SCI-Mobility Lab

Institute for Energy and Mobility Research EM at Bern University of Applied Sciences BFH

SCI-MOBILITY COMPARATIVE TESTS

Three electric drive systems for manual wheelchairs undergo our track tests. ▸ 2-6

Interview with the expert

Passive security expert Raphael Murri retraces the project's evolution. ▸ 1

User opinions

Two wheelchair users with reduced mobility share their exclusive reviews. ▸ 7-11

Berner Fachhochschule
Haute école spécialisée bernoise

CONTENTS AND PREFACE

Sebastian Tobler

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CEO and co-founder of GBY SA

Executive committee member of the Benefactors' Association of the Swiss Paraplegic Foundation

Preface by Sebastian Tobler

Imagine that you are a wheelchair user. You'll quickly realise that getting around isn't always easy. Fortunately, electric mobility aids exist. Electric mobility aids? This means that there is a range of possibilities and therefore, a choice to make. But which device is best suited to your needs? I have asked myself these very questions as a person with incomplete quadriplegia since July 2013. The SCI-Mobility Lab at Bern University of Applied Sciences BFH has tested three systems to gather factual data on their day-to-day use.

Measurements and comparisons, as well as two user reviews, made this initial assessment possible. We also raised questions concerning safety and even performed crash tests. The work compiled in this paper is the first in a series of studies, tests and comparisons in the context of reduced mobility.

I would like to thank all colleagues and students who made this work possible, as well as the suppliers of the equipment covered in this study.

I hope you enjoy reading it.

SCI-Mobility Lab, in a nutshell

Launched on 7 April 2022, the SCI-Mobility Laboratory of the School of Engineering and Computer Science at Bern University of Applied Sciences BFH combines technical expertise in vehicle construction and neurorehabilitation.

The unique concept of combining these two specialities in a laboratory stem from the dedication of its director and creator, Sebastian Tobler, to vehicle development and neurorehabilitation research, both as a patient and a researcher.

The SCI-Mobility Lab is supported by the expertise of the BFH network, such as Prof Kenneth Hunt's RehaLab.

The SCI-Mobility Lab currently has five team members:

- Prof. Ing. Sebastian Tobler, Head of Laboratory
- Prof. Ing. Remo Lauener, Vehicle Design
- Prof. Ing. Roland Rombach, Finite Element Analysis
- PhD Edeny Baaklini, Neuroscience Coordinator
- Vincent Morier-Genoud, Master's Student in Biomedical Engineering and lab assistant

INITIAL DYNAMIC BEHAVIOUR STUDY

Raphael Murri

Director of the Institute for Energy and Mobility Research IEM

Professor of Vehicle Mechanics at Bern University of Applied Sciences

Initial study of the E-Pilot by Alber GmbH

The initial studies carried out on this type of vehicle at BFH were performed on the E-Pilot by Alber GmbH as an example, in order to test the structural stress on the manual wheelchair to which it is mounted, as well as the vehicle's driving dynamics. The results obtained show that no manoeuvres led to localised distortion of the plastic. However, due to the raised and rear centre of gravity, the risk of losing traction on gradients (greater than 10%) is increased. More critically, the weight distribution and precarious stability resulting from the single, frontal point of contact can cause the rear wheels to lift on bends with a lateral acceleration of 2m/s2 (Fig. 1).

Crash tests: user risk analysis

Based on these initial conclusions, various accident scenarios were identified. The scenarios presumed to be the most dangerous were then reproduced using a Hybrid III 50th percentile male dummy.

A first crash test evaluated the risk of injury when toppled from a stationary position, with and without a helmet.

The second crash test was performed with the vehicle in motion. The transversal acceleration tilted the vehicle when cornering on a steady bend.

Finally, the third and final crash test, performed at a high speed of 20km/h – the E-Pilot's top speed – involved a collision with a small stationary motor vehicle.

Discussion of results

The actions of travelling forward and stopping safely on a gradient greater than 10% are particularly problematic and can lead to a loss of control.

The low lateral acceleration results in limited stability and poses a potential risk to users. When toppled, even when stationary, loads exceed biomechanical limits, particularly at head level. Shoulders, elbows, hands, knees and feet are also at risk of injury. This is in addition to abrasions to the parts of the body in contact with the road.

In the final crash test consisting of a collision with the rear of a vehicle, we observed that the pelvis remained secure in the wheelchair seat, and there was a restraining effect when the knees came into contact with the rear of the vehicle. The upper body was pressed into the E-Pilot's handlebars. There was no head contact with the rear of the vehicle (Fig. 4). Consequently, the loads measured at various points on the dummy were weak.

Suggested improvements

The tests demonstrate that any adjustment options may represent a potential weak point. Vehicle stability could be improved by adding two front wheels with extra weight. Sharp edges and corners on the steering column and handlebars must be strictly avoided (Fig. 2).

A headrest securely fixed to the wheelchair could reduce stress on the cervical vertebra in the event of whiplash following a collision (Fig. 3). Furthermore, given lateral acceleration and kinetic energy are mainly determined by speed, this should be limited to a maximum of 10km/h. Finally, the risk of head injury could be significantly reduced by wearing a cycling helmet.

▲ Figure 1 – Lifting of rear wheel following excessive transverse acceleration.

▲ Figure 2 – Display screen on the E-Pilot handlebars can come into contact with the chest on impact.

▲ Figure 3 – Final position of the crash test dummy, after impact, on a wheelchair with no headrest.

▼ Figure 4 – Crash test at 20km/h: collision with the rear of a stationary vehicle.

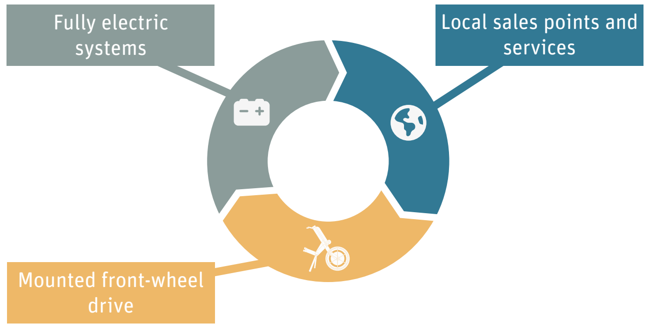
SELECTION AND DESCRIPTION OF TEST DEVICES

Three criteria for selecting test products

Design: The weight distribution of front-wheel drive systems often causes a loss of traction and grip on inclines. Their occasionally unstable dynamic behaviour and potentially high travel speeds make their dynamic analysis vital for user safety.

Type of drive system: Electric auxiliary mobility devices target a wide demographic of people who may have severely restricted mobility and for whom safety is paramount.

Availability: We wanted to test products marketed by Swiss retailers who also offer users assistance for the purchase and maintenance of equipment.



▲ Figure 5 – Summary of product selection criteria.

Partners contacted	Final participants
Alber GmbH	✓
Batec Mobility	✗
Stricker	✓
Swiss-Trac	✓
Triride	✗

Product technical data

The following table outlines the main technical data common to all three test products.
Quotes were then requested for the purchase and installation of the products from different Swiss retailers, based on their product catalogue. Various options are also available for each model tested.

For air travel, even if the battery for the drive system is fully compliant, requesting written confirmation from the airline before flying is recommended.

LIPO LOMO MICRO R&E STRICKER REHA-ENTWICKLUNGEN GMBH	E-PILOT ALBER GMBH	SWISS-TRAC SWT-1 ATEC ING. BÜRO AG
Weight (without wheel ballast)	Weight (without wheel ballast)	Weight
14 kg	18.4 kg	70 kg
Motor power	Motor power	Motor power
350 W	250 W	400 W
Max. speed	Max. speed	Max. speed
15 km/h (25 km/h on request)	10 km/h (20 km/h on request)	6 km/h
Mount type	Mount type	Mount type
Mounting brackets either side of legs	Drawbar between the legs	Drawbar between the legs
Range	Range	Range
+ 25 km	up to 50 km	+ 30 km
Vehicle loading aid	Vehicle loading aid	Vehicle loading aid
Not integrated	Not integrated	Loading ramps
Air travel	Air travel	Air travel
yes	yes*	yes
Price: 7'979.95 CHF TTC	Price: 8'819.55 CHF TTC	Price: 14'038.70 CHF TTC
REHA HILFEN AG quote with installation	Orthoconcept quote with installation	ORTHOTEC quote with No. 2 drive assistance and installation

*Air travel requires a smaller battery (range of 20km), not included in the price indicated.

MEASUREMENTS AND STATIC ANALYSIS OF PRODUCTS

Estimating behaviour by calculation

The initial aim of this step is to quickly establish an estimation of each system's behaviour and then compare it with the experiment's actual results.

Result by product	Tilt calculated [°]	Lateral acceleration [m/s²]
Lipo Lomo Micro	19.5	4.4
E-Pilot	22.9	4.7
SWT-1	31.1	5.5

The tilt angle tells us the maximum gradient at which it is possible to drive on a camber. This result cannot be used as a direct reference for dynamic cases where other parameters increase the risk of toppling on an incline.

The maximum permitted lateral acceleration indicates the maximum steady speed at which it is possible to take a bend of radius R without a risk of toppling:

$$\text{Lateral acceleration [m/s}^2\text{]} = \frac{\text{speed}^2\text{ [m/s]}}{\text{radius [m]}}$$

The SWT-1 mounting system which allows a degree of rotation around the chair's roll axis was judged to be rigid. This quick estimation is nevertheless costly in terms of accuracy in this specific case.

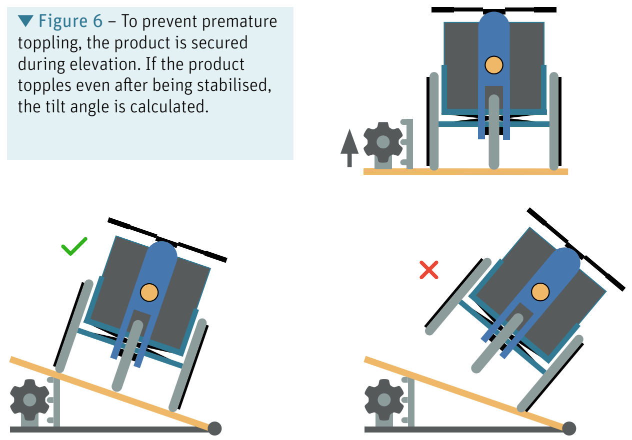
It is therefore important to carry out experimental tests in order to verify the accuracy of these approximations for models with a rigid mount, such as the Lipo Lomo Micro and the E-Pilot, and to obtain information regarding the SWT-1's behaviour.

Tilt test

To measure the lateral tilt angle of a drive system, the unit was mounted to our test wheelchair, which was loaded with a Hybrid III 50th percentile dummy weighing 78 kg.

The entire vehicle was positioned on a tilting platform with narrow supports to prevent slipping. By gradually raising one side of the platform, the gradient increases. It is therefore possible to measure the angle at which the vehicle topples over. The product was stabilised after each change in height.

▼ Figure 6 – To prevent premature toppling, the product is secured during elevation. If the product topples even after being stabilised, the tilt angle is calculated.

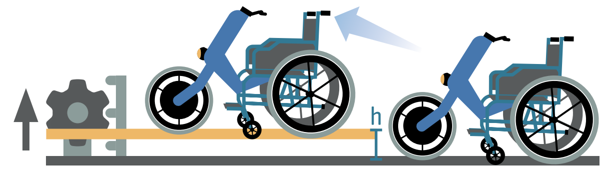


Result by product	Tilt measured [°]
Lipo Lomo Micro	17.4
E-Pilot	17.5
SWT-1	20

It should be noted that the estimated calculation of toppling for systems with a rigid mount, such as the E-Pilot and the Lipo Lomo Micro, produced results close to those measured during the experiment. As for the SWT-1, it obtained a more realistic result of 20°. The assumption that its mount is rigid is therefore inaccurate.

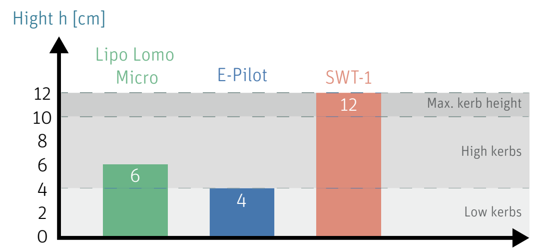
In the context of the dynamic use of these vehicles, it is important to anticipate a safety margin with regard to these values in order to avoid toppling. Furthermore, in a real-life situation, the leaning movement of the wheelchair user's torso can accentuate or reduce the risk of overturning.

Obstacle clearance test



▲ Figure 7 – From a stationary position, the vehicle must clear an obstacle at a given height. The surface of the platform is coated with a non-slip surface. If the vehicle fully lifts itself onto the platform, the platform height is increased and measured until the height at which the vehicle can no longer clear the obstacle is reached.

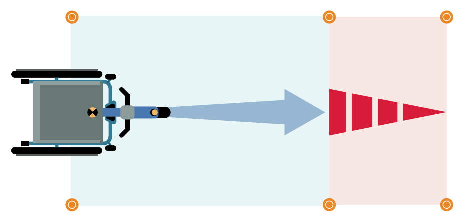
In its "pedestrian infrastructure" planning manual, the Federal Roads Office (FEDRO) advises against the construction of kerbs over 12 cm high. Two groups are also identified: low kerbs and high kerbs.
As one of the main obstacles encountered for wheelchairs in an urban setting, below are the results for each vehicle compared to the different pavement heights indicated:



For the Lipo Lomo Micro, the front castors of the test wheelchair limited the clearance to 6cm. A further measurement was taken after removing the wheelchair's front castors. The Lipo Lomo Micro was then able to clear obstacles up to 10cm high. In this case, clearance height may be affected by the wheelchair itself. On the other hand, the E-Pilot was restricted by its own stabilising wheels. The results for the SWT-1 are slightly lower than those obtained by the manufacturer (13 cm according to the technical data). This difference may be due to the fact that the test platform did not provide as much surface support as an obstacle, such as a pavement, would.
Slightly higher results are potentially possible across all three products with increased momentum. However, we advise against this method which impacts comfort and can damage equipment in the long term.

MEASURING DYNAMIC BEHAVIOUR

Emergency braking

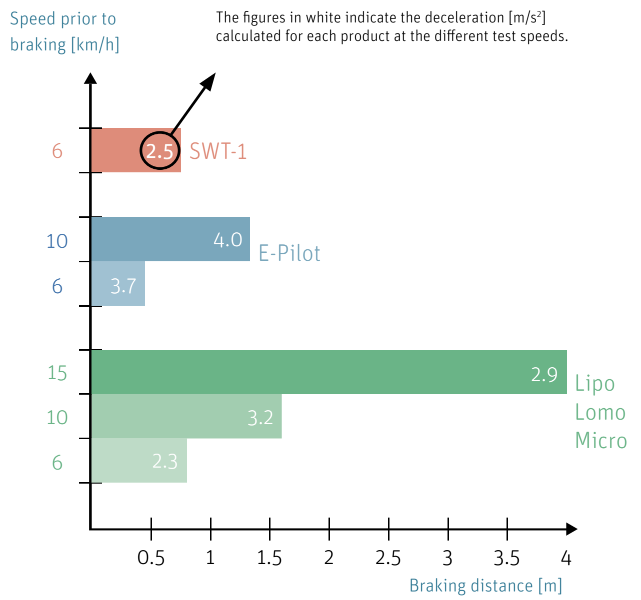


▲ Figure 8 – The vehicle accelerates until a steady cruising speed is reached. The test is conducted at the vehicle's maximum speed and at the lower top speeds of its competitors. Once the braking line is crossed, the user performs an emergency stop. The distance required to stop, the acceleration and the vehicle's behaviour (vibrations, instability) are observed.

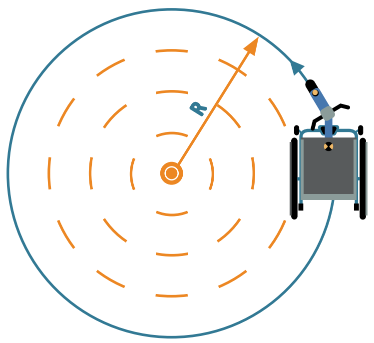
The first important point to take into consideration is that the braking distances measured in this test do not take into account the user's reaction time. They only represent the stopping distance after actively deciding to stop. With a reaction time of 0.5 s, distances double at 6 km/h. At 15 km/h, the Lipo Lomo Micro takes 6 m, and not 4 m, to come to a complete stop.

With regard to behaviour while braking, no product encountered any issues at speeds below 10 km/h.
The behaviour of the Lipo Lomo Micro was disrupted by the front wheel moving backwards towards the chair at speeds upwards of 15 km/h. The product's top speeds were also tested (configurable up to 25 km/h on request).

Instability was observed with the Lipo Lomo Micro chair-mounted frame at speeds upwards of 20 km/h. These results reinforce the hypothesis that speeds above 10 km/h greatly increase incident risk, even in a straight line.



Lateral acceleration



◀ Figure 9 – By turning at a constant speed, the vehicle maintains a circular trajectory with radius R. The vehicle's lateral acceleration is measured and its behaviour is observed. If the vehicle completes the test without tilting, a new test is conducted at the same speed around a circle with a smaller radius.

All products remained stable at speeds of 6 km/h. This demonstrates that while potentially faster vehicles may be unstable at high speeds, by maintaining a speed of 6 km/h, no stability issues while cornering could be identified.

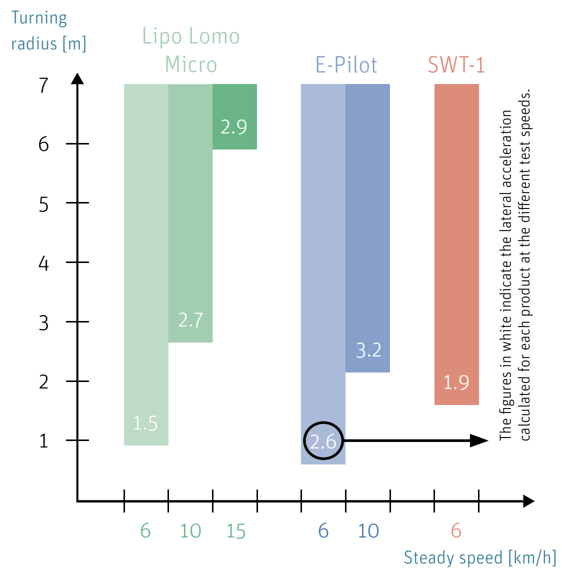
During testing at 10 km/h, the Lipo Lomo Micro and the E-Pilot experienced the first losses of control for lateral accelerations measured at around 3 m/s^2. Significant tilting, close to toppling, was recorded at 4 m/s^2.

These values show that the calculated theoretical estimation of vehicle behaviour is fairly accurate for this type of rigid mount.

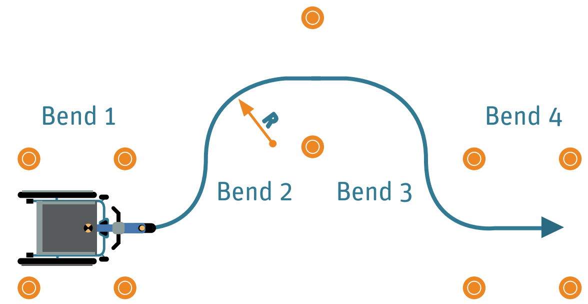
Regarding the SWT-1, lateral acceleration causing tilting could not be measured due to its speed and minimum turning radius. Nevertheless, the platform tilt test suggests that the value is close to, although slightly higher than, the two other products.

Lateral accelerations higher than those measured during the preliminary study with the E-Pilot (see page 1) could be explained by the fact that the user was not weighted and was therefore lighter. For the vehicles tested, increasing the weight of the user results in a higher centre of gravity. The comparative tests discussed here were not conducted with a maximum load, but with a total load of approximately 80 kg (user and measuring equipment) in order to obtain results more representative of the average user.

Despite remaining stable, the vehicles were restricted in the minimum turning radius by their own steering radius. This factor determined the minimum turning radius tested.



Evasive manoeuvres



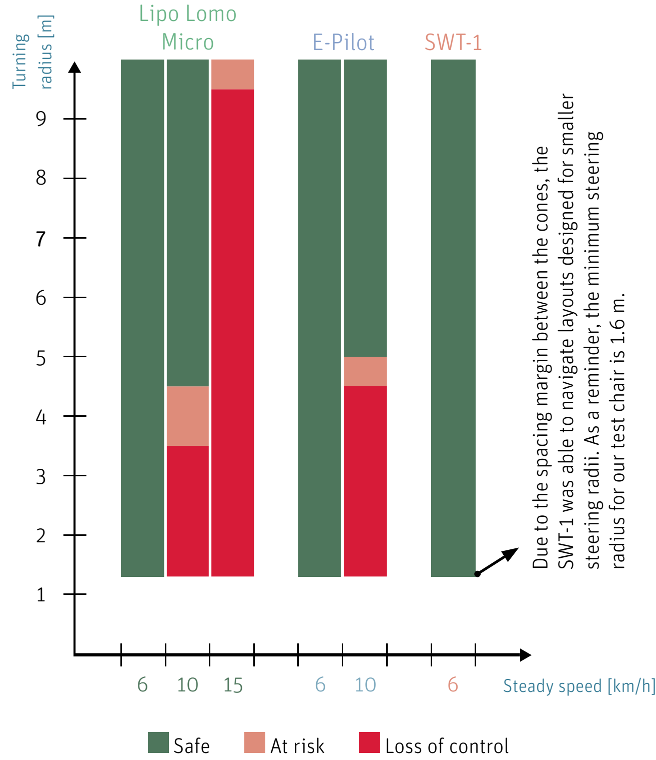
▲ Figure 10 – At a steady speed, the vehicle is driven through a slalom course, passing through a chicane of four bends with identical radii. The dynamic behaviour is observed and if no tilting occurs, a new slalom course is set up with bends of smaller radii.

During testing at 6 km/h, all vehicles once again remained stable. Lateral acceleration values below or equal to 2m/s^2 were observed.

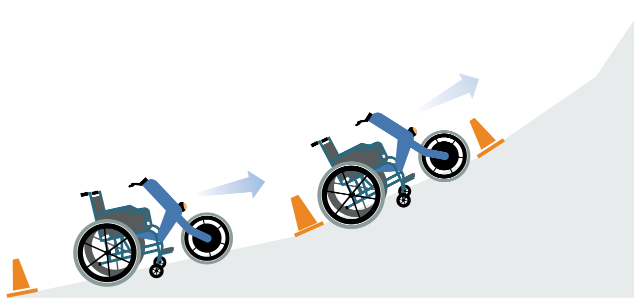
Above 10 km/h, a loss in stability occurred in much wider bends than in the circular lateral acceleration test. As this manoeuvre involves counter-steering, the forces resulting from the vehicle's mass greatly increase the likelihood of lateral tilting.

The following graph shows the vehicles' dynamic behaviours at a steady speed for various turning radii. The term "passage" is used to describe passing through a chicane. A safe passage, with no raised wheels, is represented by the colour green. A passage with a slightly raised wheel is shown in yellow and is considered "at risk".

The passages in red represent a loss of control of the vehicle, falls, or bends that were too tight for the user to take at the indicated speed without falling (passage abandoned).



Behaviour on an incline



▲ Figure 11 – On an incline where the increasing gradient is known, different start zones are marked by traffic cones. Starting at the zone with the weakest gradient, the vehicle is driven and then stopped. If it is able to move off and travel forwards from this zone, a new test is conducted from a zone with a higher gradient.

The main risk with this type of vehicle is driving on a slope that is too steep to negotiate. When the vehicle drives on an incline, its weight and that of its passenger progressively shift to the system's rear wheels, reducing the load on the front drive wheel. This results in a significant reduction in speed and a loss of traction. However, leaning slightly forward may initially be sufficient to continue on the incline.

By continuing, the vehicle may no longer be able to travel forwards. These factors can make the situation significantly worse. The unit's braking system is located on the drive wheel. Therefore, if there is insufficient downforce on the front wheel, not only does the user risk getting stuck on the incline, there is also the risk of rolling backwards given the lack of necessary contact to keep the vehicle stationary through braking.

By rolling backwards, the vehicle's speed can increase considerably, making stopping extremely difficult and potentially causing falls and serious injury. A test highlighting the gradients above which these kinds of accidents can occur for each product was therefore vital:

Products	Gradient [%]
Lipo Lomo Micro	15.8
E-Pilot	13.2
SWT-1	28.7

It is important to add a safety buffer to these values, as other parameters – such as road surface humidity, the weight of the system, as well as tyre condition and pressure – can vary from user to user.

Regarding hill starts, only the SWT-1 was able to remain in place on an incline without having to continuously apply the brakes. For the other products, braking had to be applied until the moment of acceleration – similar to a clutch-operated vehicle – in order to perform a hill start without rolling backwards between lifting the brakes and activating the throttle handle.

Finally, for downhill behaviour, the speed limiting systems of the E-Pilot and the Lipo Lomo Micro were not able to control speed when the vehicle accelerated due to a force external to its motor. This is not ideal in terms of downhill safety where vigilance is essential, as it is possible to reach high speeds very quickly. This speed can, of course, be controlled with the help of a braking system. With the SWT-1, it was impossible to gain too much speed on an incline, voluntarily or involuntarily. This product automatically maintains a speed of 6 km/h or less, ensuring a very high level of safety.

Energy consumption and daily use

The manufacturers determine the estimated range of their products. This depends on the battery type and on a wide range of parameters (vehicle load, incline, driving behaviour, driving speed, etc.). In this case, the aim is to move away from the typical range tests and use a standard route as the only constant. By performing several laps of the circuit, with no speed limit, the same user was able to drive each product in the manner that they felt was best adapted to the course.

The vehicles were fitted with the following batteries:

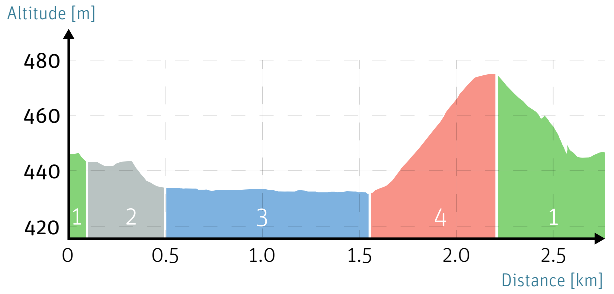
Product	Voltage [V]	Capacity [Ah]
Lipo Lomo Micro	36	11.6
E-Pilot	36	13.6
SWT-1	24 (2x12)	40

The average time to complete one lap was also used to determine the time required for day-to-day journeys. An estimated consumption per kilometre, as well as the range of a full charge was also calculated:

Product	Lap time [min/lap]	Consumption per km [Wh/km]	Estimated range per charge [km]
Lipo Lomo Micro	17.1	15.5	26.9
E-Pilot	19.5	16.7	29.8
SWT-1	27.1	25.2	38.1

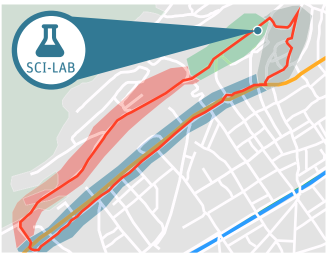
The standard route is a circuit of approximately 2.7 km around the SCI-Mobility Lab in Bern. The goal is to cover different surfaces and varying gradients. It is therefore possible to illustrate a typical example of a daily journey.

Significant elevation gain means a product's performance can be tested in more extreme conditions. A downhill section was also included, so that in the future, vehicles with regenerative braking are not adversely affected by a flat course.



▼ Figure 12
Map of test route

▲ Figure 13
Elevation profile



Discussion of results

If you live in a rural or hilly area, the SWT-1 seems to be the only product tested that ensures reliable travel. Its qualities are evident when it comes to driving on an incline and clearing obstacles. Furthermore, if the terrain is hilly even in urban areas, the SWT-1 undoubtedly remains the best option. For elderly people, the safer option also appears to be the SWT-1, which ensures safe downhill travel and facilitates hill starts.

Although the Swiss-Trac is the only device to offer a loading system as an option, solutions provided by local retailers do exist for loading the E-Pilot and the Lipo Lomo Micro into a vehicle. All three systems can therefore be transported in a car large enough to accommodate them.

Now comes the issue of speed. The tests performed demonstrated good stability in all three products at low speeds (6 km/h). It is therefore completely feasible to travel without risk using the E-Pilot or the Lipo Lomo Micro by adapting your speed to the situation. The E-Pilot has an optional speed limiter that is easily activated, so there's no need to worry too much about the throttle.

The Lipo Lomo Micro has a cruise control system which is slightly less intuitive, but is perfectly suitable. Nevertheless, caution is advised, as falls often occur unexpectedly when it isn't always possible to anticipate and slow down. The risk of tilting is, for example, greatly increased if the terrain is not flat. Sudden movements, such as jerking the handlebars, evasive manoeuvres or tight bends can very quickly lead to a fall, even at a speed at which you feel safe. This is why wearing a cycling helmet, although not very flattering at first glance, remains the best way of avoiding serious injury when travelling at speeds above 6 km/h. We advise against driving over 10 km/h with either the E-Pilot or the Lipo Lomo Micro.

Whether you choose it for its driving options, how it looks or its silent motor, the E-Pilot is an attractive product and is suitable for travelling on flat terrain (town/village).

The Lipo Lomo Micro has the advantage of being a better compromise than the E-Pilot when travelling on an incline and clearing obstacles. The turning radius and wheelbase of the E-Pilot and the Lipo Lomo Micro also have the advantage of being easier to drive than the SWT-1 in confined areas.

Both are suitable options if you live in the city and use public transport.
In terms of range, SWT-1 gives the best results. You would have to decide whether you can tolerate the longer journey times.
It is worth noting that all of the products have a range of over 25 km on a single charge. This appears to be a decent distance, which should, in the majority of cases, be further than a typical daily commute.

Vincent Morier-Genoud

Head of Comparative Testing and article editor

SCI-Mobility Lab assistant

USER REVIEWS

Involving the target consumer

In addition to the data gathered by SCI-Mobility, our intention is to also present more personal opinions that take a closer look at the products tested and possibly point out important details that only those affected would be able to identify.

In the spring of 2022, we launched a recruitment campaign targeting people with disabilities who require the use of a wheelchair. Our aim was to reproduce a typical, everyday environment as accurately as possible to allow these individuals to form a realistic opinion of what their lives would be like with one of these products.

The criteria for achieving this test environment included:

- Loaning the product for a period of two weeks
- Mounting the product on the user's personal wheelchair
- Presenting the product and how it works before each loan period

Comments

All precautions were taken in order to ensure that all conditions were met. This was not possible in certain cases:

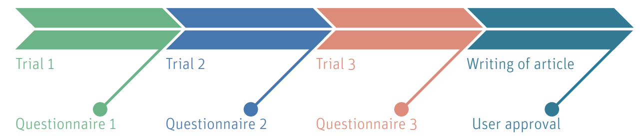
- The E-Pilot mounting system could not be mounted on Yves's chair due to incompatibility issues discovered at a late stage. A loan wheelchair was therefore provided.
- As Yves is accustomed to the SWT-1, his experience of the product will obviously be different to someone who has only used the device for two weeks.

Product scoring method

In order to collect the users' feedback as effectively as possible, a questionnaire was completed after each product trial according to the schedule below:

Start

End



Following the writing of this article, a final interview with Yves and Caroline was conducted to ensure that their opinions had been correctly recorded and accurately presented.

List of main assessment criteria

- **Safety:** braking, dynamic behaviour on an incline, downhill travel, cornering.
- **Handling:** steering angle and power, obstacle clearance, behaviour on unsurfaced terrain.
- **Convenience:** ease of operating brakes, comfort when negotiating obstacles, design, on-board system.
- **Mount:** satisfaction regarding the mounting system and the time required to connect the unit.
- **Speed:** satisfaction regarding the speed and how it is displayed.

Each category contained several differently weighted questions which were then used to obtain a score from 0 to 10.

The next page presents the review's final results. For more details on Yves and Caroline's trials, see pages 9–11.

Yves, 52 years

Wheelchair user for four years due to quadriplegia following an incomplete C6–C7 spinal cord injury.

Wheelchair
Sopur Xenon 2

Auxiliary aid
Swiss-Trac SWT-1

As the owner of an SWT-1 for four years and describing himself as rather unsatisfied with this product, Yves is interested in discovering other systems by participating in our test.

Yves lives in a hilly area, which forces him to regularly drive on inclines.

Caroline, 30 years

Wheelchair user for four years.

Has spastic paresis.

Wheelchair
Quickie Helium

Auxiliary aid
Empulse Wheeldrive

As the owner of her Empulse Wheeldrive for three years, Caroline is unsatisfied with this product and thinks that a drive system would be more suitable. She hopes to find new options by taking part in our test.

Caroline lives in the countryside, but regularly has to travel into town and sometimes encounters hilly terrain.

COMPARISON OF FINAL RESULTS

Safety

Yves puts the SWT-1 firmly in the lead in this category. The E-Pilot scores higher than the Lipo Lomo Micro, namely due to its braking, which is smoother, but effective. Yves also prefers the behaviour of the E-Pilot when cornering.

Overall, Caroline encountered very few safety issues. The spread of scores in this category, which is narrower than Yves's scores, can be explained by the fact that Caroline awarded more points to the E-Pilot and the Lipo Lomo Micro when she was asked to evaluate her level of confidence in the products.

Handling

The SWT-1's ability to clear obstacles impressed Yves. The increased difficulty of moving the Lipo Lomo Micro once detached resulted in a slightly lower score than the E-Pilot.

In terms of obstacle clearance, Caroline scored most of the products fairly highly. This suggests that the obstacles Caroline encounters on her daily commutes are not particularly high. It is, therefore, the handling which makes the difference. For her, the E-Pilot is the easiest product to operate.

Convenience

The options on offer as well as the complexity of installing them were rated fairly similarly. Comfort when negotiating obstacles and the product's design were decisive factors for both users in determining the scores of all three products.

Mount

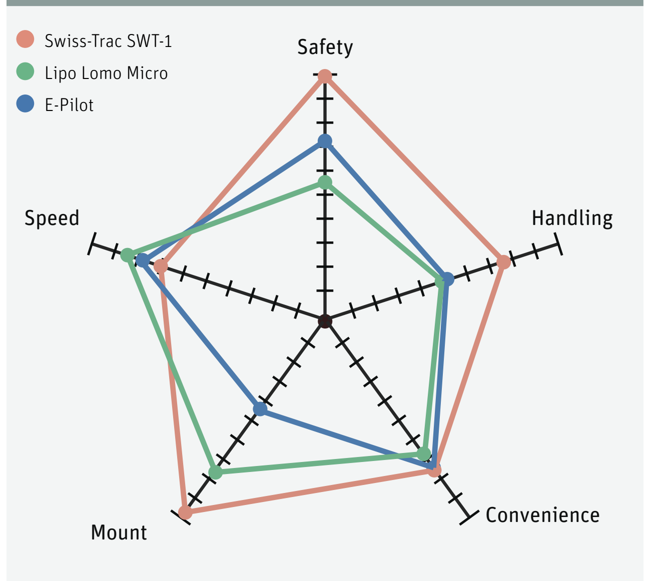
To general surprise, although the E-Pilot system can be mounted in a single step, its score was significantly lowered by the stress felt by the uncertainty of both users to be able to mount it successfully.

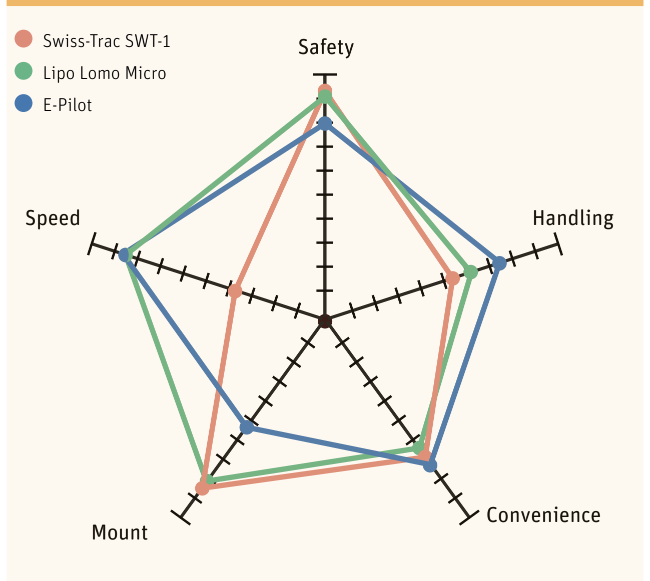
Speed

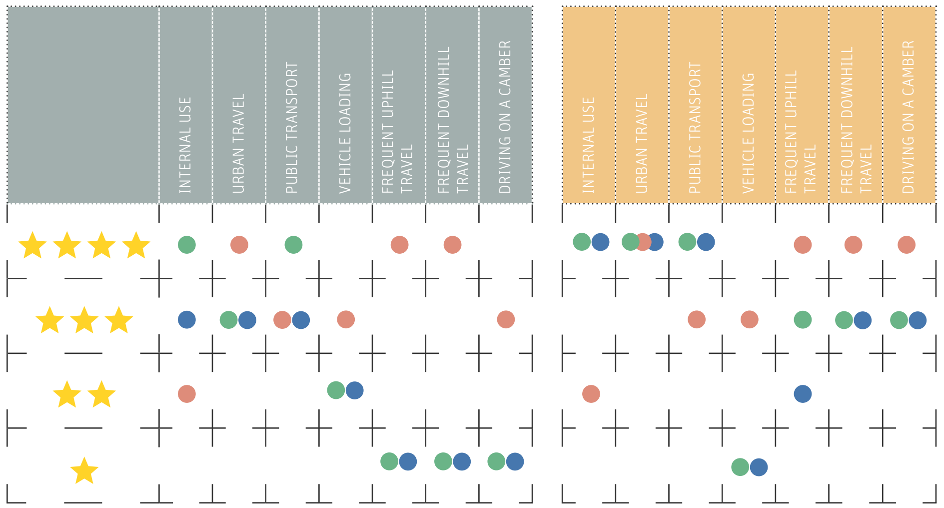
Travel speed was not a priority for Yves. Therefore, the products are closely ranked in order of increasing maximum speed.
For Caroline, who complains about how long journeys can take, the SWT-1's speed was a key concern.

▼ Figure 14 – Comparative radar charts

Results comparison of in-depth analyses on pages 9, 10 and 11.







◀ Figure 15 – Recommendation by use

Using their accumulated experiences over each two-week trial, Yves and Caroline scored the products based on specific uses.

- Swiss-Trac SWT-1
- Lipo Lomo Micro
- E-Pilot

- ★★★★ Completely adapted
- ★★★ Somewhat adapted
- ★★ Not well adapted
- ★ Not at all adapted

LIPO LOMO MICRO

Safety and dynamic behaviour

While the efficiency of the braking system suited Caroline and Yves, Yves remarked that the braking was far too harsh for him and sometimes caused instability when very sudden.

On an incline, Caroline was satisfied with the vehicle's dynamic behaviour, but admits that she tested the product on rather flat terrain. She only encountered a few minor traction issues. As for Yves, he occasionally found that he was unable to negotiate uphill sections.

For downhill travel, Yves indicated that it was very easy to quickly gain speed, which could prove dangerous. It is therefore important to stay alert and actively control your speed using the service brakes.

According to both users, when cornering, the vehicle's instability can be controlled by significantly reducing travel speed. Being able to take advantage of the Lipo Lomo Micro's higher speeds in a straight line and on suitable road surfaces was seen as a positive.

Handling

The Lipo Lomo Micro's limited ability to clear obstacles was a major disappointment for Yves. He also commented that the handling of the product once detached was not practical.

Caroline was bothered by the force required to turn the handlebars.
This little product's strength is in its handling, allowing easy and fast travel in areas where access is limited (narrow streets, shops, etc.).

Mounting

The system proved popular and was mastered relatively quickly by both users. However, Caroline found that there were far too many steps to mount the device.
According to Yves, it should be noted that the various clamping mechanisms could pose an issue for people who struggle with fine motor skills in their hands.

Convenience

Caroline remarked that the system is not entirely practical at night as the speedometer on the small display screen is difficult to read. In terms of style and design, the Lipo Lomo Micro was not to our participants' tastes. The number of steps required to mount the device is also a negative aspect for Caroline.

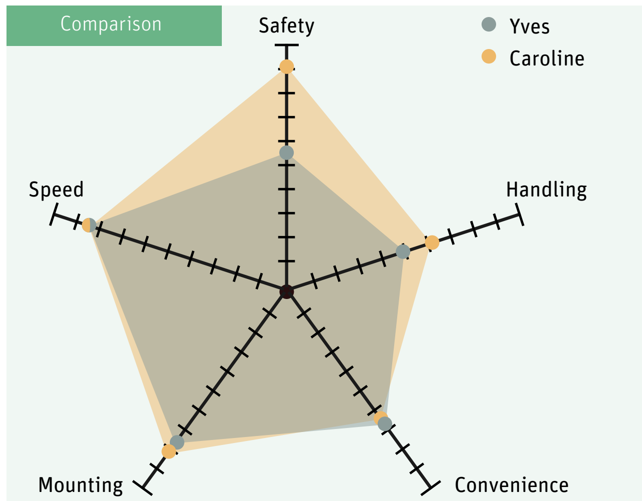
Comments

With this product, both users experienced a sudden stop (impossible to move). They had to wait several minutes before being able to reboot the device.

The participants also raised the issue that although the Lipo Lomo Micro is small in size, it is too heavy to be easily loaded into a vehicle without assistance.

Conclusion

Both users were impressed by the Lipo Lomo Micro's top speed and its "all-access" volume. To conclude, Yves was not interested in this product, as he found it too heavy and poor at clearing obstacles. Caroline said that she would be interested in purchasing the product following her trail.



Product image

Usage time over two weeks

CAROLINE'S RESULTS

Test environment:

few hills — very hilly

- Safety: 9.1
- Handling: 6.1
- Mounting: 8.2
- Speed: 8.5
- Convenience: 6.5

Strength/Weakness:

+ Good traction despite the size of the motor
− Too many steps required to mount it to the chair

YVES' RESULTS

Test environment:

few hills — very hilly

- Safety: 5.5
- Handling: 4.9
- Mounting: 7.6
- Speed: 8.5
- Convenience: 6.9

Strength/Weakness:

+ Versatile (speed, size, compatibility, weight)
− Traction issues could make the product unsuitable for hilly terrain

Alber GmbH

In-depth analysis

E-PILOT

Safety and dynamic behaviour

The E-Pilot's braking behaviour impressed both users.

Issues arose when travelling uphill. Both users experienced loss of traction, an inability to move forward, and even rolling downhill. Caroline found herself in a serious situation where she was no longer able to apply the brakes and stop her uncontrolled descent. These events contributed to the users' doubts surrounding the E-Pilot's ability to negotiate uphill travel on their daily commutes (getting around town, railway station access ramps, etc.).

To remain in control when travelling downhill, speed is maintained by applying the brakes, but for both participants, this was less bothersome than for the Lipo Lomo Micro. Could this be due to the E-Pilot's smoother braking or simply as a result of the more rigid mounting system?

When cornering, any loss of control or worrying dynamic behaviour could be avoided by adapting the driving speed to the situation. As the E-Pilot has a very effective speed limiter, it is very easy to reduce the maximum reachable speed. As a result, there is no need to use the throttle to continually adjust your speed.

Handling

The handling and force required to steer the E-Pilot won over our users. Its ability to clear everyday obstacles was not sufficient for Yves.

Mounting

To everyone's surprise, both users were extremely disappointed with the single step mounting system. Difficulty guiding the unattached E-Pilot into the bracket mounted on the wheelchair seems to be the key issue. If the product is slightly misaligned, mounting the device has a greater risk of failure when the user pushes the handlebars to lift the front of the wheelchair. Getting the E-Pilot into this position was a challenge for both Yves and Caroline. Although the manoeuvre is not time-consuming, having to repeat it several times caused considerable stress on a daily basis.

Reminder: Yves conducted this test using a loan chair. The different dimensions between Yves's usual chair and the loan chair (a difference of 6cm in seat height) may have made attaching the unit more difficult.

Nevertheless, both users found the system to be safe and stable once correctly mounted.

Convenience

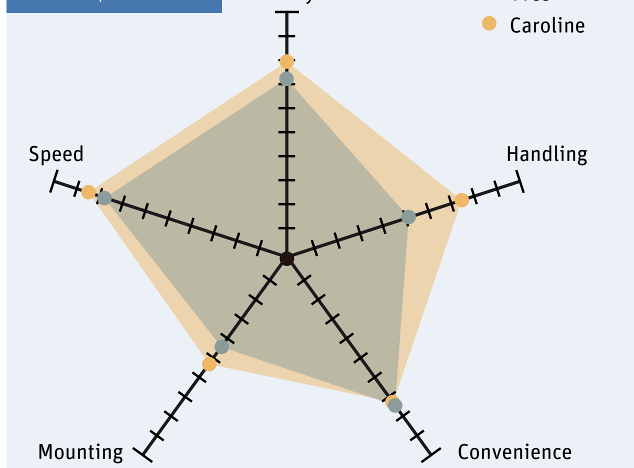
The E-Pilot's design, as well as its driving modes and system for limiting speed, impressed our users.

Conclusion

The E-Pilot's mounting difficulties and reduced driving ability got the better of Yves, who does not see himself buying this product in the future.

Caroline was impressed by the product's design and convenience. She showed interest in purchasing an E-Pilot.

Comparison



Product image

Usage time over two weeks

CAROLINE'S RESULTS

Test environment:

few hills — very hilly

- Safety: 7.9
- Handling: 7.4
- Mounting: 5.3
- Speed: 8.5
- Convenience: 7.2

Strength/Weakness:

+ Best design by far
− Mounting system hard to get to grips with. Gets trickier with something on your lap

YVES' RESULTS

Test environment:

few hills — very hilly

- Safety: 7.2
- Handling: 5.1
- Mounting: 4.4
- Speed: 7.8
- Convenience: 7.4

Strength/Weakness:

+ Its design
− Low traction is a real issue, even in moderately hilly areas

In-depth analysis

ATEC Ing. Büro AG

SWISS-TRAC SWT-1

Safety and dynamic behaviour

The SWT-1 is equipped with a potentiometer that can be adjusted in two directions (forward and reverse). As a result, releasing the handle of the potentiometer is enough to brake rapidly. A gradual release is an option to avoid sudden stops. Caroline needed some time to adapt to this system in order to avoid sudden braking. She also complained about occasionally having difficulty controlling the forward jolt of the SWT-1 when braking. Overall, she was fairly satisfied. As for Yves, he was impressed by the system's effectiveness.

Although the limited speed of the SWT-1 is clearly felt on flat terrain – making long distances seemingly never-ending – uphill, its performance won over both users. No slope was too steep. Furthermore, no wheel spin or skidding was reported.
Downhill, the impossibility of reaching uncontrolled speeds is a key advantage in terms of safety.

The SWT-1's cornering behaviour impressed, and no tilting, even slight movement, was identified.

Handling

Both users agree that the SWT-1's ability to clear obstacles is more than sufficient. Yves found that the SWT-1 can easily be manoeuvred once detached from the chair. Caroline, on the other hand, found it difficult. Once mounted, she also found it difficult to steer, unlike Yves.

Yves's prior experience with this product is a possible explanation for this stark contrast. However, both users would have preferred a better turning angle.

Mounting

The mounting system gets Yves's stamp of approval. Caroline, however, took time to get used to it, but made rapid progress and is now very satisfied.

Convenience

The loading ramp offered as an option for the SWT-1 impressed. Nevertheless, Caroline remarked that the entire loading process took too long and was more complicated than when she loaded the other products with her electric hoist (already installed in her car for loading her wheelchair).

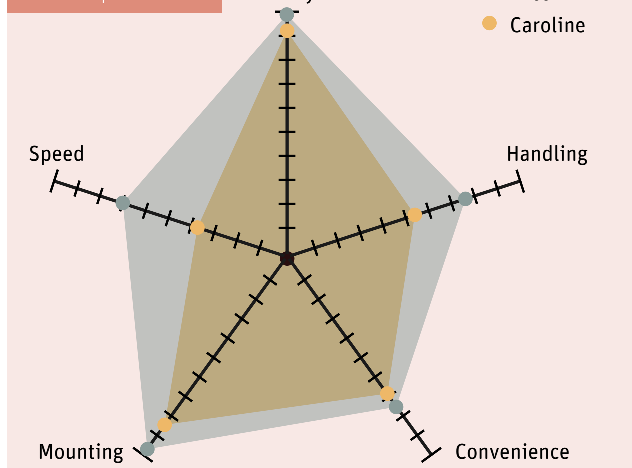
The manner in which the SWT-1 clears obstacles makes it easier to manage kerbs and improves comfort when negotiating obstacles.

On the other hand, the design was singled out by both users as being fairly unattractive.

Conclusion

After the trial, Caroline is not interested in this product. She finds it too slow and cumbersome.
Yves, who owns this product and initially declared himself as unsatisfied with it, names the Swiss-Trac as the safest and most robust. He regrets how bulky it is, but pointed out that at least the loading system limits the important issue of travelling in a private vehicle.

Comparison



Product image

Usage time over two weeks

CAROLINE'S RESULTS

Test environment:

few hills — very hilly

- Safety: 9.3
- Handling: 5.4
- Mounting: 8.4
- Speed: 3.8
- Convenience: 6.9

Strength/Weakness:

+ Its ability to clear obstacles and drive on all kinds of terrain
− Its handling and its weight

YVES' RESULTS

Test environment:

few hills — very hilly

- Safety: 9.9
- Handling: 7.6
- Mounting: 9.7
- Speed: 7.0
- Convenience: 7.6

Strength/Weakness:

+ Its dynamic behaviour and the safety that goes with it
− Its design

ADDITIONAL INFORMATION

How can I get one of these electric aids?

François Moreillon, regional manager of Western Switzerland for the Swiss Federation of Advice on Auxiliary Aids (FSCMA/SAHB) explains:

On loan from social security providers

Certain social security schemes, such as disability insurance (DI/AI/IV) or occupational accident and illness insurance (LAA/UVG), can loan out mobility aids.

Once your profile has been created, a request for an auxiliary aid must be addressed to the relevant insurer. A medical prescription must also be submitted alongside your request. For seniors receiving old-age and survivors' insurance payments (OASI/AVS/AHV), although there is assistance for manual wheelchairs, electric mobility aids are not included in the auxiliary aids offered by this insurance.

It is possible to submit your request for an auxiliary aid by specifying your preferred product. Depending on the products available in DI stocks and the evaluation of your needs by the relevant insurance company, this product may be loaned to you free of charge. The evaluation of your needs is mainly based on your health and your immediate environment, such as your primary residence.

The relevant insurance company can provide simple, suitable and economic auxiliary aids. Only auxiliary aids with optimal value for money are considered. If the product you have chosen is more expensive than an alternative suited to your needs, you may be asked to pay the difference in price if you still wish to use the product selected. You will then receive your loaned equipment, which must be kept in good condition. An auxiliary aid may be replaced if it would be more economical to do without it – taking into account the extent of repair costs and provided your obligation to look after the equipment has not been neglected – or if it is no longer adapted to your health requirements. This loan can only be granted for one product of the same type at a time.

Therefore, you cannot submit a second request for another electric mobility aid. Other methods: If the insurance company refuses your request, you can contact Pro Infirmis. A mobility aid may be granted once your financial situation has been evaluated. Other organisations can also provide financial assistance, depending on your disability (Cerebral, Swiss Paraplegics Foundation (SPA/ASP/SPS) or Verein SLA/ALS for people with motor neurone disease, for example). Private purchase: As a last resort, and if you can afford it, you can purchase these kinds of devices at your own expense from a retailer in your region.

François Moreillon

Which questions should I ask when making my choice?

The team at the SCI-Mobility Lab have compiled a selection of useful questions to keep in mind when discussing with your local retailer.

We recommend at least testing the product in-store and, if possible, asking for a one-week trial period at home.

Test the routes you usually take as much as possible. Depending on the route, it is important to have someone with you. From experience, surprises do happen...

- Is my wheelchair adapted to this kind of drive system and at what speeds?
- Is my wheelchair compatible with the model I'm interested in?

- Does this drive system correspond to my needs (and not my vendor's needs)? If you have quadriplegia, think about how easy it is to operate. For example, check if you can keep your hands on the handlebars, even on uneven surfaces or over small obstacles.
- Car travel: think about loading. Can you do it alone?
- Which system is suited to your personal vehicle?
- Air travel: is the vehicle's battery permitted on a plane?

What does the law say?

Situation in Switzerland

The Federal Roads Office (FEDRO) considers this type of drive system as a single-seater motorised wheelchair. These vehicles cannot exceed 30 km/h for motors up to 1kW.

However, it is recommended that speeds should not exceed 10 km/h. Above this speed, a type-approval number is mandatory for full compliance.

Situation in Germany

Drive units for wheelchairs can travel at a maximum speed of 6 km/h without authorisation or insurance.

With TÜV certification (combination of a wheelchair and a drive unit) and a valid licence plate, a drive system can be used on the road at a maximum speed of 15 km/h The user does not need a driving licence. Wearing a helmet is not mandatory, but is recommended.

Defining the role of mobility aids

The main role of wheelchairs is to provide, as far as possible, the same mobility access as pedestrians without a disability. Wheelchairs are engineered and adapted to the needs of the user: manually propelled chairs for people with the necessary physical ability or electrically powered chairs for people with more significant physical limitations. Wheelchair use should take place in complete safety for both the user and people in the vicinity.

Therefore, this primary mobility need excludes any sporting activity or travel at speeds greater than a person without a vehicle. Cycling for people without a disability, which is faster but also more physically demanding and riskier, is subject by different regulations (road travel, cycle lanes, licence plates, and recommended helmets).

Whether manual, electric or towed by an electric motor, the use of a wheelchair in a public place should not extend over too broad a spectrum of uses to the detriment of safety. With the development of new technology, it seems more important than ever to clearly define the limit between alternatives to pedestrian mobility and sporting alternatives.

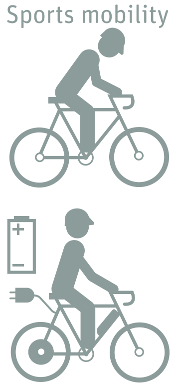
Manufacturers, authorities, insurers and even users must ask themselves the following key question: Are people with disabilities entitled to the same safety measures and are they as well protected as others?

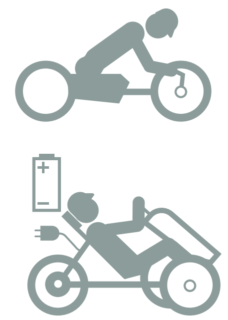
This reflection forces us to look at the laws that regulate the mobility aids tested in this paper (an electric aid fixed to a wheelchair) while bearing in mind inclusivity, equality and safety for all. We propose this vision of the future:

Pedestrian mobility / Pedestrian alternative

1. Based on our results, a maximum speed of 10km/h minimises falls and ensures the safety of the wheelchair user.
2. A maximum travel speed of 10km/h also guarantees the safety of pedestrians in the vicinity.
3. A single braking wheel is not ideal, but at lower speeds, a hand can be placed on the chair's push rims if there are any issues.
4. The wheelchair to which the auxiliary aid is mounted is engineered, optimised and certified for this reduced speed.
5. A helmet or a licence plate is not required to travel.

Sports mobility / Sporting alternative





1. Handbikes are subject to the same regulations as e-bikes (speed limits with/without pedal assistance).
2. Sporting activities are practised on cycle tracks, roads and paths, and are not permitted on pavements or in pedestrian areas.
3. To ensure the safety of the device, a minimum of two wheels must have brakes with a dual-circuit brake system.
4. Handbikes or bikes for people with disabilities are engineered, optimised and certified for travel at speeds in excess of 10km/h.
5. A helmet must be worn.

OUR SINCERE THANKS TO EVERYONE WHO TOOK PART IN THIS PROJECT.

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Dynamic Test Center