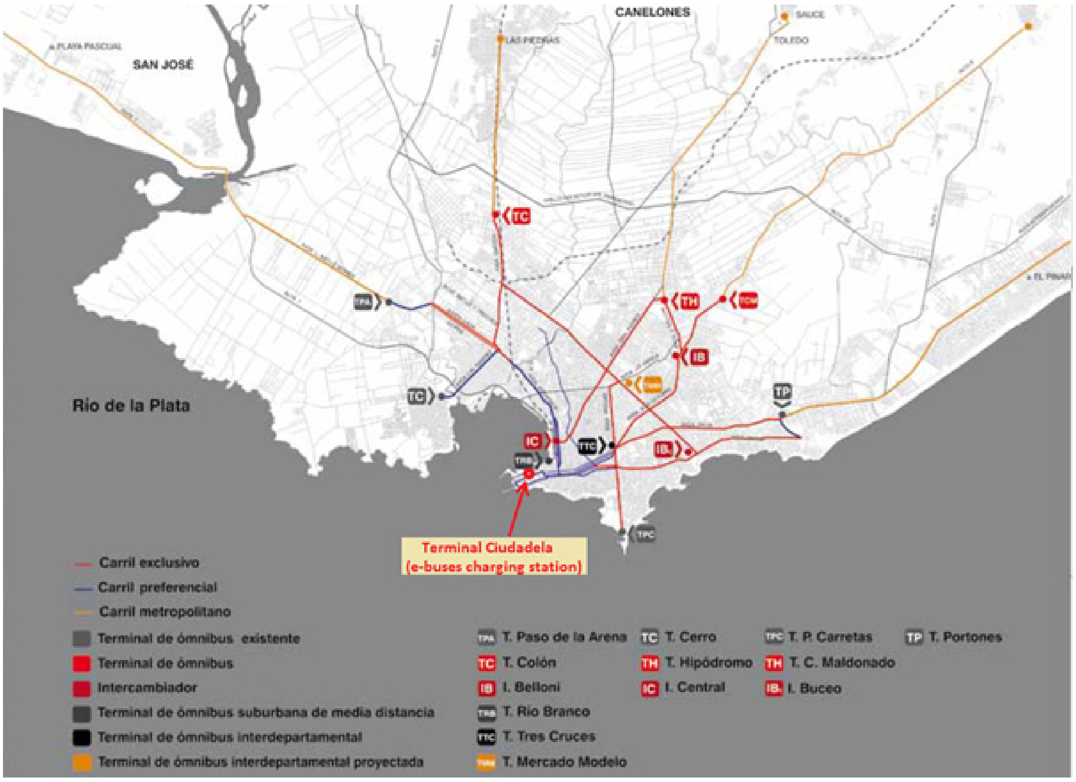

Figure 3. Montevideo city Ciudadela terminal where SolutionsPlus demonstrations will be implemented.

Law No. 19670 implements a subsidy meant to support the initial transition towards more efficient and sustainable technologies in the public transport of passengers by replacing up to 4% (four percent) of its total diesel-powered bus fleet with electrically powered buses. The subsidy is aimed at public transport operators interested in replacing a diesel bus with an electric motorized bus, according to the criteria defined in the regulation of the law. Hence, 100 electric buses will be purchased during 2021 and it is expected that the Ciudadela terminal could be referenced as “the e-buses public terminal” in the STM.

Bicycle infrastructure
There is currently 51.6 km of bicycle infrastructure in Montevideo, 9.0 km of which are bikeways (1.5 m clear width free for bikes on the street), 21.8 km are bike paths (a 1.5 m wide path on the sidewalk or similar), 7.6 km are on zone 20 on speed restricted streets (speed limit 20 km/h for all vehicles) and 13.2 km on zone 30 streets (speed limit 30 km/h for all vehicles).

The modal split in Montevideo is the following: 33% private passenger car, SUVs or minivan and taxi, 34% by walking, 25% by bus, 4% by motorcycle, 3% by bicycle and 1% by other.

1.3. IDENTIFICATION OF MAIN PROBLEMS

1.3.1. Passenger transport services

The main challenges presented here were identified by the Mobility Observatory (OMM) of the Municipality of Montevideo through an annual survey, which aimed to collect information for decision makers on public policies related to urban mobility.

Pricing
Although the ticket price is subsidized in various sectors of the population, this is not enough when compared with the purchasing power of the people, which leads to 63.7% of the people considering that the price of the urban public transport ticket is too high. Furthermore, if the quality of the service is taken into account the dissatisfaction is 56.4%.

Condition of the bus stop (sentry box)
Due to acts of repeated vandalism against bus stops, users see the conditions of the bus stop as very poor (45.6%). Additionally, the Municipality of Montevideo has implemented the construction of anti-vandalism stops that are inhospitable for users, particularly on windy and rainy days, which does not favour the improvement of this part of the infrastructure.

Travel comfort
Although the comfort of buses has improved in recent years, and even more so if the improvements introduced together with the purchase of electric buses are taken into account, there remain still many vehicles that are uncomfortable, generating noise and posing accessibility challenges. Within the comfort characteristics rated as very poor, 25.3% of users rate the ease or difficulty of getting on and off the bus as very poor. Another aspect related to comfort is the drivers’ driving style, which is classified as very poor by 23.4% of the people, while the attention of the bus staff (driver and/or guard) is perceived as very poor by 18.6% of users.

Bus cleaning
Cleanliness is one of the aspects on which the Municipality of Montevideo has focused in recent years, is noticeably improved. Despite these efforts, 30.5% of users still think that the cleanliness of buses is very poor.

Gender inclusion
Regarding the staff gender equality, the municipality has hired women as bus drivers making this service more gender inclusive.

Punctuality, travel time and service frequency
Aspects related to the time spent on a trip are perceived as very poor by almost 25% of users. Specifically, 28.5% perceive the punctuality of the buses as very poor; 27.6% of people perceive travel time as very poor and 27.3% of users have a negative assessment of the service frequency. Table 1 shows estimated travel times accordingly to the transport mode used by travellers. For example, the average trip made by bus takes 44.6 min. On the other hand, the average walking trip takes 13.9 min.

Table 1. Average travel time by mobility mode (adapted from the OMM, Municipality of Montevideo).

Travel mode	Average time (minutes)
Digital platforms	12.2
Taxi	12.7
Walking	13.9
Motorcycle	17.5
Bicycle	21.7
Car	24.8
Bus	44.6

1.3.2. Freight transport services

In Montevideo, several companies provide delivery of food and non-food items by bicycle, motorcycle or tricycle. There are also delivery services for small food businesses that are not associated with mobile phone application companies. Apart from the ready-to-eat food delivery, the delivery of other kinds of products (hardware store, bazaar, supermarkets, etc.) is also increasing, A survey on cargo mobility in Montevideo was carried out by the municipality, revealing the concerns and interests of referents of the private sector of freight transport, described in a report prepared by the National Institute of Logistics (Inalog) in 2019.
The main challenges encountered are listed below:

Space to unload cargo

- Challenges associated with the lack of space allocated on public roads for unloading activities (marked with yellow paint and vertical signage). It particularly affects small premises that do not have space within the premises.
- The biggest consequence is the parking violations (double row, non-authorized places, etc.).
- Limited space to unload cargo brings externalities with the rest of the city (double-row trucks), with the companies themselves (infractions alter the cost structure) and with the workers (they must travel greater distances with the merchandise).

Times and schedules for cargo activities

• Difficulty coordinating discharge time windows between the dealers and locals.
• Concentration of unloading at the same time (around 11 am).
• Difficulty predicting demand and planning.
• Lack of coordination affects vehicle routes producing longer travel times and increasing fuel costs.
• Lack of agreement between the parties involved as to who can define the schedules.

Available area for unloading of large cargo units (e.g., supermarkets)

• Long waiting time to unload cargo.
• Truck queues in the surroundings.
• Neighbors' complaints about occupied space, noise, movement schedules, etc.
• Difficulties in scheduling more precise cargo unloading times.
• Difficulty in implementing distribution centers.

Location of local commerce and shops

• Concentration of travel demand in the same area of the city (center and coast) is associated with a concentration of the population and therefore of consumption.
• Tendency towards the atomization of shops causes that there are more places where the vehicles that carry out the unloading must stop.
• Difficulties to install distribution centers.
• Smaller premises do not require internal loading areas or reserve space, and unloading falls only in the spaces available on public roads.

Waiting time and delays during the cargo operations

• Search for parking,
• Merchandise verification (often manually supervised),
• Loading task,
• Payment of local charges and billing (often done manually),
• Waiting times until having the permission to unload with an average of 27 minutes (in a range of 10 minutes and 2.5 hours).

Vehicle usage

• Vehicle restrictions used.
• Challenges in achieving high levels of occupancy in vehicles.
• Using smaller vehicles causes more trips and increased costs.
• Difficulties to carry different types of merchandise (e.g. varying by size) or partition trucks for these purposes.

Due to the above challenges, as well as increased demand for more cargo deliveries in the city centre, electric 3-wheelers or e-cargo bikes are a good option to provide a clean, safe, carbon free and efficient freight service.

1.3.3. Description of demonstration project

The planned demonstration activities for Montevideo City included two demo components: 1) Charging infrastructure for the Ciudadela terminal, which involves the construction of a high-capacity bus depot to charge the planned e-buses overnight

and opportunity charging, complying with Combined Charging Standard (CCS2) and Open Charge Point Protocol (OCPP) and 2) Local manufacturing of 2- and 3-wheeler e-vehicles and renting scheme for these vehicles.
Demonstration Component 1 was not implemented during the project timeframe, and therefore only the expected impacts identified in the ex-ante phase are described in this report. Moreover, regarding component 2, locally manufactured e-cargo bikes were piloted as a part of a courier service, yet a renting scheme was not piloted.

1.4. RELEVANT STAKEHOLDERS AND USER NEEDS

1.4.1. Relevant stakeholders

Several stakeholders have been identified as relevant contributors and participate in the Montevideo demonstration project. Table 2 identifies these stakeholders by group.

Table 2. Relevant stakeholders for Montevideo across the seven stakeholder groups.

Stakeholder group	Organisation Name and brief description
National / regional / local authorities	**Ministry of Industry, Energy and Mining (MIEM)** This Ministry is responsible for the energy issues. leads the above-mentioned MOVES project.
	Ministry of Housing & Planning (MVOT) Is the Ministry in charge of spatial planning issues and housing. It executes – together with MIEM – the above-mentioned MOVES project
	Ministry of Transport and Public Works (MTOP) It is responsible for the development and planning of public infrastructure works in order to promote national development.
	Ministry of Finance (MEF) With respect to e-mobility the MEF has an important role to play as it is the one that formulates the decrees, stipulating financial incentives for e-mobility.
	Ministry of Environment (MMA) Is the government ministry which oversees the environment of Uruguay. It was created in 2020, being before that date part of the MVOT.
	National Administration of Petrol (ANCAP) is a state-owned company in Uruguay. It is involved in the production of petroleum products, Portland cement and alcoholic beverages.
	UTE (Power Utility Company) Public company responsible for the generation, transmission, distribution and commercialization of electric energy, as well as providing advisory services and technical assistance in the areas of its specialty.
	Interinstitutional group of energy efficiency for the transport sector This group is made up of MIEM, MVOT, MMA, MTOP, MEF, IM, UTE and ANCAP. The main goal is to avoid duplicating efforts, share information, formulate a shared vision for the transport sector and generate synergies.
	Municipality of Montevideo (IM) is the local government of the capital city. It is the regulator of the public transport, and oversees sanitation and cleaning of the city and many more areas.

National / regional / local authorities	**MOVES** "Towards a sustainable and efficient urban mobility system in Uruguay" is a project that promotes sustainable mobility, funded by the Global Environment Facility.
	Consultative Council for Urban Transport (CCTCUM) This Council was established in December 2016 with the objective of improving the quality of the transport service in Montevideo.
	Congress of Mayors (CI) Its institutional objective is about the coordination of the policies of the regional governments.
	National Agency for Research and Innovation (ANII) Government entity that promotes research and the application of new knowledge to the productive and social benefit of the country.
	Uruguayan Agency for International Cooperation (AUCI) Is a cooperating partner in the MOVES project.
	National Development Agency (ANDE) Institution that promotes the development through programs that seek to improve business and territorial competitiveness, with an emphasis on MSMEs.
Public transport companies	**Compañía de ómnibus Pando S.A. (COPSA)** PTO that has 65% market share with 3 million tickets a month for routes that connect Montevideo with other important cities of the metropolitan area. This company doesn´t operate inside the Montevideo city.
	Compañia Uruguaya de Transportes Colectivos SA (CUTCSA) It is the largest transportation company in Uruguay and the largest private operator in South America.
	Cooperativa de Obreros y Empleados del Transporte Colectivo (COETC) This Montevideo-based urban transit company launched a pilot project in August 2018 to test Yutong's ZK 6125 CHEVG diesel-electric hybrid model.
	Unión Cooperativa Obrera de Transporte (U.C.O.T.) This is a Uruguayan passenger transport cooperative and provides services in the city of Montevideo. In 2020, a few Yutong electric buses were incorporated on its fleet.
	Corporación Ómnibus Micro Este1 (COME S.A.) COMESA is a public transport company and has been operating since 1963 and has a fleet of 240 buses. In 2020, a few Yutong electric buses were incorporated on its fleet.
Passengers / individual travellers / users	**Red Uruguaya de ONGs Ambientalistas (umbrella organization of environmental NGOs)** The umbrella organization of all environmental NGOs in Uruguay.
	Uruguayan Center for Appropriate Technologies (CEUTA) Independent, non-profit foundation, created in 1985. Its mission is to disseminate, research and train in the use of appropriate technologies, generating alternatives that strengthen local communities by integrating social, economic and ecological aspects.
	Urban Cycling Self-Management Workshop (TACU) Cycling associations that seek to promote the use of the bicycle as an active means of transport, sharing experiences of own use and others to move safely and consciously in the city.

Passengers / individual travellers / users	**Uruguayan Automotive Trade Association (ACAU)** Non-profit Civil Association, duly constituted following current legislation and which brings together 22 companies representing and importing 50 brands (e.g. passenger cars, light utility vehicles, trucks and buses).
	UNiBiCi Unibici is an initiative that belongs to the University of the Republic (UdelaR) that promotes the use of bicycles among university students throughout the country for transportation to and between university premises.
Small and medium-sized enterprises (SMEs) and original equipment manufacturers (OEMs)	**GreenStar SRL** 3&4-wheeler local manufacturer.
	Wheele E-cargo bike local manufacturer.
	CargoBike E-cargo bike local manufacturer.
Academia/ Research	**Faculty of Engineering (FING) of the Public University** Public institution of higher education in engineering of Uruguay.
	Electric Vehicle Work Group (GTVE) Research group on e-mobility that belongs to the FING which teaches a postgraduate course on the electric vehicle topic every year.

1.4.2. User needs

The user needs assessment (UNA) conducted via online survey and interviews allowed the identification of main motivations for the demonstrations, as well as to collect feedback on e-mobility solutions implementation, and insights on obstacles and barriers related to the SolutionsPlus demonstrations. The main findings of this analysis are summarized next. More details about Montevideo's user needs assessment can be found in the city report (SolutionsPlus Consortium, 2021).

The most important aim for Montevideo is to analyse costs related to the implementation of e-vehicles and to increase the share of trips made with e-vehicles. For that purpose, it is also important to improve quality of travelling. Additionally, the reduction of emissions, such as CO2 and also NOx, CO, PM, VOC emissions, and decreasing exposure of citizens to air pollution are important. The first and last mile delivery is the most relevant targeted use case of e-vehicles in Montevideo city, followed by the transport of people. For transport of people, two user groups are relevant: all citizens as well as people with disabilities and senior citizens. It is worth mentioning that these UNA results suggest envisioning e-mobility solutions as enhancing new possibilities for inclusive and equitable mobility, which is very encouraging and also aligned to the UN Sustainable Development Goal 11, called "Make cities and human settlements inclusive, safe, resilient and sustainable" (UN, 2021).

In addition to the expected benefits, Montevideo's stakeholders are also aware of barriers in relation to SolutionsPlus demo prototype implementation in the city. The most relevant challenges for the successful implementation of e-vehicles are lack of money or financial resources, organizational issues, and investments needed. Several regulatory barriers were identified, such as requirements for the homologation of the 3-wheelers and regulatory framework to provide standards for safe use in public spaces.

Regarding business models, stakeholders find the scheme of private service or public-private partnerships promising. For example, private companies are endorsed by the Municipality of Montevideo as a main service operator.

Stakeholders also revealed some concerns. For the first component of the demo, the e-buses implementation, the conventional bus is evaluated from a financial point of view in 16 years but the electric buses will have a battery life of 8 years, which makes the economic and financial evaluation more complex and would force companies to perform a battery replacement within the financial evaluation period. On the other hand, there is a very high level of risk given that these are new technologies, and the behaviour of the batteries and recharging systems might cause issues.

Concerning implications for planning and urban development, the Ciudadela initiative provides an opportunity for technologies and use of charging system and e-buses to be tested.

Regarding the second component of the project, electric delivery vehicles could imply certain economic benefits for the owners of the vehicles, due to the savings in fuel costs. However, there are certain challenges in making this known to dealers who use conventional vehicles that are purchased at a very low price and whose fuel consumption is affordable.

In general, the Municipality of Montevideo and other actors of Montevideo have positive expectations in the improvement of Ciudadela bus terminal. For wide-scale electric mobility, it is essential to coordinate actions with the "Department of Urban Development and Planning" (for example in the green space that is adjacent to the citadel terminal) with "Department of Mobility "which is SolutionsPlus' counterpart in the city.

Regarding the local manufacturing of e-cargo bikes and 3-wheelers, and to fulfill the gap of non-existent legislation for this type of vehicle, the DNI is expecting to issue a regulation by the end of 2021 / beginning of 2022. For e-cargo bikes, as there is no current regulation, the plan is to comply with the UN regulations, thus the power of the motor must be no bigger than 250 W. Regarding charging infrastructure and fast charging for e-buses, there have been recently issued the standard UNIT-1234/2020 which set down the requirements for connectors for fast charging infrastructure, taking as reference the IEC61851 and the IEC62196 standards. Beyond the regulation issues, it is necessary to improve and expand the bikeways in particular for bikes and e-cargo bikes. Additionally, in some areas such as the Old City, the 3-wheelers would be a good option for last mile logistics since there is not much space for big and medium vehicles. Besides, there is the need for additional public charging stations for e-buses along with the city. The charging station at the Ciudadela terminal could represent a good model for further replications in the city. To better support the implementation of these e-mobility solutions, and to promote employment, it is necessary to train the PTOs employees in EV topics.

2 KEY PERFORMANCE INDICATORS

2.1. PRIORITIZATION OF KPIS ADDRESSING THE SPECIFIC CITY NEEDS

The priorities of the stakeholders are formally determined through the weights assigned to the selected KPIs. The weighting of KPIs in Montevideo took place in conjunction with the stakeholder interviews organized under the user needs assessment analysis of Section 1.1.5. The KPI aggregation procedure (based on Chapter 2 Methodology in D1.6) takes into account all the eleven interviewed stakeholders, representing five stakeholder groups. Nevertheless, the aggregation procedure has not been completed yet.

Figures 4 and 5 exhibit the mean values of the weights received from the 11 stakeholders for all Level 1, 2 and 3 KPIs with relative (in black) and cumulative (in red) numeric digits. Relative weights indicate stakeholder priorities within a family and sum to 1, whereas the cumulative weights at each level are determined by applying the relative weights of that level to the cumulative weight of the parent attribute. The attributed weights calculation model was set to a maximum value of 100 for the sum of all cumulative weights at each level to minimise potential errors. The cumulative weights of level 1 KPIs are identical to the corresponding relative ones but expressed at a different scale.

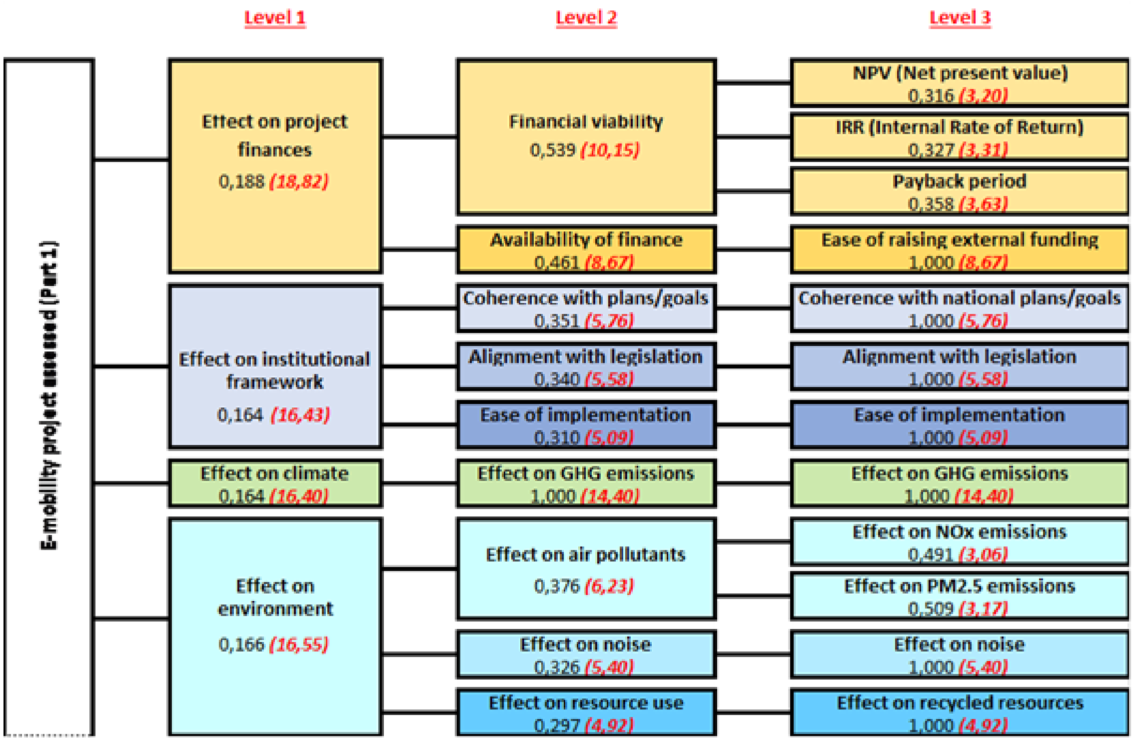

Figure 3. Montevideo city Ciudadela terminal where SolutionsPlus demonstrations will be implemented.

The project finances are the most relevant priority identified by Montevideo stakeholders with a cumulative weight of 18.82, followed by society with a cumulative weight of 18.02, as exhibited in Figure 4 and Figure 5 for level 1 KPIs. Nevertheless, these groups show a very small difference in weight (0.08), thus suggesting that the effect on society is perceived as relevant as the effect on project finances. A similar ranking was attributed across the groups, environment, institutional and climate with the corresponding weights of 16.55, 16.43 and 16.40, respectively. On the other hand, the wider economy was ranked with the lowest priority (13.78).

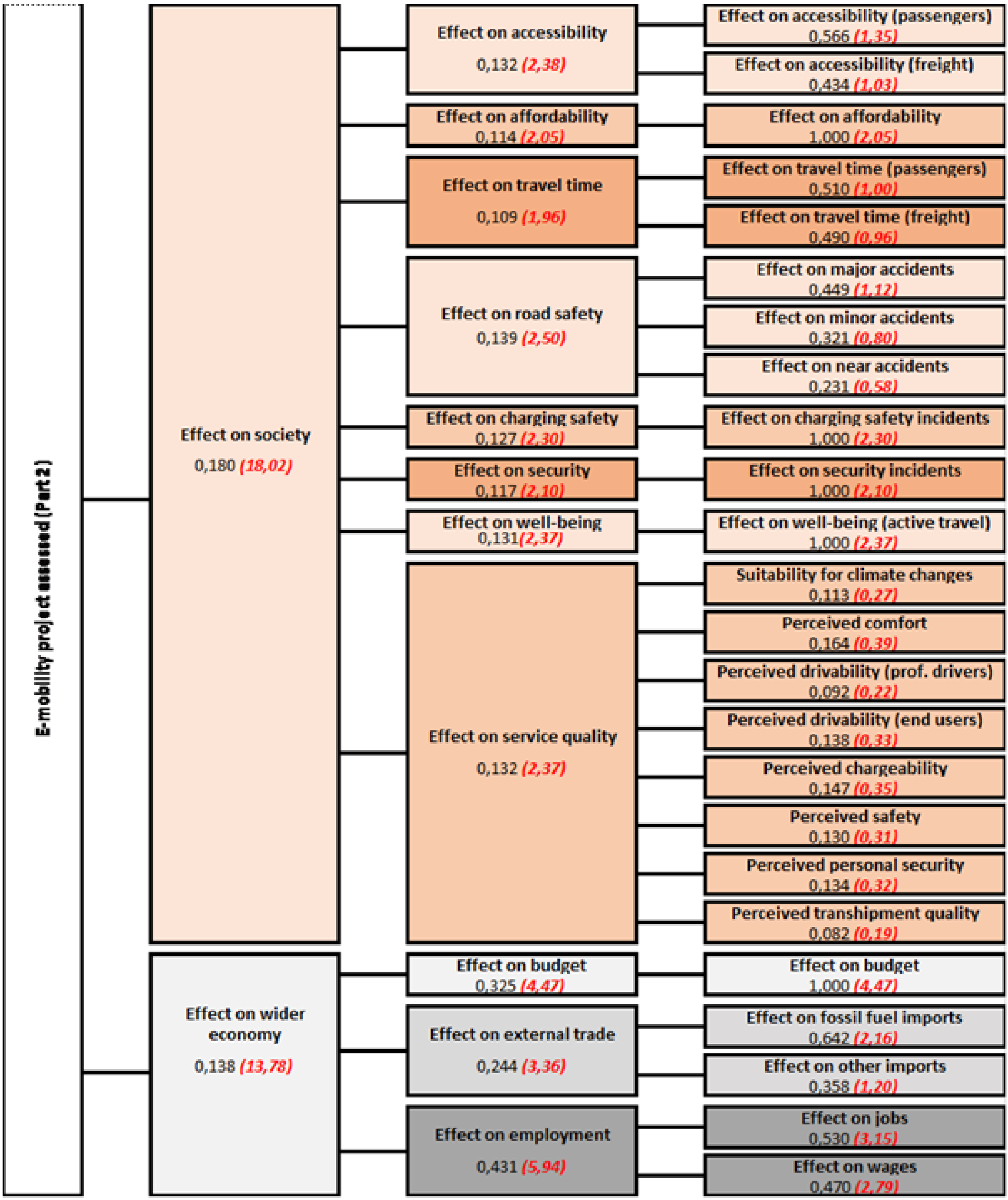

Figure 5. KPI weights indicated by the Montevideo stakeholders (provisional) for effects on society and wider economy.

For level 2 KPIs, the effect on GHG emissions shows the highest score (14.40), which is aligned with the aim to improve air quality as well as public health (as presented earlier in Section 1.1.5.2). Other observations for level 2 KPIs are summarised next.

- For project finances, financial viability (10.15) gets a higher weight than availability of finance (8.67). The former is also the highest priority across all level 2 KPIs.
- For the environment, the effect of air pollutants is the priority (6.23).
- For society, the highest priority is accessibility (2.38) but with a minor difference from well-being and service quality (both with weights of 2.37).

- For the wider economy, the highest priority is employment (5.94), whereas the lowest priority is external trade (3.36).

For level 3 KPIs, stakeholders prioritise charging safety incidents (2.30) over major accidents (1.12). Besides, higher importance was attributed to budget (4.47) over wages (2.79).

3 EX-ANTE IMPACT ASSESSMENT OF THE E-BUS CHARGING STATION IN THE CIUDADELA TERMINAL

E-bus charging station was planned to be installed in the bus terminal called "Ciudadela", in the Old City of Montevideo. The Ciudadela terminal is a hub for public transport owned by the Municipality of Montevideo and it is used mainly by the four operators of urban public transport (COETC, COMESA, CUTCSA and UCOT). The bus terminal is used by these companies as a destination of the bus lines as well as for fueling the buses and their overnight parking.

Currently, there are 31 electric buses (e-buses) operating in Montevideo. They were incorporated into the public transport system in June 2020. For this component, the electricity and charging infrastructure company ABB was expected to provide the charging infrastructure to be installed in Ciudadela terminal. Additionally, the public electricity utility company (UTE) was expected to conduct the electric installation that would supply electric energy to the chargers.

Regarding the technical requirements for the e-bus charging station, it must comply with the standard CCS2 for connectors and OCPP for the communication protocol. These technical requirements don't apply to the 31 existing e-buses, so the charging infrastructure will be used exclusively for charging of the new generation of e-buses introduced during the year 2021.

The e-bus charging station was not implemented during the SolutionsPlus project timeframe. Therefore, the assessment only overs the ex-ante assessment which was based on the current understanding of the demo implementation. This assessment was done by comparing the situation before the implementation to the expected situation after the demo implementation. Thus, the situation before (without any implementation) was considered as the reference state. This reference state was then compared with the situation with the demo implementation including the proposed e-mobility solutions. The expected hypothetical impacts were assessed by selecting relevant level 2 KPIs (covering both weighted and non-weighted KPIs) subject to the ex-ante assessment.

The objectives of the e-bus charging station demonstration were defined as follows:

- to increase deployment of e-buses by replacing the buses equipped with an ICE.
- to reduce air pollution and improve the quality of life in the city centre.
- to improve the accessibility and comfort of buses by incorporating a flat floor without steps/stairs and universal accessibility, among other additional comfort elements.

The ex-ante impacts for this demo component are listed in the following Table 3.

Table 3. Ex-ante assessment of E-bus charging station using relevant KPIs.

Relevant Level 2 KPIs	Description of estimated effect
Impact on GHG emissions	GHG emissions are expected to decrease due to shift from Diesel buses to e-buses (10 e-buses in terminal).
Impact on air pollutants	Shift from diesel buses to e-buses (10 e-buses using the new terminal) is expected to improve local air quality by reducing NOx and PM emissions.
Impact on noise	Noise levels could potentially decrease due to transfer from Diesel buses to e-buses (10 e-buses using the new terminal).
Impact on accessibility	Accessibility is expected to increase with the introduction of new e-buses as they will incorporate a flat floor without steps/stairs. Hence facilitating users to get on / off the bus (concerns only the new e-buses).
Quality of e-mobility services	Comfort of buses is expected to increase with the introduction of flat floor buses without steps/stairs (concerns only the new e-buses).
E-vehicles – operational Charging infrastructure – technical & operational	Better, faster and public charging facilities. New opportunity charging possibilities.
E-vehicles - operational	Cheaper electricity prices for overnight charging.
Market share of e-mobility	The number and type of trips made with an e-vehicle are expected to increase.

4 EX-POST IMPACT ASSESSMENT – E-CARGO BIKE DEMONSTRATION

Demonstration Component 2 involved the manufacturing and testing of LEFs (light electric freight vehicles) in an urban logistics pilot.

Three local start-ups were selected for the LEF manufacturing: CargoBikeUY, Wheele and GreenStar. Eight bikes and two e-tricycles were finished (Figure 6). The vehicle design was supported via the EU Innovators Call. Also, the BMS selection and vehicle performance testing were supported.

In the urban logistics pilot, two LEFs (a bicycle and tricycle) were tested. The duration of the pilot was 2 weeks (December 14-23, 2022). PedidosYA (Delivery Hero) was the logistics operator, and the operating model of the pilot involved direct deliveries from origin to destination (local businesses to customers). Driving training was provided for the e-cargo bike riders prior to commencing the pilot.

During the pilot, a total of 156 trips (26/day on average) were made, covering a total of 187 km (31 km/day on average). A total of 90 packages (15/day on average) were delivered, with a total mass of 135 kg (23 kg/day on average).

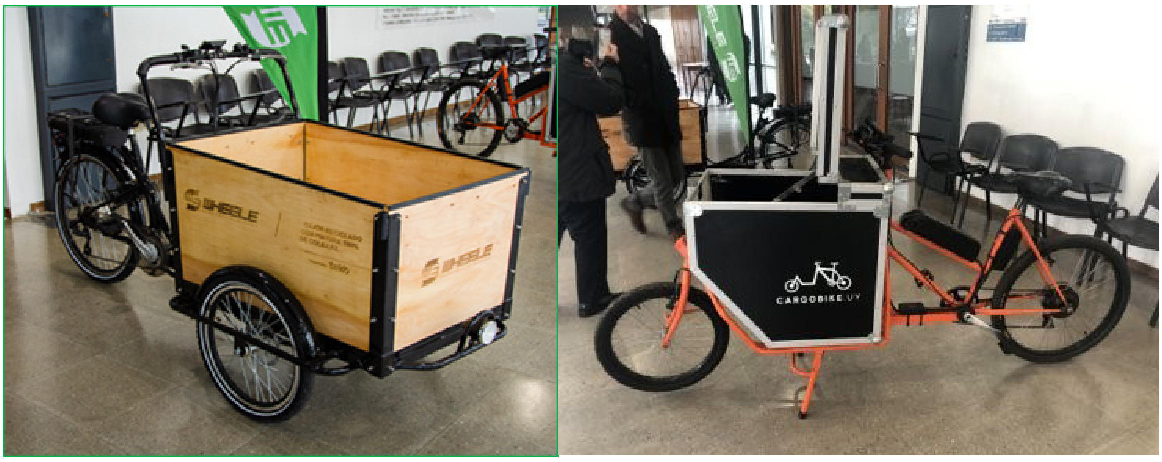

Figure 6. E-bicycle and e-tricycle models used in the pilot implementation.

In the ex-ante phase, the KPI's presented in table 4, were deemed relevant for the e-cargo bike demonstration. Additionally, the impacts in terms of financial feasibility, and quality were assessed in the ex-post phase.

Table 4. Relevant KPIs and ex-ante assessment of component 2.

Relevant Level 2 KPIs	Description of estimated effect
Impact on GHG emissions	GHG emissions are expected to decrease due to the replacement of conventional vehicles (motorcycles and vans) using petrol by e-vehicle solutions in the city centre.
Impact on air pollutants	Air pollutants are expected to decrease due to the introduction of e-vehicle solutions, thus reducing the emissions of NOx and PM.
Impact on noise	Local noise emissions levels can potentially be reduced due to the introduction of 15 e-cargo bikes and 4 e-cargo tricycles replacing engine combustion vehicles.
Impact on accessibility	Accessibility of freight transport trips is expected to increase due to the introduction of new e-mobility solutions as they provide an agile alternative to ICE motorcycles and vans.
Impact on travel time	No changes in travel time are expected due to the use of e-cargo bikes and e-cargo-tricycles. It could be expected that this e-mobility solution could provide more flexibility within the city than motorcycles and vans. On the other hand, the speed of these e-cargo-vehicles could be slower compared to motorcycles and vans.
Impact on road safety	A slight decrease in the number of accidents or dangerous situations in the Montevideo city centre is expected as some motorized vehicles (motorcycles and vans) will be replaced by e-cargo bikes and e-cargo-tricycles. In addition, the severity of road accidents is expected to somewhat decrease (especially in accidents with pedestrians and cyclists) since vehicles with higher mass (e.g. vans) will be replaced with lighter e-vehicles, thus decreasing the injury risk in the event of an accident.
Impact on employment	The introduction of new e-mobility solutions for freight delivery could have a slightly positive impact on employment due to the introduction of new delivery services.
Willingness to pay for the e-mobility services	Willingness to use and pay for the e-mobility services might be slightly increased. Changes in the price of this type of vehicles and/or services are not expected. Some shops might be willing to use and pay for these e-mobility solutions for freight deliveries to promote their business branding and advertisement.

Impact on existing fleets	This demo is expected to have a marginal increase in the existing vehicle fleet due to the introduction of 19 e-vehicles (15 e-cargo bikes and 4 e-cargo-tricycles) designed in the context of the SolutionsPlus demo.
Impact on transport work with EV (freight)	The total vehicle km performed with e-vehicles is expected to increase as new 19 e-cargo vehicles will potentially be used several times per day to provide a delivery service for the city centre.
Market share of e-mobility	The number of freight trips conducted by the e-vehicles is expected to increase as the e-cargo bikes and e-cargo tricycles are available for rent.

4.1. FINANCIAL VIABILITY

Financial viability of the pilot implementation is assessed through three KPIs: Net Present Value (NPV), Internal Rate of Return (IRR) and payback period. These are calculated separately for the two models used, i.e., e-Long John cargo bike and the e-3-wheeler cargo bike that were manufactured locally and used during the two-week pilot by a courier company.

E-Long John cargo bike
Table 5 presents the general information, costs, operational profile, and revenues of the e-Long John cargo bike based on the demonstration which provides the basis for the financial calculations.

Capital costs. The capital costs comprised the purchase of the vehicle as well as battery. The purchase price of a Long-John e-cargo bike used in the pilot implementation was 2,562 USD, expected useful life 5 years, and the price of a new battery 500 USD.

Operational profile. Based on the pilot implementation, the average number of daily round trips was 18, each being on average 3.3 km. Considering the number of operational days per year (288), the yearly mileage per vehicle is 17,107 km, with 5,184 delivery round trips.

Total operating costs. The basic salary of drivers was 1,105 USD per month. With an electricity consumption of 0.01 kWh/km, and a tariff of 0.20 USD/kWh, the yearly electricity costs are 34 USD per vehicle. Additional costs consist of maintenance fees of 212 USD/year. This leads to yearly total operating costs of 13,766 USD per vehicle.

Yearly revenues. Considering an income of 3.00 USD per delivery, the yearly revenues per vehicle are 15,552 USD with 5,184 annual deliveries.

Table 5. The general information, costs, operational profile and revenues of the e-Long John cargo bike

Category	Parameter	Value	Unit
General info	Year built	2022	
Propulsion	Battery type	Li-ion	
	Battery size	624	Wh
	Battery price	500	USD
	Number of batteries	1	
Capital cost	Purchase price	2 562	USD
	Expected useful life	5	years

Capital cost	Residual value	500	USD
	Depreciation schedule	16 %	
Operational profile	Length of round trip	3,3	km
	Round trips/day	18	trips/day
	Total distance/day	59	km/day
	Operating days/year	288	days/year
	Delivery trips/day	18	trips/day
	Chargings/day	1	
Yearly operating cost	Total operating cost	13 766	USD/year
	* Insurance	256	/year
	* Personnel cost	13 264	/year
	- Basic monthly salary	1 105	/month
	* Electricity cost	34	/year
	- Energy consumption	0,010	kWh/km
	- Electricity tariff	0,20	/kWh
	* Maintenance cost	212	/year
	- Tires	25	/year
	- Brake shoes	13	/year
	- Dent paint	14	/year
	- Suspension	39	/year
	- Wiring	40	/year
	- Head- & tail-lights	14	/year
	- Display system	28	/year
	- Throttle pedal	40	/year
Yearly revenues	Total revenues	15 552,00	USD/year
	Average income per trip	$ 3,00	/trip

Financial indicators. Considering the costs and income outlined above, the pre-tax NPV of an e-cargo bike is 3,844 USD, pre-tax IRR 62.99%, and pre-tax payback period 1.43 years (Table 6).

With the Uruguayan income tax rate of 25%, and an assumed discount rate of 12%, the after-tax NPV is 2,521 USD, after-tax IRR 47.01%, and after-tax payback period 1.79 years (Table 7).

Table 6. Financial calculations for the e-Long John cargo bike before tax.

Discount rate	12 %					
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Year	2023	2024	2025	2026		
Investment	-2 562					
Residual value						500

Annual revenues		15 552	15 552	15 552	15 552	15 552
Annual operating & maintenance costs		-13 766	-13 766	-13 766	-14 266	-13 766
Net pre-tax cash flow	-2 562	1 786	1 786	1 786	1 286	2 286
Cumulative pre-tax cash flow	-2 562	-776	1 011	2 797		
Year	0	1	2	3	4	5
Pre-tax NPV	3 844					
Pre-tax IRR	62,99 %					
Pre-tax payback (years)	1,43					

Table 7. Financial calculation for the e-Long John cargo bike after tax.

Discount rate	12 %					
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Year	2023	2024	2025	2026	2027	2028
Depreciation		-410	-344,3	-289,2	-243,0	-204,1
Taxable income	-2 562	1 376	1 442	1 497	1 043	2 082
Tax		344,1	360,5	374,3	260,9	520,6
Net post tax	-2562	1442,3	1425,9	1412,1	1025,5	1765,8
Cumulative post tax	-2562	-1119,7	306,2	1718,3	2743,8	4509,7
Year	0	1	2	3	4	5
Pre-tax NPV	2 521					
Pre-tax IRR	47,01 %					
Pre-tax payback (years)	1,79					

E-3-wheeler cargo bike

Table 8 presents the operational general information, costs, operational profile and revenues of the e-3-wheeler cargo bike used in the deliveries.
Capital costs. The purchase price of a 3W cargo bike was 3294 USD, expected useful life 5 years, and the price of a new battery 500 USD.

Operational profile. Based on the pilot implementation, the average number or round trips was 18, each being on average 3.3 km. Considering the number of operational days per year (288), the yearly mileage per vehicle is 17107 km, with 5184 deliveries.

Total operating costs. The basic salary of drivers was 1105 USD per month. With an electricity consumption of 0.01 kWh/km, and a tariff of 0.20 USD/kWh, the yearly electricity costs are 34 USD per vehicle. Additional costs consist of maintenance fees of 212 USD/year. This leads to yearly total operating costs of 13766 USD per vehicle.

Yearly revenues. Considering an income of 3.00 USD per trip, the yearly revenues per vehicle are 15552 USD.

Table 8. Operational general information, costs, operational profile and revenues of the e-3-wheeler

Category	Parameter	Value	Unit
General info	Year built	2022	
Propulsion	Battery type	Li-ion	
	Battery size	624	Wh
	Battery price	500	
	Number of batteries	1	
Capital cost	Purchase price	3 294	USD
	Expected useful life	5	years
	Residual value	500	USD
	Depreciation schedule	16 %	
Operational profile	Length of round trip	3,3	km
	Round trips/day	18	trips/day
	Total distance/day	59	km/day
	Operating days/year	288	days/year
	Delivery trips/day	18	trips/day
	Chargings/day	1	
Yearly operating cost	Total operating cost	13 766	USD/year
	* Insurance	256	/year
	* Personnel cost	13 264	/year
	- Basic monthly salary	1 105	/month
	* Electricity cost	34	/year
	- Energy consumption	0,010	kWh/km
	- Electricity tariff	0,20	/kWh
	* Maintenance cost	212	/year
	- Tires	25	/year
	- Brake shoes	13	/year
	- Dent paint	14	/year
	- Suspension	39	/year
	- Wiring	40	/year
	- Head- & tail-lights	14	/year
	- Display system	28	/year
	- Throttle pedal	40	/year
Yearly revenues	Total revenues	15 552,00	USD/year
	Average income per trip	$ 3,00	/trip

Financial indicators. Considering the costs and income outlined above, the pre-tax NPV of an e-3-wheeler is 3,073 USD, pre-tax IRR 44.44%, and pre-tax payback period 1.84 years (table 9).

With the income tax rate of 25%, and depreciation rate of 12%, the after-tax NPV is 2,605 USD, after-tax IRR 41.61%, and after-tax payback period 1.92 years (table 10).

Table 9. Financial calculations for the e-3-wheeler cargo bike before tax

Discount rate	12 %					
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Year	2023	2024	2025	2026	2027	2028
Investment	-3 294					
Residual value						500
Annual revenues		15 552	15 552	15 552	15 552	15 552
Annual operating & maintenance costs		-13 766	-13 766	-14 266	-13 766	-13 766
Net pre-tax cash flow	-3 294	1 786	1 786	1 286	1 786	2 286
Cumulative pre-tax cash flow	-3 294	-1 508	279	1 565	3 352	5 638
Pre-tax NPV	3 073					
Pre-tax IRR	44,44 %					
Pre-tax payback (years)	1,84					

Table 10. Financial calculations for the e-3-wheeler cargo bike after tax

Discount rate	10 %					
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Year	2023	2024	2025	2026	2027	2028
Depreciation		-527	-442,714	-371,879	-312	-262,4
Taxable income	-2800	1 259	1 344	915	1 474	2 024
Tax		314,8427	335,9243	228,633	368,51	506
Net post tax	-2800	1 472	1 450	1 058	1 418	1 780
Cumulative post tax	-2800	-1328,43	122,0543	1179,83	2597,7	4378,1
Pre-tax NPV	2 605					
Pre-tax IRR	41,61 %					
Pre-tax payback (years)	1,92					

Previous solution: ICE motorbike

Table 11 presents the operational general information, costs, operational profile and revenues for an ICE motorcycle that was the means for transport used prior to the SolutionsPlus implementation.

Table 11. Operational general information, costs, operational profile and revenues of an ICE motorbike

Category	Parameter	Value	Unit
Capital cost	Purchase price	2 000	USD
	Expected useful life	5	years
	Residual value	500	USD
	Depreciation schedule	16 %	
Operational profile	Length of round trip	3,3	km
	Round trips/day	21,951	trips/day
	Total distance/day	72	km/day
	Operating days/year	288	days/year
	Delivery trips/day	21,951	trips/day
Yearly operating cost	Total operating cost	15 434	USD/year
	* Insurance	256	/year
	* Personnel cost	13 264	/year
	- Basic monthly salary	1 105	/month
	* Fuel cost	1 619	/year
	fuel consumption	0,040	l/km
	fuel price	1,94	USD/l
	* Maintenance cost	295	/year
	- Tires	60	/year
	- Brake shoes	40	/year
	- Dent paint	30	/year
	- Suspension	50	/year
	- Wiring	40	/year
	- Head- & tail-lights	20	/year
	Fuses	15	/year
	- Throttle pedal	40	/year
Yearly revenues	Total revenues	18 966	/year
	Average income per trip	3	/trip
Income tax	Income tax rate	25 %	

Capital costs. The purchase price of an ICE motorbike is 2,000 USD, and the expected useful life 5 years.

Operational profile. Based on the information obtained from the delivery company, the average number or round trips conducted using a motorbike is 21.951, each being on average 3.3 km. Considering the number of operational days per year (288), the yearly mileage per vehicle is 20,862 km, with 6,322 delivery round trips.

Total operating costs. The basic driver salary was 1,105 USD per month. Considering the fuel consumption of 0.04 l/km, and the fuel price of 1.94 USD/l, the yearly fuel costs are 1,619 USD. Additional costs consist of maintenance fees of 295 USD/year. This leads to yearly total operating costs of 15,434 USD.

Yearly revenues. Considering an income of 3.00 USD per trip, the yearly revenues per vehicle are 18,966 USD.

Financial indicators. Considering the costs and income outlined above, the pre-tax NPV of an ICE motorbike is 11,016 USD, pre-tax IRR 175.77%, and pre-tax payback period 0.57 years (Table 12). With the income tax rate of 25%, and depreciation rate of 12%, the after-tax NPV is 7,980 USD, after-tax IRR 134.49%, and after-tax payback period 0.73 years (Table 13).

Table 12. Financial calculations for an ICE motorbike before tax

Investor's perspective - Calculations (BEFORE TAX)						
Discount rate	12 %					
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Year	2023	2024	2025	2026	2027	2028
Investment	-2 000					
Residual value						500
Annual revenues		18 966	18 966	18 966	18 966	18 966
Annual operating & maintenance costs		-15 434	-15 434	-15 434	-15 434	-15 434
Net pre-tax cash flow	-2 000	3 532	3 532	3 532	3 532	4 032
Cumulative pre-tax cash flow	-2 000	1 532	5 064	8 596	12 128	16 160
Year	0	1	2	3	4	5
Pre-tax NPV	11 016					
Pre-tax IRR	175,77 %					
Pre-tax payback (years)	0,57					

Table 13. Financial calculations for an ICE motorbike after tax

Investor's perspective - Calculations (25% income tax rate)						
Discount rate	10 %					
	Y0	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**
Year	2023	2024	2025	2026	2027	2028
Depreciation		-320	-268,8	-225,8	-189,7	-159,3
Taxable income	-2 000	3 212	3 263	3 306	3 342	3 873
Tax		803,0	815,8	826,6	835,6	968,2
Net post tax	-2000	2729,0	2716,2	2705,5	2696,4	3063,8
Cumulative post tax	-2000	729,0	3445,2	6150,7	8847,1	11910,9
Year	0	1	2	3	4	5
Pre-tax NPV	7 980					
Pre-tax IRR	134,49 %					
Pre-tax payback (years)	0,73					

Financial comparison

Table 14 presents the comparison of financial KPIs between ICE motorbike (previous solution) and the two e-cargo bike models implemented during the pilot demonstration. As can be seen, the previous solution (motorbike) is superior in terms of financial feasibility. However, due to the small-scale implementation, the operating scheme was not adjusted to suit e-cargo bikes which faced difficulties in efficiency during the demonstration. Therefore, in the future, it can be expected that if the operating scheme to suit e-cargo bikes is adopted regarding e.g., routing and locations, their financial feasibility could improve.

Table 14. Financial indicator comparison

Motorbike		E-long John		E-3-wheeler	
Pre-tax NPV	11 016	Pre-tax NPV	3 844	Pre-tax NPV	3 073
Pre-tax IRR	175,77 %	Pre-tax IRR	62,99 %	Pre-tax IRR	44,44 %
Pre-tax payback (years)	0,57	Pre-tax payback (years)	1,43	Pre-tax payback (years)	1,84
Post-tax NPV	7 980	Post-tax NPV	2 52	Post-tax NPV	2 605
Post-tax IRR	134,49 %	Post-tax IRR	47,01 %	Post-tax IRR	41,61 %
Post-tax payback (years)	0,73	Post-tax payback (years)	1,79	Post-tax payback (years)	1,92

4.2. ALIGNMENT WITH LEGISLATION AND REGULATIONS

In Uruguay, there exists no regulation concerning e-bikes, yet the implemented solutions comply with UN regulations, according to which the power of the motor must be no bigger than 250 W.

4.3. CLIMATE RELATED INDICATORS

4.3.1. Impact on GHG emissions

Based on the assumption that the SolutionsPlus vehicles replaced ICE 2-wheelers (0.04 kg CO2/km), the deployment of two e-cargo bikes during the pilot for a total distance of 187 km decreased CO2 emissions by 7.48 kg.

The yearly CO2 savings, considering the distance of 16,992 km, are 670 kg.

4.4. ENVIRONMENTAL INDICATORS

4.4.1. Impact on noise

The demonstration component had a reducing impact on noise in comparison to vehicles that were previously used for deliveries. According to the user and rider survey, two of the riders and logistics operators were satisfied and one strongly satisfied with the perceived noise of the SolutionsPlus vehicles.

Moreover, one of the pilot participants was neutral, three agreed, and one completely agreed that regular use of the SolutionsPlus vehicles could reduce noise. The three logistics operators and riders participating in the demo had used ICE scooter/moped before for some of the deliveries but also bicycle, e-cargo bike and tricycle had been used.

4.5. SOCIAL INDICATORS

4.5.1. Impact on accessibility

Accessibility impacts were assessed using the results of the user survey. Based on the responses, the implementation had negligible impact on accessibility. The two survey respondents recognised very little changes in the number of packages, delivery trips, orders, or delivery hours before and after the demo. The two tested pedal assisted cargo bikes are a bit bigger than a typical bicycle and have specific characteristics such as their size, the way to ride, the position of the rider and the load, the electric propulsion, and the total mass. According to the PedidosYa (delivery service provider) statistics, the productivity (orders/h) during the demo period decreased by approx. 18% compared to the rest of the fleet. The current business model (from origin to destination directly) does not take advantage of the larger delivery capacity of the vehicle but on the contrary highlights the disadvantages (Technology testing programme).

4.5.2. Impact on delivery time

The impacts on delivery time were assessed using the results obtained from the user survey. The implementation had a slight negative effect on delivery time. One survey respondent recognized an increase in the delivery hours with the SolutionsPlus vehicle compared to the situation before the demo. The two tested pedal assisted cargo bikes are a bit bigger than a typical bicycle and have specific characteristics such as their size, the way to drive, the position of the rider and the load, the electric propulsion and the total mass. According to the PedidosYa (delivery service provider) statistics, the productivity (orders/h) during the demo period decreased by approx. 18% compared to the rest of the fleet. The current business model (from origin to destination directly) does not take advantage of the larger delivery capacity of the vehicle but on the contrary highlights the disadvantages. The technology testing program indicates potential increase in travel time by changing the business model and consolidating goods. The lack of goods consolidation is one of the most important barriers for this type of business in the city.

4.5.3. IMPACT ON ROAD SAFETY

Overall, the perception of SolutionsPlus vehicle safety was rather low. The rider participating in the pilot survey completely disagreed when asked their perception on whether the SolutionsPlus vehicle is safer than that previously used. Additionally, one accident happened to one of the riders during the pilot. Moreover, one participant completely disagreed, one disagreed, two were neutral, and one agreed that the regular use of SolutionsPlus vehicles would improve the general road safety in Montevideo. Some considerations should be considered such as gender, age of the rider, type of vehicle, street conditions, etc. Deficit in bike and e-bike city infrastructure in Montevideo is one of the most important barriers for the development of this type of goods transport mode grows.

4.5.4. IMPACT ON QUALITY

Quality dimensions were assessed based on a user survey conducted during the pilot implementation. Three respondents (logistics operators, riders) assessed the quality

dimensions on a 5-point Likert scale (strongly unsatisfied – strongly satisfied).
Perceived safety. Two of the respondents were unsatisfied and one strongly satisfied with the safety of the implemented vehicles.

Suitability for changing weather conditions. One of the respondents was strongly unsatisfied, one unsatisfied, and one neutral regarding their perception of the suitability for changing weather conditions.

Comfort. One of the respondents was strongly unsatisfied, one unsatisfied, and one neutral regarding the comfort of using the implemented vehicles.

Ease of driving. Two of the respondents were strongly unsatisfied and one neutral regarding their perception on the ease of driving with the implemented vehicles.
Ease of charging. Two of the respondents were neutral and one satisfied with the ease of charging the implemented vehicles.

Perceived security. One of the respondents was strongly unsatisfied, one unsatisfied and one satisfied with the personal security of using the implemented vehicles.

Perceived continuity of journey chains. One of the respondents was unsatisfied and two were neutral when asked about the perceived continuity of the journey chains using the implemented vehicles.

4.5.5. Impact on existing fleet and modal share

The demonstration had very little impact on the existing vehicle fleet, since only two e-cargo bikes were introduced in the context of the SolutionsPlus demo. Three out of five survey respondents had used ICE scooter/moped before for some of the deliveries but also bicycle, e-cargo bike and tricycle had been used.

4.5.6. Impact on transport work with EV (freight)/ total vehicle kms performed

The vehicle km performed per day was 31 km and total kilometres travelled 187. The vehicles made in average 26 trips per day, 156 trips in total and delivered 15 packages per day, 90 in total. The tested cargo-bikes hold a potential for decreasing the transport kms due to their larger carrying capacity, but the present business model does not support such development.

4.5.7. Willingness to pay for the e-mobility services

The participating riders and operators were hesitant when it came to their willingness to acquire the SolutionsPlus vehicle. When asked whether the participating logistics operators and riders would be willing to buy the vehicle they had used, one (33.3%) responded No and two (66.6 %) responded Maybe. Moreover, we assessed the operating costs and revenues for the piloted vehicles and the vehicles used previously (bicycle and motorcycle). The calculations were presented in Table 14.

4.5.8. Market share of e-mobility

Due to the small scale of the demonstration, the increase in freight trips conducted using e-cargo bikes in the Montevideo area is marginal.

4.5.9. Impact on employment

The vehicles used in the demonstration were manufactured locally by three companies, which might have a slight positive impact on employment in the city.

5 SCALED-UP IMPACT ASSESSMENT - CHARGING INTEROPERABILITY

The Montevideo scaled-up impact assessment considers a development of interoperable charging that will enable e-vehicle owners to charge their vehicles at multiple charging points regardless of the charging point operator, thus making charging more convenient.

5.1. BACKGROUND

While private charging at home and at work remains the predominant means for charging e-vehicles, public charging infrastructure plays an important role in fulfilling EV users' charging needs if driving for a longer time/distance or not having the possibility to charge at home or at work. Notably, public charging infrastructure can reduce range anxiety and build confidence in the future EV market (Greene et al., 2020; Potoglou et al., 2023). For example, in the EU, a ratio of 10 EVs per charger is also recommended by the alternative fuel infrastructure regulations, and prior research indicates that to encourage e-vehicle uptake, the ratio of EVs per charging point should be between 5 and 25 (Harrison & Thiel, 2017; European Court of Auditors).

The main actors involved in charging infrastructure and service provision are charging point operators (CPOs) and mobility service operators (MSOs) that have distinct tasks (Anadón Martínez & Sumper, 2023). CPOs install and manage the charging infrastructure whereas MSOs manage the operations and end-user services (Anadón Martínez & Sumper, 2023). Public charging point operations mainly comprise three different business models (Yong et al., 2023). In the network-operator model, the charging providers construct and manage the charging network but leave the control over fee structures, along with business risks, to the site hosts (MSOs). In the owner-operator model, the charging providers construct and manage their own charging network, and charge customers for their services. Finally, in the integrated model, the operator builds its own charging equipment, develops the charging network, sets the pricing, and invoices users for service use (Yong et al., 2023).

These different business models, however, pose problems to charging point interoperability, i.e., the ability of electric vehicles to interact with different chargers, and for payments to be processed between charging service providers that operate charging different charging networks. This poses difficulties for EV users in finding and accessing compatible charging points, and may also necessitate the use of multiple applications, subscriptions, and payment methods to charge their vehicles across charging networks. This makes the use of public charging points more laborious and complex.

To tackle these conundrums, different ways to improve charging interoperability have been developed. One of these ways is establishing charging roaming, where each operator has their own payment platforms, but it is possible for the user to use other operators' networks for an extra roaming fee without having to subscribe or download a separate application. Payment roaming can be based on peer-to-peer bilateral agreements between service providers, that mainly uses Open Charge Point Interface protocol (OCPI), or centralized hubs that enable their members integration with various partners, that mainly use Open InterChange Protocol (OICP). Interoperable payment also enables umbrella payment platforms that cover different networks.

5.2. BASELINE SCENARIO

The baseline scenario for assessing the Montevideo scaled-up concept is the projected future development of the e-vehicle fleet and the charging infrastructure under the assumption that an interoperability scheme is not deployed, i.e., a 'do-nothing scenario'.
Table 15 presents the 2-wheeler fleet evolution and Table 16 the 3-wheeler fleet evolution, and Table 17 the urban vehicle fleet evolution by vehicle type in Uruguay. As can be seen, only a fraction of the fleet is electric.

Table 15. 2-wheeler fleet in Uruguay.

Year	2-wheelers	Gasoline	Electric	%
2017	482685	482264	421	0,09%
2018	483679	483078	601	0,12%
2019	469159	468362	797	0,17%
2020	450884	449959	925	0,21%
2021	444166	442898	1268	0,29%
2022	446102	444248	1854	0,42%

Table 16. 3-wheeler fleet in Uruguay.

Year	2-wheelers	Gasoline	Electric	%
2017	3573	3424	149	4,17%
2018	3651	3434	217	5,94%
2019	3629	3286	343	9,45%
2020	3712	3256	456	12,28%
2021	3806	3253	553	14,53%
2022	4051	3347	704	17,38%

Table 17. Urban vehicle fleet evolution in Uruguay.

	Urban vehicles							Hybrids		EVs	
Year	Cars	Pick Up	Vans	SUV, Crossover & Rural	Taxis	Remises	Total Urban Vehicles	Total	%	Total	%
2017	539046	142474	56164	82887	4454	2073	827098	180	0,02%	101	0,01%
2018	566161	153568	58856	90706	4559	4516	878366	1019	0,12%	175	0,02%
2019	578155	160230	60006	96186	4588	3923	903088	1903	0,21%	237	0,03%
2020	584094	165274	60542	101657	4569	3263	919399	2570	0,28%	331	0,04%
2021	596629	175292	62179	111064	4515	3427	953106	3823	0,40%	857	0,09%
2022	606440	185056	63241	121803	4466	2776	983782	5462	0,56%	1860	0,19%

As of 2023, most of the charging points in Uruguay are owned and operated by the public institution National Administration of Power Plants and Electrical Transmissions (UTE) with 174 charging points of the total 200 (87 %), whereas another charging point operator Effiza owns and operates a network of nine charging points (4,5 %). Other public charging points include destination charging, such as those operated by the airport operator Aeropuertos Uruguay.

In the baseline scenario, the existing state remains unchanged, wherein most of the new public charging points are operated by the National Administration of Power Plants and Electrical Transmissions (UTE).

For the baseline Scenario, we expect the charging network development to follow current projections, reaching 276 charging stations by 2025 as presented in Table 18.

Table 18. Baseline charging network development
(Statista, 2023).

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Number of charging stations	26.00	36.00	56.00	56.00	58.00	131.00	204.00	276.00	349.00	422.00	495.00

We also assume that the e-vehicle sales follow current projections, reaching 2,137 BEVs, 366 hybrid plug-in vehicles, and a total of 2,503 electric vehicles sold yearly as presented in Table 19.

Table 19. Baseline e-vehicle sales in Uruguay
(Statista, 2023)

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Battery Electric Vehicles sales	34	36	119	644	1347	1508	1795	2137	2543	3028	3604
Plug-in Hybrid Electric Vehicles sales	22	15	43	262	282	292	327	366	410	458	513
Total sales	56	51	162	906	1 629	1 800	2122	2503	2953	3486	4117
Cumulative total sales	56	107	269	1175	2804	4604	6726	9229	12182	15668	19785

Based on these projections, while assuming that the total number of EVs equals to the cumulative total sales, the number of charging points per 1000 EVs will decrease to 29.9 by 2025.

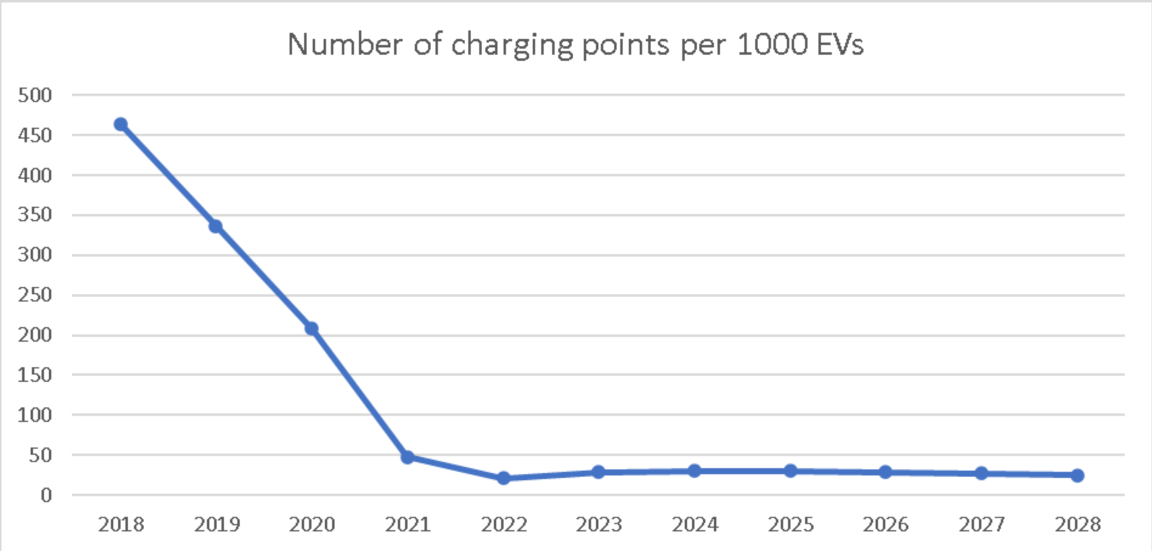

Figure 7. Projection of the number of charging points per 1000 EVs.

5.3. SCALED-UP SCENARIO DESCRIPTION AND ASSUMPTIONS

The scaled-up concept considers the development and uptake of interoperable e-vehicle charging. The interoperability focuses on creating a platform which allows e-vehicle owners to charge their vehicles at various charging points using a single app or a membership card, regardless of the charging point operator.

Business models. We assume that the deployment of interoperability will enable new charging businesses to enter the market. This is based on the notion that interoperability will enable new network operators and owner-operators to enter the market and diversify the charging infrastructure in Uruguay that is currently dominated by the UTE. With interoperable charging systems, new network operators can establish charging networks that seamlessly integrate with existing infrastructure, contributing to overall interconnected charging. On the other hand, owner-operators can enter the market with the flexibility to construct and manage their own charging networks that is integrated within the existing network. Overall, one of the assumptions for the assessment is that interoperability removes barriers and allows new entrants to compete on a more equal footing, contributing to market developments in Uruguay.
Charging network, charging time and availability. We assume that the enabling of new business models due to interoperability will improve the quality of the charging network, which will contribute to charging availability in many locations and decrease the charging time at the charging point due to less queueing. Firstly, this is based on the assumption that interoperability will open the field for other charging operators in Uruguay, which is currently dominated by the UTE, as previously described.

Secondly, for the scaled-up scenario, we assume that all new and existing charging point operators will open their networks to the interoperability scheme, which will improve the quality of the charging services. This is because interoperability will simplify the payment methods and thus make charging less time-consuming, and due to all charging points being operational with a single platform, save app downloads for consumers (Department for transport, 2022). Moreover, user preferences for interoperable charging have been demonstrated by prior research (Visaria et al., 2022).

E-vehicle adoption. We assume that as interoperability will enable charging network development, it will facilitate a larger number of EVs and accelerate EV adoption in Uruguay. Although interoperability and the following charging infrastructure improvements to be expected is only one factor affecting e-vehicle adoption, and there is a lack of research on its effects, existing between countries and areas comparisons, and recommendations for the EV to charging point ratio provide a frame of reference for this assumption. On average, in the top e-vehicle countries, there are 153 public chargers per 1000 vehicles (97 slow chargers and 56 fast chargers). However, this varies depending on whether consumers typically have access to home charging. For example, in Norway and the US, where most consumers have a possibility to charge at home, the ratios are 61 and 72 chargers per 1000 vehicles respectively (Hardman et al., 2018). In a study conducted in the UK, the correlation between the number of e-vehicles and charging point connectors in different boroughs was found to be 0.53 (0.60 for rapid chargers, 0.47 for fast chargers and 0.44 for slow chargers) (Jordan et al., 2020). Other studies have, however, found that installing more than one charger per 10 EVs (100 charging points per 1000 vehicles) leads to little gains in terms of e-vehicle sales, while posing unnecessarily high costs, whereas the impact on charging point provisions is relatively insensitive at the levels below 5 vehicles per charging point

(200 charging points per 1000 vehicles) and above 25 vehicles per charging point (40 charging points per 1000 vehicles) (Harrison & Thiel, 2017). The ratio of 10 EVs per charger is also recommended by the EU alternative fuel infrastructure regulations (Special Report 05/2021: Infrastructure for Charging Electric Vehicles: More Charging Stations but Uneven Deployment Makes Travel across the EU Complicated, n.d.). This leaves to a rough and simplistic estimation that providing one charging point could result in an increase of 5-25 new e-vehicles. Additionally, the ease of charging due to interoperability can be assumed to have a direct effect on e-vehicle adoption in Uruguay, while we can assume that this is marginal in comparison to the effect resulting from the improved charging network coverage.

5.3.1. Financial impacts

Introducing interoperable charging payment will pose various one-off and direct costs for charge point operators (CPOs) and service providers. According to (Department for transport, 2022), the costs for setting up interoperable charging include the following:

- One-off labor costs related to setting up a roaming agreement, such as developer time and legal fees.
- One-off familiarization costs for CPOs to learn how to use the interoperable system and comply with the agreement.
- Roaming agreement fees charged by the service provider for each charging session provided by the roaming agreement in case roaming option is implemented.

On the other hand, the monetized benefits of interoperable charging result from the assumption that it will increase the utilization of charging points by making them more attractive and accessible to electric vehicle (EV) users. This will generate more revenue for CPOs and service providers.

Furthermore, given the assumption that interoperable charging would increase e-vehicle uptake in Uruguay, it will increase the customer base of CPOs and service providers, and therefore increase the revenue.

5.3.2. CLIMATE-RELATED AND ENVIRONMENTAL IMPACTS

Interoperable charging means that electric vehicles (EVs) can use any compatible charging point across different networks and pay for the service with a single method. This can ease the range anxiety of EV owners, who may worry about running out of battery power on long trips or in unfamiliar areas. By making EV charging more convenient and accessible, interoperable charging can encourage more households to switch from internal combustion engine (ICE) vehicles to EVs, or to use their EVs more frequently if they have both options. This can result in lower CO2 emissions from road transport, as EVs generally have a lower carbon footprint than ICE vehicles, especially when powered by renewable electricity sources.

Additionally, interoperability could potentially lead to an increased adoption of e-vehicles, and therefore have indirect impacts on greenhouse gas emissions as well as local air pollutants due to larger share of the fleet being electric.

5.3.3. Social indicators

Quality of services. Having to have a different app for each charging operator has been identified as a major hurdle that hinders the user experience of BEV owners by prior research (Figenbaum et al., 2022). Therefore, interoperability is likely to improve the quality of services as it allows users to use different operators charging points using a single application.

Impact on accessibility. Interoperable charging can be assumed to be a key feature in improving the accessibility and convenience of charging stations for electric vehicle (EV) users in Uruguay. It allows EV drivers to charge their vehicles at any station, regardless of the network provider or the vehicle brand. This eliminates the need for multiple subscriptions, simplifies the payment process, and reduces range anxiety.

Affordability of e-mobility services. We anticipate that the expanded charging interoperability will influence the affordability of charging services, driven by two key assumptions. Firstly, interoperability will incur costs to charge point operators, including labor costs, legal costs and agreement fees. This could potentially result in increased costs for users, especially if charging point operators opt to absorb these additional expenses. However, interoperability may also increase the level of price competition as it enables new operators to enter the market in Uruguay, which could result in decreased prices in the long term. Additionally, based on the assumption that interoperability will improve the charging network in Montevideo, the demand for used electric vehicles that have a reduced range might increase due to decreased range anxiety. This could make e-vehicles more affordable and accessible to the public.

Impact on travel time. Interoperability will allow EV users to access a wider network of charging points from different operators. This will potentially decrease the time spent by EV drivers to find and access charging stations. Moreover, interoperability will decrease the time spent at the charging station as it improves the ease of using charging stations from various operators. Additionally, due to the wider range of charging point options, the waiting time at the charge points is likely to be reduced as they have the option to use other providers networks. In a similar vein, interoperability is likely to decrease the number of helpline calls as well as app downloads, which will result in time savings for EV users.

Impact on security. The transferring of transaction information in the network entails security and privacy issues. The OCPP-related attacks comprise physical, cyber or cyber-physical attacks (Garofalaki et al., 2022). In Uruguay, security is a key consideration when developing interoperable charging according to the interoperable charging developers. For instance, CPO systems must acquire updated security certificates, and in most instances encrypted communication between loads and servers is used. Moreover, a token is established to ensure secure communication between CPO and the eMSP.

Impact on employment. The setting up of interoperable charging will demand labor, including legal and technical labor of setting up agreements. However, it can be expected that interoperability will also reduce the need for helpline personnel due to charging becoming simplified (Department for transport, 2022).

6 DISCUSSION

In Montevideo, the main identified problems in freight transportation include lack of adequate space for unloading cargo, which affects especially small businesses in the city, and leads to parking violations. Moreover, the city faces difficulties in coordinating deliveries, which concentrate on the same time windows, leading to longer travel times and consequent costs. At the same time, the waiting times for cargo unloading and the time for searching parking pose problems to logistics operations, together restrictions for ICE vehicles.

To tackle these challenges, e-cargo bikes were implemented in Montevideo to courier deliveries. The pilot implementation took place within two weeks in December 2022, during which 2 cargo bike models were tested. Throughout the pilot, 156 delivery trips were made that covered a total distance of 187 km.

Given the information obtained during the pilot, for Long John e-cargo bike mode, the after tax NPV is 2,521 USD, IRR 47%, and payback period 1.79 years, while the respective indicators for the implemented e-3 wheeler were 2,605 USD, 41.6 % and 1.92 years. Furthermore, based on the pilot operations, the yearly CO2 savings per vehicle are 670kg, based on the assumption that they replace ICE motorbikes that were used for conducting deliveries.

The pilot participants were previously unfamiliar with e-cargo bikes which was likely to have an effect the pilot impacts. Therefore, the implemented vehicles were perceived e.g., as unsafe, difficult to operate and uncomfortable. With long-term implementations that increase rider familiarity with e-cargo bikes, such issues could be expected to become mitigated.

Additionally, the operating scheme and business model that focused on direct deliveries from origin to destination failed to take advantage of the benefits that e-cargo bikes provide in comparison to ICE motorbikes (i.e., larger capacity for carrying goods). This is likely to be one of the main reasons why the implemented e-cargo bikes increased the delivery time and hindered the efficiency in comparison to ICE motorbikes that were previously used. Overall, considerations should be given to find appropriate operational and business models to realize the potential of e-cargo bikes.

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