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Light electric vehicles in winter conditions

Findings of eight different vehicles' test drives in Turku, Finland, January 2019

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CONTENTS

1 INTRODUCTION

This report covers piloting of eight different light electric vehicles (LEVs) in Finnish winter conditions. This study supports and supplements the work of Turku University of Applied Sciences in work package 3 of the *BSR Electric* project. The tested vehicles were loaned from the city of Turku who runs their own e-mobility pilot under the Horizon2020 funded *Civitas Eccentric* project.

The devices were tested during five days on the period of 16 - 30 January. The test team consisted of four student assistants of Turku University of Applied Sciences, all of whom study in Bachelor's degree programme focusing on energy & environmental technology. This report was first conducted in Finnish and was then translated to English by Eetu Simpanen.

The performance of the vehicles and their batteries was tested by driving various routes in and around downtown Turku. Test drives took place both along a well-maintained *winter cycling test route* and outside it on other bicycle lanes.

In addition, a speed test was performed in order to check the accuracy of the vehicles' speedometers and the vehicles' compliance with the current Finnish legislation on light electric vehicles.

Image 1 For speed test at the Kupittaa park the test team used radar speed-meter *Stalker ATS*

Winters are typically rather mild in coastal Finland and the amount of snow varies: according to weather statistics the average January temperature of Turku is -4°C. This held true also during the test period 16 - 30 January as temperatures ranged from 0 to a few minus degrees Celsius. At the beginning of the test period in mid-January there was only some snow on the ground but then a heavy blizzard hit the country challenging cities' road maintenance and causing several problems in the traffic all around southern Finland. The above average snowfall challenged the performance and low ground clearance of the tested LEVs as well.

The tested vehicles are listed below, and the current Finnish legislation related to LEVs is shortly discussed in the second subchapter. Each vehicles' test outcomes are discussed in chapter 2 and conclusions are drawn in chapter 3. The tested vehicles' main features and test performances are listed in table format in Annex 1.

If not mentioned otherwise, the photos are taken by the student team.

1.1 Term discussion

The markets of *light electric vehicles* (LEVs) are under development and new types of vehicles appear constantly. The legislations on LEVs vary between countries and the trade names of the products differ between markets. For instance, the tested Xiaomi's product is in this report called a *standing scooter* but in many contexts this product category is labelled as *kickbikes* or simply *e-scooters*. In this report the term *light electric vehicle* (LEV) is used as an umbrella term covering different types of vehicles from electrically assisted cargobike to the named small standing scooter. This practice is in accordance to the definition coined ten years ago by *Light Electric Vehicle Association LEVA*:

> "Light electric vehicles are defined as battery, fuel cell, or hybrid-powered 2-or-3-wheel vehicles generally weighing less than 200 pounds (100 kg). Of this group, electric bicycles (e-bikes) are most common."
>
> Excerpt of a press release by LEVA at ExtraEnergy.org on January 9, 2009

1.2 Tested vehicles

Five out of eight of the tested vehicles are still on the market and the manufacturer or marketer provides thorough product information on their websites. *Skand*'s scooters and *Kalkhoff*'s special edition e-bike are at the time of writing not any more in the market and no product information was available to the test team so these devices' technical specifications are only discussed very shortly.

1. Ordinary electrically assisted bicycle (pedelec) *Kalkhoff Jubilee Move* 	2. Electrically assisted cargo bike *Babboe Big-E* 
3. E-scooter with pedals *Skand ZT-09* 	4. Ordinary e-scooter *Skand ZT-09* 
5. Small standing scooter *Xiaomi Mi M365* 	6. Large standing scooter *Ribber* 
7. Fourwheeled mobility assistance scooter *Skand Leijona 1400* 	8. Fourwheeled mobility assistance scooter with a cabin *Skand goMOTO 2.4+* 

1.3 Light electric devices in Finnish legislation

Light electric mobility devices have been road-legal in Finland since beginning of 2016. In the legislation on road traffic these devices are divided in three main categories:

1. Devices to assist or replace walking, such as electric skateboards and light scooters
2. Light electric vehicles, such as *Segway* and mobility scooters
3. Electrically assisted and motorised cycles

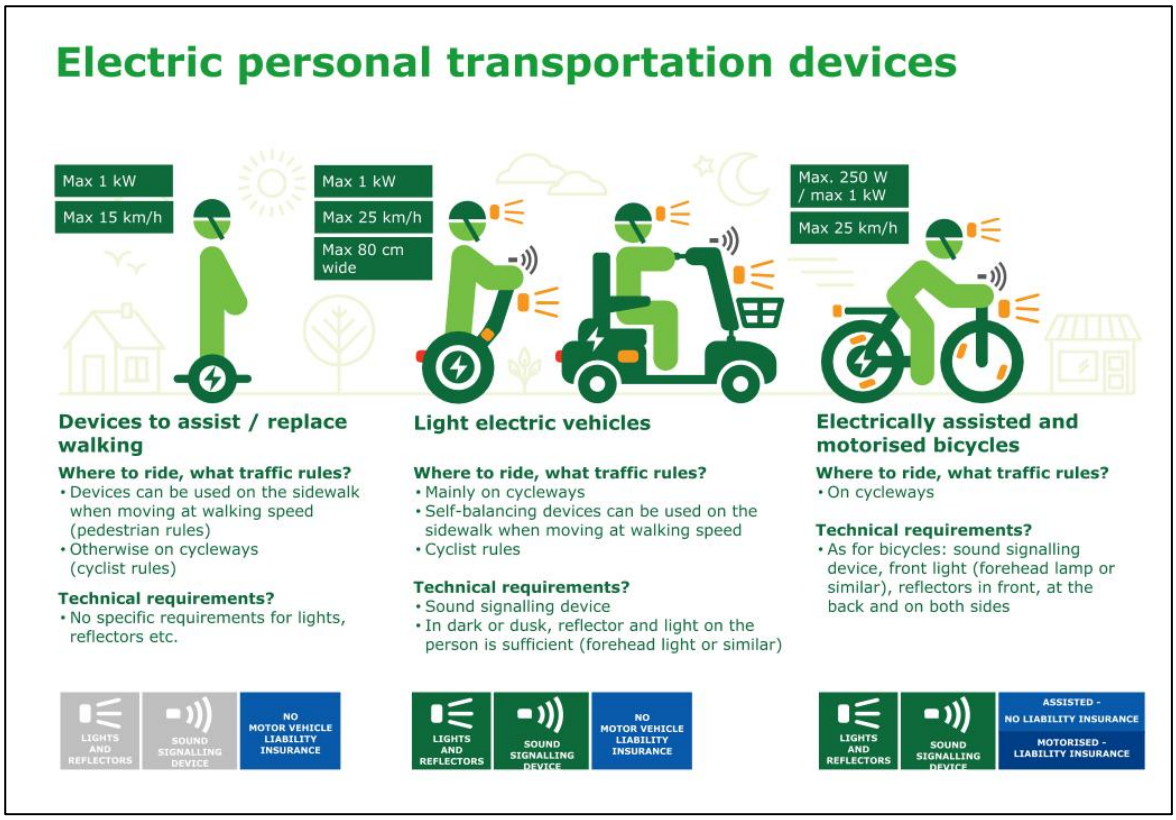

Image 2 Categorisation of electric personal transportation in the Finnish legislation (TrafiCom, 2019)

As we can see in the image above, the **devices in the first category** have a speed limit of 15 km/h and their motor can have up to 1 kW of nominal power. These devices are allowed to be used on sidewalks when moving on walking speed. However, at higher speeds the driver has to follow the same rules as cyclists and use cycleways. For these devices there are no requirements concerning lights, reflectors or sound signaling devices. This report does not cover any device from this category.

The **devices in the second category** are allowed to drive up to 25 km/h and they should mainly use cycleways, however self-balancing devices like Segways are allowed to be used on sidewalks at walking speed. The width of devices in this category may not exceed 80 cm and the device must be equipped with lights, reflectors and a sound signaling device.

Electrically assisted and motorized bicycles of **the third category** are concerned equivalent to ordinary bicycles if the auxiliary electric motor has a maximum continuous rated power of 250 W, of which the output is progressively reduced and finally cut off as the vehicle reaches a speed of 25km/h (15.5mph) or if the cyclist stops pedaling. These requirements comply with the European Union directive 2002/24/EC on pedal assisted electric bicycles. In addition, the Finnish legislation sets a limit for the nominal power of the pedelecs' motor at 1 kW. If the e-bike does not fit the mentioned criteria the Finnish law sees it equivalent to a moped or motorbike.

2 EXPERIENCES AND COMMENTS ON THE TESTED DEVICES

In this section the test team's experiences on the eight different vehicles are discussed. As a basis for the tests the student team used questions which had also been asked from the City of Turku's personnel participating in their e-mobility pilot. Out of the following four questions the test team concentrated on 1,2 and 4:

1. **Suitability of the device in year-round use,** concerning for instance battery life and tires in winter conditions
2. **Suitability of the device in different needs and weather conditions**. Also the demands for the road infrastructure are concerned.
3. Compliance of the devices with the current road traffic legislation
4. The electrically assisted bicycles' **compliance to the laws regarding bicycles**

Image 3 Student team about to race with three of the tested vehicles: *Skand goMOTO 2.4+*, *Skand ZT-09* and *Skand Leijona 1400*
Photo credits: Suvi Harvisalo, TUAS.

2.1 Ordinary electrically assisted bicycle *Kalkhoff Jubilee Move*

Technical specifications

The bicycle is equipped with a brushless electric motor featuring nominal power of 250 Watts. The charging time of the 416 Wh Li-ion battery with 11 Ah capacity is some 5 hours. The detachable battery can be found under the seat attached to the seat tube. In ideal weather conditions and lowest assistance level the driving range is expected to be approximately 140 km.

User experiences

Kalkhoff Jubilee Move was found to be easy to use even for a person who did not have previous experience of electrically assisted bicycles. Driving the bicycle was simple and the motor's assistance allowed comfortable driving even on snowy and bumpy roads. Acceleration of the bicycle was easy thanks to the assistance feature, which noticeably automatically turned off at the speed of 25 km / h. After some 6 kilometers of driving on different roads and speeds the battery symbol indicated less than half of the capacity being used.

2.2 Electrically assisted cargobike *Babboe Big-E*

Technical specifications

The cargo bike is 217 centimeters long, 88 cm wide and 110 cm high. *Babboe Big-E* features a 250 Watt electric assistance motor and a detachable 375 Wh Li-ion battery, which is located under the back carrier. After a full charge (some 4-6 hours) the battery allows assisted driving range of approximately 40-60 kilometers. The cargo box carries up to 100 kg of carriage or 4 children and is equipped with foldable benches and seatbelts. The weight limit for the driver is 100 kg.

User experiences

Despite its notable size the cargo bike was surprisingly easy to drive and handle. *Babboe Big-E*'s steering system has a tilting feature, which makes turning the large vehicle easier in comparison to some other cargo bikes the test team had tried earlier. However, an inexperienced driver might be slightly frightened of the tilt as one could feel like the whole bicycle was falling on its side. Despite the advanced

steering system, the turning radius of the bike is wide and needs to be taken into consideration in traffic: one must slow down before any major turns and sharp turns are simply impossible to maneuver.

Thanks to studded winter tyres slipperiness was not an issue but wet snow on the ground made driving hard even if the assistance was turned on. Even on a clear road the sheer size and weight of the robust cargo bike made it impossible to reach maximum speed of 25 km / h so speeding is clearly not an issue with *Babboe Big-E*. Either way the test team missed having a speedometer on the handlebar as the bike in use didn't have one. The battery charge indicator showed different levels depending on the speed and load of the cargo bike so the driver might have felt somewhat confused on the available driving radius.

Images 4 and 5 The wider vehicles such as the cargobike and the mobility assistance scooters had challenges to fit on the bicycle lane in places where banks of snow or construction sites had taken over.

2.3 E-scooter with pedals *Skand ZT-09*

Technical specifications

This scooter features pedals like a bicycle, though smaller and they work differently. The device is equipped with a 1,12 kWh detachable battery which is located under the seat. With a full charge the scooter has driving range of 20-60 km.

User experiences

The scooter's pedals regulate the speed but in a different way than in an ordinary bicycle or an electrically assisted one: The thrust of the motor depends on the kick of the driver but in order to change this speed one must first gently brake and then pedal differently. In other words, the regulation of the speed is not continuous, and this unique logic requires some extra attention.

Due to the pedal system this type of a scooter might not be the best alternative in busy downtown traffic but is likely to be comfortable on longer rides as the driver can simply sit and enjoy the ride as the scooter drives smoothly until braked. However, this feature of not having to pedal or turn a handle in order to keep the motor driving might also pose a risk in situations when the driver for one or another reason loses control and ability to brake and the motor keeps on driving at constant speed.

Image 6 *Skand*'s e-scooter with pedals was challenging to drive in variable downtown traffic due to the strange speed regulating system

2.4 Regular e-scooter *Skand ZT-09*

Technical specifications

The red Skand ZT-09 was a modified version of the white namesake as the pedals had been replaced with a retrofitted regular gas handle.

User experiences

This more regular scooter was very simple to use and more logic than the one featuring pedals. Several passersby commented on the scooter driver at traffic lights as they took it as a traditional petrol driven scooter which is not allowed to be driven at most bicycle lanes. After being corrected these people very excited of the new technology.

In the speed tests the scooter reached 27 km/h according to its own speedometer but according to the radar the speed was 25. So the scooter is road-legal but the tested vehicle's speedometer wasn't working properly.

This scooter had the weakest battery of the tested vehicles as the device ran out of power after only some 8 km of driving. At that time the temperature was not colder than - 3°C and the scooter had been stored in a warm garage prior to the test drive. Handling of this scooter on a slippery road was easier than with the pedal version because changing speeds was easier using the traditional gas handle.

2.5 Small standing scooter *Xiaomi Mi M365*

Technical specifications

The compact Xiaomi Mi M365 weights 12,5 kg and can be folded for storage or when carrying it for example in public public transportation. In full size the scooter is 108 cm long, 43 cm wide and 114 cm high, and after folding 108 x 43 x 49 cm. The scooter's brushless electric motor is located inside the 8" front wheel, has nominal power of 250 Watts and peak power of 500 W, allowing the scooter up to 16 Nm torque. The 280 Wh 36V battery is located under the deck and charges full in 5 hours. The only visual information in the handlebar is the battery charge indicator but with Xiaomi's smartphone application it's possible to see current speed ride statistics etc thanks to the scooter's Bluetooth feature. The scooter has two brake systems: traditional disc brake in the back and e-ABS regenerative anti-lock brake

in the front. Other safety features include a classic signal bell in the handlebar, led headlight and red taillights for braking. In optimal conditions (75 kg load, 25 °C temperature and no wind) the manufacturer promises approximately 30 km range for the scooter. Xiaomi M365's maximum load is 100 kg.

User experiences

Xiaomi scooter is beautifully designed and easy to use but the sleek and thin tires did not perform well in winter conditions: loose snow got stuck around the tires and on an icy surface the driver easily lost control of the device and then of their balance. Therefore, this vehicle cannot be recommended for snowy and icy roads. Furthermore, steeper hills like Sepänkatu leading to our campus were too much for the scooter's engine. Due to these challenges the test team did not see it necessary or safe to drive Xiaomi's battery empty.

2.6 Large standing scooter *Ribber*

Technical specifications

With its 9,5" wide "fat" tires Ribber is very large example in the standing scooters' range of vehicles as the total width is 75cm, height 77 cm, length 175 cm and weight 60 kg. The scooter's brushless motor is located inside the back tire's rim, has nominal power of 1 000 Watt and can drive up to 45 km/h, though in Finnish road traffic 25 km/h is the highest allowed speed for such devices[1]. The 60 V, 20 Ah battery is located under the deck and allows up to 50-80 km driving range. Ribber features hydraulic disc brakes and a headlight. The maximum load of the Ribber is 200 kg.

Ribber's v-shaped handlebar features a safety lock with a classic metallic key, gas handle, brake handles and a battery charge indicator. Ribbber's built-in Bluetooth connection can be used either for an anti-theft feature or to tune the motor's settings.

[1] See Chapter 1.2. for more information on the law

User experiences

Ribber looks like the *Harley Davidson* of standing scooters and is very comfortable to drive in normal road conditions thanks to the wide tyres and low center of gravity. In more slippery winter conditions, the beast's fat tyres didn't, however, have enough grip for instance in loose snow. Also starting off was difficult as the back tire kept spinning on the icy ground. And once the vehicle was moving the driver had to pay extra caution to the surface as loose snow caused the wheels to spin and braking was difficult, too, as the tyres didn't have enough friction. Another thing to keep in mind upon driving was the rather wide turning range of the vehicle.

Even in mild subzero temperature the vehicle's driving range was rather good as the vehicle's battery run out first after some 17 kilometers of varying drive.

Apart from better winter tyres, the test team also missed some signaling device as Ribber doesn't have any blinkers; using one's hand as signal while turning can be difficult especially if the driver must pay extra attention to the surrounding road and traffic.

In addition to street credible looks the designers of the vehicle have paid attention to practicality as Ribber is surprisely easy to push around when taking it to storage or parking. Extra points were given for the basket behind the seat for the driver's bag or small cargo.

Image 7 Despite the convincing looks Ribber's fat tyres didn't perform well in winter conditions. Photo credits: Heta Laiho, TUAS.

2.7 Fourwheeled mobility scooter *Skand Leijona 1400*

Technical specifications

Leijona 1400 is 152 cm long, 68 cm wide and 105 cm high. The four-wheeler has road clearance of 13 cm and all wheels feature spring suspension. The vehicle is rear-driven and the 1 kW motor has three gears: two forwards and reverse. The vehicle's 1,4 kWh non-detachable battery sits under the seat and enables up to 55 km driving range after a 4-8-hour full charge. The vehicle weighs 126 kg and can carry 140 kg.

The vehicle's safety features include blinkers, sound horn, wing mirrors, headlight and rear lights. In addition to a speedometer the scooter's dashboard features an USB port which can be used to charge a smartphone or other device.

User experiences

Leijona 1400 was found to be surprisingly well performing. Thanks to studded tyres and powerful motor Leijona did well even on snowy and icy roads.

The vehicle's torque was put to a test in some of Turku's hills with following results: Leijona survived the well maintained Kaskenkatu hill but steeper and snowier Tinanvalajankatu was already too much. Also higher banks of snow caused the lion (leijona in Finnish) real problems as its belly got stuck in the snow and the four-wheeler came to a full stop. At such occasions the driver had to get off, start pushing and perhaps even ask for helping hands as the vehicle is rather heavy.

In addition to the road clearance the user must pay attention to the gas handle's lag: when handling the vehicle in a garage or some other tight space it's sometimes easier to push the vehicle around than try to maneuver minor moves back and forth.

Leijona 1400's battery performed well and only during the last test day the device run out of energy after some 15 kilometers of very variable driving. Also the lockable box behind the seat earns the vehicle extra points.

The test team missed more exact digital displays in the dashboard as the ones with needle didn't show either speed or battery charge level very precisely. Another nuisance was the blinkers' switch: operating the small switch on the left-hand side of the dashboard required extra attention especially when wearing winter gloves. Further on, after the turn the driver had to remember deactivating the blinkers by pushing a small knob in the center of the switch.

Images 8 and 9 Snowbanks caused by road maintenance and less maintained paths with soft snow were impossible to cross with *Skand Leijona 1400*'s 13 cm road clearance

2.8 Fourwheeled mobility scooter with a cabin *Skand goMOTO 2.4+*

Technical specifications

GoMoto 2.4+ is 192 cm long, 80 cm wide and 155 cm high. The fourwheeler's road clearance is 18 cm and the vehicle's brushless motor has 1 kW nominal power. GoMoto's 2,4 kWh, 20 Ah non-detachable battery sits under the driver's seat and allows some 20-100 km driving range after 4-15 hours of charging. The vehicle weighs 175 kg and can carry 125 kg. There's a small back seat in the vehicle and the driver can have one passenger under 12 years of age – just like with bicycles.

User experiences

GoMoto 2.4+ performed well with its studded wheels on even, well maintained roads and even after some 20 km of driving the battery charge indicator showed half-full. However, just like the other four-wheeler, also this one had difficulties with bumps, pot holes and higher banks of snow. After own experience the test team

can tell that this vehicle is quite heavy to push if it gets stuck. On the latter test drive days there were lots of snow banks on sides of the streets and in some places these banks gained ground also from cycleways. In such conditions the 80 cm wide Go-Moto 2.4+ didn't always fit on the cyclist side of the lane marks but had to be partially driven on the pedestrian side. In other words, winter weather severely limits the usability of this vehicle in question.

At the speed test the lawful maximum 25 km/h was not reached as the highest performed speed against the radar speed-meter was only 23 km/h. However, at 23 the vehicle's own speedometer indicated 30 so the meter's accuracy left much room for improvement. Another subpar feature was the blinkers' switch: just like in the other four-wheeler, also in GoMoto 2.4+ the switch on the left-hand side of the dashboard was small and required extra attention especially when wearing winter gloves. Further on, after the turn the driver had to remember to return the switch back to its centre position in order to deactivate the blinker. Also the inside door handles were impractical and some users didn't intuitively know how to get out of the cabin. One can't but wonder why such impractical user interface has been designed on a device that is mainly aimed for elderly and other physically challenged people.

Image 10 Driver's view from the cabin of GoMoto 2.4+

Another design flaw the test team encountered is the height of the cabin; due to the low roof GoMoto 2.4+ is not suitable for over 180cm tall drivers specially if they wear woolly hats because taller user might hit their head to the roof after driving over some bump. It goes without saying that a rearview mirror would be impossible accessory for a taller driver but average and short people could find one useful.

Just like Leijona 1400, also GoMoto 2.4+ had a lag in the gas handle's reaction. In other words, when handling the vehicle in a garage or some other tight space it's perhaps easier to push the vehicle around than try to maneuver minor moves back and forth.

Image 11 Fourwheelers got stuck; A bank of snow by the crossroads was too much for the vehicles' low road clearance and they both got stuck.

3 CONCLUSIONS

The aim of the test drives was to find out whether the eight vehicles are fit for year-round use, for different kinds of weathers and mobility needs. Further on, the student team also assessed, whether the vehicles comply with the current Finnish traffic legislation which sees LEVs – under certain conditions – equivalent to ordinary bicycles.

The standing scooters were the only ones without studded tyres and by far the weakest performers on icy and snowy roads. The other six vehicles survived pretty well on different surfaces in the mild January weather.

However, after a blizzard some cycleways and tracks had became too narrow for the wider vehicles and the driver had to partially use the motor road or pavement. Further on, both four-wheeled mobility assistance scooters got stuck on some banks of snow due to their low road clearance. It must be noticed, though, that during the test period Turku faced a heavy blizzard and therefore the driving conditions and those snowbanks were much worse than on average winter days.

All vehicles' batteries lasted over five kilometers of driving in mild subzero conditions. It would have been very interesting to test the vehicles in even colder conditions in order to find out whether the batteries last in serious frost. Unfortunately, the tests had to be performed during certain time period so there was no option to wait for colder days.

In other words, according to the performed test drives it is impossible to say how the vehicles would perform in colder winter conditions.

The vehicles' compliance to the Finnish legislation was tested by metering their speeds. According to the radar speed-meter none of the vehicles' motors allowed faster than 25 km/h speed which is also the limit in the law.

Most of the vehicles could fit cycleways and thus be used as equivalent to ordinary bicycles but in some places the wider vehicles didn't fit on the marked lanes. Further on, it has to be noticed that some of Turku's cycleways are two-way so a cargobike could drive towards another one. In such a case the width of the current lanes would definitely not be enough for a safe encounter of the wider vehicles. Another challenge for driving in Turku are the hills: For instance, the Sepänkatu hill was too much for the small standing scooter Xiaomi.

The vehicles' performances and main features are listed in Annex 1.

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ANNEX 1: Tested vehicles' main features and test performances

Vehicle	Measures (L*W*H) [cm]	Measured max speed	Motor's mominal power	Battery capacity	Detachable battery	Driving range on full charge	Test drive length (approx.)	Battery status after test drive
Ordinary electrically assisted bicycle	-	31 km/h (no more assistance after 25 km/h)	250 W	416 Wh	Yes	Ca. 140 km	6 km	Over 50 % left
Electrically assisted cargobike	217*88*110	24 km/h	250 W	375 Wh	Yes	40-60 km	6 km	50-75 % left
E-scooter with pedals	-	24 km/h	-	1,12 kWh	Yes	20-60 km	8 km	About 50 % left
Ordinary E-scooter	-	25 km/h	-	1,12 kWh	Yes	20-60 km	8 km	0 %
Small standing scooter	108*43*114	24 km/h	250 W	280 Wh	No	Ca. 30 km	-	-
Large standing scooter	175*75*77	26 km/h	1 kW	20 Ah (kWh value not given)	No	50-80 km	17 km	0 %
Fourwheeled mobility assistance scooter	152*68*105	22 km/h	1 kW	1,4 kWh	No	Ca. 55 km	15 km	0 %
Fourwheeled mobility assistance scooterc with a cabin	192*80*155	23 km/h	1 kW	2,4 kWh	No	20-100 km	20 km	About 50 % left