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Obstacles and risks in the traffic environment for users of powered wheelchairs in Sweden

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ABSTRACT

Objective: According to the European Union, fatal road accidents involving Vulnerable Road Users (VRUs) are equal in proportion to fatal car road accidents (46%). VRUs include individuals with mobility challenges such as the elderly and Powered Wheelchair (PWC) users. The aim of this interdisciplinary qualitative study was to identify obstacles and risks for PWC users by exploring their behaviour and experiences in traffic environments.
Methods: Videos and in-depth interviews with 13 PWC users aged 20–66 were analysed for this study. The interviews and videos, which include real-life outdoor observations, originate from a qualitative study exploring experiences of PWC use on a daily basis in Sweden. Underlying causal factors to identified risks and obstacles were identified, based on human, vehicle (PWC) and environmental factors in accordance with the Haddon Matrix.
Results: The results show significant potential for improvement within all three perspectives of the Haddon Matrix used in the analysis. Participants faced and dealt with various obstacles and risks in order to reach their destination. For example, this includes uneven surfaces, differences in ground levels, steep slopes, as well as interactions with other road users and the influence of weather conditions, resulting in PWC users constantly accommodating and coping with the shortcomings of the vehicle and the environment.
Conclusions: There are still major challenges with regard to preventing obstacles and risks in the traffic environment for PWC users. To discern PWC users in traffic accident and injury data bases, a start would be to register type of aid used for persons involved in an accident. Furthermore, to emphasise PWC users' role as VRUs, it may also be advantageous to describe them as drivers rather than users when navigating the traffic environment. Given the limited sample, further research covering more data from a broader perspective would be beneficial. By incorporating emerging knowledge of PWC users' prerequisites and needs, and including them in research and traffic planning, the society will grow safer and more inclusive, and become better prepared for meeting future demands on accessibility from an aging population.

1. Introduction

According to the European Union, the involvement of Vulnerable Road Users (VRUs) in fatal road accidents equalled the proportion of car road fatalities (46%) in 2017 (European Commission – Fact Sheet, 2017). The Intelligent Transport Systems (ITS) directive (2010:4) describes VRUs as "non-motorised road users, such as pedestrians, cyclists as well as motor-cyclists, elderly, and persons with disabilities or reduced mobility and orientation". The Vision Zero charter has provided a foundation for traffic safety measures successfully helping to reduce

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vehicle occupant fatalities in Sweden since 1997 (Belin et al., 2012; Government Offices of Sweden, 1997; Johansson, 2009). A similar approach, frequently referred to as Sustainable Safety (SWOV Institute for Road Safety Research, 2018) or the Safe System Approach (International Transport Forum, 2008), has been adopted by several other countries. Traffic safety enhancement for VRUs, such as pedestrians and cyclists still face major challenges, although the plight of VRUs has increasingly been recognised (Swedish Transport Administration, 2017, 2018; WHO, 2009, 2015). The term 'road' generally includes "footpaths, bridleways and cycle tracks, and many roadways and driveways on private land (including many car parks)" (Department for Transport, 2019:169), thus VRUs can also be described as "road users".

Powered Wheelchair (PWC) users is a subgroup of VRUs, often overlooked in the context of traffic safety. A threefold increase in the number of accidents involving PWCs and motorised mobility scooters has been observed in Sweden over the past decade (Carlsson and Lundälv, 2019). PWCs boost independence, allowing users to engage more easily in daily activities and interact socially (Stenberg et al., 2016). Previous research has shown the importance of PWCs for users' quality of life, as well as convenience, when navigating traffic environments (Bigras et al., 2019; MacGillivray et al., 2018; McIlvenny, 2019; McIlvenny and Davidsen, 2017; Smith et al., 2016; Stenberg et al., 2016; Torkia et al., 2015, 2019; Widehammar et al., 2019). As the number of elderly citizens rise, the number of PWCs is also expected to increase (LaBan and Nabity, 2010). The World Health Organization (WHO) has emphasised the importance of suitable living conditions, the ability to participate, and mobility for people with disabilities (WHO and World Bank, 2011). Similarly, each individual's right to health, safety and mobility has been declared by the United Nations (UN) in several conventions (Government Offices of Sweden, 2008). The UN Convention on the Rights of Persons with Disabilities (UN, 2006) states that people with disabilities must have the same rights as the rest of the population. Reinforcing sustainable mobility, comfort and quality of transport and transport in traffic for "pedestrians, cyclists and public transport passengers has become a matter of course" (Söderhäll, 2010:20).

At present, a unified way of categorising PWCs is yet to be established, making this particular subgroup of VRUs, the PWC users, more or less invisible in a traffic safety context (LaBan and Nabity, 2010; Carlsson and Lundälv, 2019). According to Swedish traffic regulations (Swedish Transport Agency, 2016), PWC users are categorised into pedestrians or cyclists. They are allowed on pavements as well as cycle lanes and roads depending on the speed the PWC is propelled at, and they must obey associated regulations. Furthermore, traffic injury databases commonly lack specific variables regarding type of mobility aid used, such as PWC, manual wheelchair or rollator, making it difficult to extract and analyse accident and injury statistics. For example, in the Swedish Traffic Accident Data Acquisition (STRADA) database, PWCs are currently classified in the categories; Pedestrian, Moped, Other Vehicle and Bicycle (Carlsson and Lundälv, 2019). Beside the lack of injury data for the PWC user subgroup, research into user experiences of accidents and perceived risks in the traffic environment is also limited.

The aim of this interdisciplinary qualitative study was to identify obstacles and risks for PWC users by exploring their behaviour and experiences in traffic environments. The long-term goal is to contribute to improved mobility and reduced risk of accidents and injuries for the PWC users, and consequently reinforcing the active participation of people with disabilities in society in accordance with the UN Sustainable Development Goals (UN, 2015). For this study we have chosen to apply William Haddon's matrix, a basic scientific structure promoting different perspectives as well as a holistic overview frequently used within traffic safety and injury prevention, based on human, vehicle and environmental factors (Haddon, 1968, 1980). This is in line with Vision Zero and the Safe System Approach, which emphasises that the road transport system is an entity in which the different components such as roads, vehicles and road users (i.e. the factors in Haddon's Matrix) must interact in order to ensure safety.

2. Material and methods

This study is based on data collected in a previous study which aimed to explore the experience of PWC usage on a daily basis (Stenberg et al., 2016). In the previous study, 15 individual interviews were conducted between 2012 and 2013, involving PWC users (seven men and eight women) aged 20–66 years, analysed with Grounded Theory. Important information about experienced traffic-related obstacles and risks was identified in 13 of the 15 interviews. However, these issues were only dealt with briefly due to not being included in the aim of the previous study (Stenberg et al., 2016). Video recordings of seven participants had not been previously analysed, five of which were deemed suitable for further analysis within the remit of this new aim.

2.1. Context

This study was conducted in Sweden, where people in need of PWCs are entitled to borrow such items from their local healthcare authority. Outdoor PWCs are heavier, have a wider base of support and larger wheels, more suitable for uneven ground than indoor wheelchairs designed for even surfaces and smaller spaces. Indoor PWCs therefore have smaller wheels, are narrower and lighter. At the time of this study, county council legislation generally granted one PWC per person; hence users usually select a PWC compromising between outdoor and indoor features. Furthermore, PWC users are always supplemented with a manual wheelchair for backup purposes.

The analysis focuses on videos and interviews in the public urban traffic environment where PWC users move independently in interaction with pedestrians and other vehicles.

2.2. Data collection

Participants in the previous study were chosen deliberately and consecutively as data interpretation progressed. To ensure as comprehensive data as possible, the sample was chosen to provide variation on the basis of diagnosis, duration of PWC use, age, gender, marital status, geographical location, level of education and type of PWC. Since the climate in Sweden involves snowy, cold winters and hot summers, with significant regional variations, participants were recruited from four different county council areas; one in the south of the country, one in central Sweden and two in the north. See Stenberg et al. (2016) for more information about the sampling procedure in the previous study.

Video observation was combined with contextual interviews, made at one or two occasions with each participant, and recorded in environments chosen by the participants in order to best capture daily living using a PWC. Different situations were chosen by different people. Videos from homes, workplaces, different traffic environments and private and public transport were represented. For this study, videos showing traffic environments were used. The video observations were filmed with a video camera and a smartphone, and were transcribed verbatim. Video analysis, contextual interviews and the photovoice method utilised in this study, have previously been used in observational studies in the traffic environment (Feldner et al., 2019; McIlvenny, 2019; McIlvenny and Davidsen, 2017; Parent, 2016; Payyanadan et al., 2017).

The individual interviews were semi-structured, with open-ended questions, and transcribed verbatim. See Stenberg et al. (2016) for more information about the collection of interview data. The authors (Henje and Stenberg) collected all data between May and November 2012.

2.3. Participants

To qualify for inclusion in this study, sequences from video recordings and interviews had to contain information about obstacles and risks in the traffic environment. Information from a total of 13 interviews and videos from five participants (13 in total) were included and analysed further. All participants had physical impairments, most of them also suffered from pain and two had spasticity. All participants had combined indoor/outdoor PWCs, except for two who only used outdoor PWCs. The PWCs in the study were controlled with a joystick either on the armrest or placed in front of the user's chin. The latter is used when users are unable to use their hands due to a disability. See Table 1 for background data.

2.4. Data analysis

This study applied Haddon's Matrix (Haddon, 1968, 1980) as an analytical framework for a descriptive qualitative research methodology. Haddon's Matrix is commonly used in injury prevention where human, vehicle and environmental factors are analysed in order to facilitate a broad perspective on risks and injuries in traffic settings. The data analysis procedure was carried out as follows:

Step 1: The video recordings were split into shorter sequences (not exceeding 3 min, Fig. 1), and studied (at least) three times, one by one, in order to enhance reliability when identifying obstacles and risks in the traffic environment. The entire multidisciplinary research group 1) watched individually; 2) watched and took individual notes; and 3) watched, commented on the content and shared individual notes. These notes were then labelled with codes and compiled.

Step 2: Relevant interview sequences in transcripts from all the video and in-depth interviews, were identified in accordance with the aim of this study. The sequences were analysed individually and labelled by the research group in the same way as for the videos.

Step 3. In order to explore causality with regard to human, vehicle (PWC) and environment, all codes from Step 1 and 2 were sorted and grouped into sub-categories and categories during discussion and negotiation between all authors, in accordance with the three factors of the second dimension of the Haddon Matrix (Haddon, 1968, 1980).

The analyses were performed by researchers from different fields, including industrial design, traffic safety, social science and physiotherapy, and the analyses were scrutinised and discussed among the researchers.

2.5. Ethics

This study is compliant with the Helsinki Declaration. The original study (Stenberg et al., 2016) was approved by the Regional Ethics Committee in Umeå (Dnr 2012-220-31M), and an additional approval from the Ethics Committee in Gothenburg (Dnr 401-17) was obtained to allow two further researchers (Carlsson and Lundälv) to view the data. In 2017, each individual featured in the videos was contacted in order to provide them with information verbally and in writing, and to obtain new written consent as it was not possible to anonymise the videos. All personal data has been deliberately excluded from the results so as to ensure anonymity. The participants received no financial compensation.

3. Results

Nine sub-categories emerged within the three classification perspectives applied in the Haddon Matrix, human, vehicle (PWC) and environmental factors, when analysing and categorising obstacles and risks identified in the interviews and videos *(*Table 2*)*. Detailed results for each sub-category are presented below, including examples reflecting content and quotations from participants.

3.1. Human factors

The category includes observations correlated to the individual that, in various ways, are associated to the traffic environment, such as PWC users' challenges in the interaction with other road users, related to or reinforcing implications correlated to each user's disability, as well as each individual's own approach to risks and risk-taking.

3.1.1. Interaction with other road users

The built environment defines the criteria for accessibility and the preconditions for interaction with other road users in the traffic environment. Crowded and narrow spaces, particularly pavements with benches and outdoor cafés, result in obstructed visibility for participants and increase the risk of collision. Participants explained that the PWC being electric might also constitute a risk as people are unable to hear it, especially if they are wearing headphones. Pedestrians are also at risk of being hit by, or tripping over, heavy PWCs due to not allowing them enough space. Participants described how people they encounter in the street find it difficult estimating the size of the PWC.

> *…When you meet people on the pavement and they make way for you, they lean to one side but keep their feet in the same place. And you say 'Sorry, I actually need you to move'. Because… I mean, I need the space on the ground so that I don't run over their feet.*

Participants explained that the risk of injury increases if a pedestrian trip and fall onto their lap and accidentally hit the joystick, making the user liable to subsequently losing control of the PWC. Everyone involved would be subject to serious consequences in cases where the PWC unintentionally enters the road, hitting other pedestrians. Furthermore, participants also highlighted the risk of the joystick being inadvertently touched by someone passing too close in a crowd, or when a friend leans forward to say hello. To prevent accidents, participants explained that they usually stop and turn off the PWC when they find people coming too close.

Table 1
Background information about study participants. PWC = Powered wheelchair, P = Participant, M = Male, F = Female, Full = Full-time, Part = Part-time.

Participant	Age [years]	Gender	PWC usage	Time used [years]	Diagnosis	Video
P2	49	F	Part	10	Chronic pain from trauma	Video
P3	37	M	Part	7	Charcot-Marie-Tooth disease	–
P4	39	F	Full	30	Rheumatoid arthritis	Video
P5	20	F	Full	18	Cerebral palsy	Video
P7	38	F	Full	35	Osteoporosis	Video
P8	26	F	Full	14	Charcot-Marie-Tooth disease	–
P9	23	F	Part	16	Juvenile dermatomyositis	–
P10	63	M	Part	36	Rheumatoid arthritis	–
P11	24	F	Full	20	Cerebral palsy	–
P12	66	M	Part	0.9	Spinal cord injury	–
P13	43	F	Part	0.25	Multiple sclerosis	–
P14	40	M	Full	28	Cerebral palsy	Video
P15	44	M	Full	10	Spinal cord injury	–

Fig. 1. The images are captured on a short video sequence analysed in the study. The sequence shows a PWC user with a personal assistant entering a new street where both of them opted for the street instead of the pavement. The PWC user motivated the strategy by pointing out the narrowness of the pavement, preventing them from exiting the pavement at the end of the street, due to the lack of dropped kerbs. In the data analysis, videos showing PWC users' behaviour and experiences in the traffic environment were selected, split into short sequences and analysed, step by step, in order to identify obstacles and risks for PWC users as well as explore the causalities related to human, vehicle and environment, in accordance with the Haddon Matrix (for quote, see Sub-section 3.1.3).

Table 2
Identified sub-categories of risks and obstacles in the traffic environment for PWC users that emerged in analysis of the material, applying the three classification perspectives of the Haddon Matrix, human, vehicle (PWC) and environmental factors (Haddon, 1968, 1980).

3.1 HUMAN FACTORS	3.1.1 Interaction with other road users 3.1.2 Disability related challenges 3.1.3 Managing risks and safety
3.2 VEHICLE (PWC) FACTORS	3.2.1 Technical performance 3.2.2 Poor visibility 3.2.3 Low temperature and precipitation
3.3 ENVIRONMENTAL FACTORS	3.3.1 Built environment
	3.3.2 Temporary road solutions and poor maintenance 3.3.3 Precipitation and poor snow clearing

3.1.2. Disability related challenges

Participants described and demonstrated how issues with pain and spasticity occasionally may aggravate due to shortcomings in the built environment. Counteracting gravity when driving on pavements sloping towards the road amplifies static muscle tension, leading to more pain. Vibration caused by uneven surfaces such as paving slabs, gravel, snow and ice causes similar problems. Participants said that even if paving slabs are good for driving on, the grooves between the slabs are an inconvenience and worsen their pain.

> *Gravel doesn't need to be deep to cause problems. The surface needs to be pretty hard if it's to be pleasant to drive on. Asphalt is the best, of course, asphalt and paving slabs. Although all the gaps between the slabs are a nuisance.*

By constantly sitting still and not being able to move, the participants described how they feel the cold more, even in summer. Some explained how they compensate by wearing warm clothes, not least gloves as the hand gets cold from steering the PWC using the joystick. Wearing thick gloves in winter, in combination with low temperatures, can affect hand and finger movement and tactility, and reduce the fine motor skills required to operate the joystick when driving the PWC in the traffic environment

> *People ask why I don't wear gloves. But if I'm wearing gloves when I'm operating the joystick, it gets slippery and I lose control. I don't listen to them. People find it hard to understand, but I want to be able to grip the joystick firmly.*

Another risk observed and also described by participants is associated with being seated while driving, and thus having a restricted view of the traffic situation. Extra attention is also required for participants with restricted neck mobility, or when operating the PWC with chin control, as lateral and rear visibility is limited when driving.

> *When you drive with your chin, it's not… I can't… I have to look straight ahead all the time. … If I want to look in a shop window, I first have to stop [demonstrates by turning the PWC through 90 degrees] and then check to make sure nobody walks into me from behind.*

3.1.3. Managing risks and safety

The video observations showed how participants faced various obstacles and risks in order to reach their destination when getting around in the traffic environment. Built obstacles, temporary road work and pavements without dropped kerbs forced the PWC users to enter the road instead of remaining on the pavement in order to get through, despite the increased risk.

> *I always use the road here, although I usually tell anybody walking with me that they can use the pavement if they want. The pavements here are really narrow, and if you approach from this direction and use this pavement, you can't get down over there [as there is no dropped kerb at the other end of the pavement] (Fig. 1)*

Both videos and interviews indicated that reversing is a strategy used regularly by participants when moving from a higher to a lower level, even when using dropped kerbs or ramps. Participants said they prefer continuing ahead so that they can see. Yet, they chose to reverse to reduce the risk of overturning or falling off the PWC, despite being aware of losing overview of the traffic situation when reversing off a pavement without the appropriate dropped kerbs.

Risks related to not being visible in the dark were seen to be approached in different ways by participants. While some chose to fit their PWCs with additional reflectors and lights to safeguard being seen, others even hesitated turning the built-in lights on when around other people, telling that they feel the lights affect the way in which they wanted to be perceived by others.

> *They [the lights] are good when driving in the dark, of course. But I'm a bit vain – I don't want the lights on if I don't have to. Obviously, people can see me anyway when I'm in a crowd.*

Study participants did not wear the integrated standard two-point belt when driving in the traffic environment. They stated that this is because the belt tends to slip down and is hard to reach, or is in the wrong place, useless or broken. Others claimed it interferes with their clothing or prevents them adjusting their seated position. Some were also afraid of getting stuck or seriously injured if the PWC overturned while they were wearing the belt. Instead of wearing the belt, some of the participants adopted a particular strategy to prevent them falling out of the PWC when driving over low kerbs and bumps, by tilting the seat and backrest backwards while approaching and passing obstacles.

3.2. Vehicle (PWC) factors

Vehicle-related factors associated with obstacles and risks in the traffic environment were linked to the vehicle's technical performance and its limitations in negotiating uneven surfaces, visibility in the dark and the adverse impact of low temperatures and precipitation.

3.2.1. Technical performance

According to participants, the size of the PWC is significant with regard to accessibility and stability. A bigger PWC is more robust and difficult to tip over, while smaller, shorter PWCs are more convenient in narrow or crowded environments, due to their manoeuvrability and simplicity of turning in limited space. That said, smaller PWCs do not negotiate kerbs or obstacles as well.

Although the participants' combined indoor/outdoor PWCs were able to cope with minor irregularities in the urban environment, they have not been designed to cope with significant height differences, such as small steps, i.e., kerbs. According to participants, they risk the footrest getting stuck on the ground when moving forward and down off a (dropped) kerb or ramp, putting the user at risk of falling off; or the entire PWC to tip over. This is one reason why users prefer reversing off differences in height despite the lack of visibility. Video recordings showed one participant getting stuck on a ramp when reversing away from her car and out into the street, which forced her to move back and forth before completing the manoeuvre.

According to participants, PWCs weigh about 150 kg (330 lb), excluding the user, making them very heavy and difficult to move manually if they get stuck.

> *Once it [the PWC] actually stopped in the middle of the tram tracks, and it wasn't even possible to disconnect the clutch and push it. No, it was… well… anyway, I had to get someone to help me. They got it to a 7-Eleven and I had to leave it there for the night. The police turned up… a police van… It was quite a drama.*

Using a joystick controlled by chin movements has its own implications. Placed in front of the user's chin, the joystick is protected more effectively from others nearby than the hand-steered variety. Although, one participant using a chin-steered joystick explained how his upper body swings involuntary when travelling on uneven surfaces, causing the joystick to slap him in the face, resulting in momentary loss of control of the PWC. Consequently, he avoids any long periods of outdoor activity in his PWC as he finds the experience too exhausting.

> *…This [chin control] smacks me in the face when I… well, when… when the wheelchair goes over bumps… over kerbs, things like that.*

3.2.2. Poor visibility

The video analysis showed that incorporated lamps and reflectors on participants PWCs' were positioned on the lower part of the PWC, and that many of them were missing, damaged or hidden by the integrated storage bag. Participants found it easy to damage them when riding the PWC.

> *These things break – lamps, reflectors. And… I've probably broken… I don't know which side… Oh yes, this side. I was responsible for wrecking that.*

One participant complained that her PWC had not been equipped with factory fitted reflectors, and that she regrets turning down the offer to fit her PWC with lamps, as they were not part of the initial standard equipment for the model.

3.2.3. Low temperature and precipitation

According to participants, cold weather and precipitation may adversely affect PWCs. Some users had experienced their PWCs suddenly come to a halt after being exposed to moisture and rain. Cold weather, on the other hand, reduces the PWC display and battery capacity while low temperatures slow the whole PWC down, they said.

> *It [the PWC] becomes more sluggish after a couple of hours [in cold weather in winter].*

Videos and interviews show clearly that snow, ice and slush impair the PWC's driving properties. Participants explained that the front-wheel drive makes driving in snow easier, although deep snow can easily cause the wheels to cut into the snow, particularly the rear wheels "*the rear wheels have a mind of their own*". They also explained how difficult it is to steer and ride straight in snow as the wheels keeps sliding. Hence, there is a constant risk of getting stuck, not least in deep snow or if snow accumulates underneath the PWC.

> *No, but… you always get stuck at some point in winter. Snow and… so you can end up stuck when you're out in the snow. Because the snow is so deep, nobody's been out to clear it, that kind of thing.*

3.3. Environmental factors

The built environment, unsatisfactory road structures and temporary compensatory solutions and factors relating to precipitation and poor snow clearing were all environmental factors cited by participants or visible in the observations.

3.3.1. Built environment

The interviews and videos showed that kerbs and steps constitute obstacles, causing problems and risks in the traffic environment, that participants were both aware and afraid of. The video analysis showed that uneven and bumpy surfaces, differences in ground levels, steep slopes and ramps have the potential to put the PWC at risk of overturning or cause the user to fall off the PWC.

> *I somersaulted, and… because there was a kerb there that I didn't see. The ground was covered in stones and grass, so I didn't see the kerb. So, I flew out of the chair and managed to pull this off at the same time… the knob [of the joystick]. So, I was just like 'WTF?!'.*

If dropped kerbs are not available, or if the participants suspect they will be missing at the far end, they chose the road instead of the pavement. They also enter the road if pavements are narrow, blocked by outdoor restaurants or taken up by shop ramps.

> *It's bloody annoying not to be able to get through.*

According to participants, irregularities, kerbs and differences in ground levels are even more difficult to detect in poor lighting and visual contrasts, increasing the risk of accidents. The video analysis indicated a risk of accidents or collisions with other road users due to visibility being restricted by bushes along pavements and temporary barriers along roadworks.

3.3.2. Temporary road solutions and poor maintenance

The videos and interviews showed that construction work in the traffic environment, involving temporary solutions or poor maintenance, sometimes can result in uneven surfaces, differences in ground levels, kerbs, loose gravel, sand and mud, presenting participants with the same risks and problems as described above for the built environment. Obstacles and risks could be difficult to detect, especially if the participants' vision was low or there was insufficient temporary lighting. In case of inappropriate temporary solutions, participants explained how they had no option but to make their way along the road instead or turn back and find another route.

Participants explained how driving into grass, sand or mud, or encountering unexpected differences in ground level, may cause the PWC to come to a halt, with risk of falling off. The interviews and videos indicated that participants are at risk of getting stuck if they accidentally drive into grass, sand or mud. When they are stuck, there is no way for the PWC users to escape without assistance from others.

> *Well… yes, I've been stuck in puddles a few times when they've been a bit too deep, that kind of thing. So yes, I've got stuck. Once they actually had to come and rescue me with an excavator. / Yes, that happened once but I wasn't left hanging around too long… They scooped me up with an*

excavator. / That puddle was pretty deep… We went to a place where they were doing some construction work, and I just happened to drive into a puddle that was deeper than usual… and it was quite muddy too.

3.3.3. Precipitation and poor snow clearing

Snow and poor snow clearing, were shown to radically impair accessibility for participants.

Accessibility in snow is the biggest problem in winter.

One of the participants explained that sometimes only the roads get cleared from snow and not the pavements. Then, only thing to do is to go back home or use the road, placing both themselves and other road users at increased risk.

…You can't apply the '6 cm principle' like for roads before the snow-ploughs have passed, because a heavy car can manage 6 cm with no problems. But a wheelchair, a pram or a walking frame can't manage that… / … they should at least clear the bigger footpaths. Maybe they should be ploughed earlier, and above all be ploughed and cleared. / Just removing the snow isn't enough, you also have to clear the path. Clear it completely, I mean. Because… If you just plough and leave loads of ridges, it can make it really difficult to use the path…

Participants declared and demonstrated that poor snow clearing can result in ridges, grooves and heaps of snow obstructing their way (when thawed or frozen), making paths severely challenging and unpleasant to use. At times, this also makes it more difficult, or even impossible, for participants to access and use public transport or their own cars.

Well, the worst thing is in winter, when it's cold and snowy and icy and you have to… Well, when you need to lower your car ramp and you need a flat surface, but you haven't got one because they've piled up all the snow on the kerbs and the heaps are all frozen. You have to lower the ramp and the surface is uneven when you leave the car in your PWC… and then when you want to get back [to your car], the ramp is slightly raised and on an uneven surface… It's not all that easy. Your PWC might slip, so you might end up stuck in the snow if things go wrong. That does happen sometimes, and in that case, somebody has to come and give you a push.

Snow presents a hazard for participants even when melting. The video analysis showed one participant criss-crossing the road, trying to avoid accumulation of slush and puddles of water, keeping the eyes on the road rather than the traffic while crossing.

4. Discussion and conclusions

The results of this study show the importance of paying more attention to the perspectives of PWC users in order to contribute to the Vision Zero charter adopted by Sweden over 20 years ago (Government Offices of Sweden, 1997; Swedish Transport Administration, 2019). We perceive a considerable potential for improvement within all three Haddon Matrix factors that were applied for our analysis; at the human, vehicle and environmental factors. Involving users of PWCs and working on all perspectives will be imperative in the process, if we are to bring about successful improvements in terms of prevention of injuries on the roads and make the built environment equally accessible and safe for all.

Human Factors including coping strategies and negotiating different circumstances, are crucial with regard to the ability of users to get themselves from one place to another as well as assessing any risky situations that may arise in traffic. Significant opportunities present themselves in this regard, alongside certain challenges with regard to implementing safe and effective mobility. For example, a Danish study revealed that PWC users continuously negotiate with other VRUs, such as pedestrians, when navigating the traffic environment (McIlvenny, 2019). We can conclude from our study that PWC users must accommodate prevailing traffic situations, which have not been adapted to their needs. Besides having to evaluate and process large amounts of information, users must also consider various risk scenarios as well as apply different coping strategies in order to minimise, avoid and otherwise deal with emerging risks. Commonly, these scenarios involve advanced precision manoeuvring and individuals continuously having to consider the pros and cons of every decision they have to make.

For PWC users, the wheelchair can be viewed as part of the body and/or as a vehicle (Stenberg et al., 2016). On the one hand, when out and about, they do not want to be lit up like "Christmas trees" or attract attention because they are using lamps or other prominent equipment (Stenberg et al., 2016). They prefer to be seen for who they are, not be viewed as people with disabilities. On the other hand, they are aware of the importance of being visible when in traffic. Therefore, to emphasise PWC users' role as VRUs, it may be appropriate to describe them as *drivers* rather than users when navigating the traffic environment.

For several reasons, drivers in this study rarely wore the two-point belt integrated in the PWCs featured in this study, one reason being the fear of serious injury should they become trapped under the PWC in the event of it turning over. PWCs provided by the local healthcare authorities in Sweden are usually equipped with a built-in two-point belt as an accessory, and recommendation on usage is provided after assessment and in consultation with the user. As confirmed by previous studies (Chen et al., 2011), many PWC drivers oppose the use of existing safety systems such as seatbelts, helmets or other equipment. Consequently, drivers may fall off their vehicle and sustain injuries (16% of single accidents, Carlsson and Lundälv, 2019). The multidisciplinary approach of this study identified that for successful injury prevention, it is crucial to have a holistic perspective and consider users' different views of their PWC, both as part of the body and/or as a vehicle. This presents a design challenge when developing sustainable mobility aids and imply that drivers of PWCs must be included and actively involved in injury prevention measures, as well as in designing the traffic environment.

Vehicle Factors include the vehicle's technical performance, function and construction, such as the brakes, engine, electronics, mechanics and wheels, as well as safety equipment, adjustments and stability (Kirby and Ackroyd-Stolarz, 1995). The results of this study show that vehicles used both indoors and outdoors must be small and flexible enough to manoeuvre indoors yet stable enough to be used outdoors. PWC stability when negotiating kerbs, uneven surfaces or snow-covered roads presents a major challenge, given the relatively narrow wheelbase, the high centre of gravity and the small size of the wheels (Corfman et al., 2003; Carlsson and Lundälv, 2019). Overturned PWCs were involved in 71% of single accidents in the traffic environment in Sweden (Carlsson and Lundälv, 2019). Research on improving the PWCs technical capacity, safety and comfort is ongoing (Choi et al., 2019), still more is strongly recommended in order to improve the performance of these vehicles in outdoor and winter conditions. Furthermore, using the same vehicle both indoors and outdoors results in significant amounts of dirt being brought indoors, such as mud or slush, if the outdoor surface is inadequate. Consequently, in certain circumstances users may avoid bringing their PWCs outdoors, thereby impeding their mobility.

Environmental Factors, in this study, as well as previous research, has identified kerbs as a major obstacle and a cause of accidents for powered mobility devices (Corfman et al., 2003; Edwards and McCluskey, 2010; Erickson et al., 2016; Carlsson and Lundälv, 2019). In Sweden, one in three (34%) single accidents involving a PWC is caused by a difference in ground level, typically a kerb (Carlsson and Lundälv, 2019). Furthermore, the results confirm earlier studies showing that pavements sloping towards one side, and uneven and rough footpaths result in harmful vibration and/or discomfort for wheelchair users (Duvall et al., 2016). The risk factors mentioned are important to map and assess from an accident preventive point of view, beneficial for all pedestrians (Hunt-Sturman and Jackson, 2008). Moreover, this study clearly shows that accessibility is challenging in winter. This correlates with previous studies carried out in Denmark, Canada and Sweden, which have reported reduced outdoor activity among drivers of powered mobility devices in winter (Brandt et al., 2004; Morales et al., 2014; Carlsson and Lundälv, 2019). Previous studies have also highlighted issues due to heavy snowfall in winter, making it difficult to manoeuvre PWCs (Mortenson et al., 2015; Torkia et al., 2015).

Sweden has been developing laws and regulations aimed at enhanced accessibility since the 1960s (Persson Bergvall and Sjöberg, 2012). In 2008, Sweden ratified the UN Convention on the Rights of Persons with Disabilities (UN, 2006), including the principles for Universal Design (Center for Universal Design, 1997). However, more is still required in order to provide accessibility and safe mobility. A continuous process towards increased urbanisation, alongside transformation of the transport system based on electrification, automation, digitisation and adaptation of the entire infrastructure, is in place globally. It is crucial to consider all road user groups, including PWC users, when planning for the sustainable society of the future (Charlton, 1998; UN, 2015). Furthermore, in this study we highlight that also PWC users should be regarded as drivers in order to reinforce that they are a subgroup of VRUs, and thus raise awareness that they must be considered in urban planning and in traffic safety contexts. Different road user groups have different needs, and it is important to establish what those needs entail. Hence, it is important also to involve both individuals with disabilities as well as organisations representing people with disabilities when effecting change within traffic planning, as well as traffic safety measures (locally, nationally and internationally).

There are still major challenges to address with regard to inclusion of PWC drivers in both research and traffic planning. Ensuring safety and reducing injuries and risks in the traffic environment for this subgroup of VRUs are important incentives. This observational study was conducted to present both stated and unspoken strategies and decisions, and it incorporates the knowledge and first-hand experiences of people with motor disabilities. The approach applied is based on various disciplinary fields; design, physiotherapy, social work (disability studies), biomechanics and injury prevention. The long-term goal is to contribute to improved mobility and reduced risk of accidents and injuries for PWC users, thereby reinforcing the active participation of people with disabilities in society.

To secure integrity of this study, the research method was discussed at *The 6th Annual Scientific Seminar of the Nordic Traffic Safety Academy* where we received valuable comments from other researchers in this research field. Valuable insights were also received from the audience during *Transportforum 2019* (Ekström et al., 2019: 371). Furthermore, the analysis was made separately by the authors and later discussed in the research group, consisting of different professions and experiences from different research fields; industrial design, traffic safety, social science and physiotherapy. The research results have been reinforced by the broad prior knowledge brought to discussions and reflection during the entire research process. An advantage of qualitative studies is that new unexpected information can emerge. In this study, for ethical reasons, we wanted to present important information from the previous data collection on conditions in traffic situations which had not been analysed before as the objectives when collecting the data was different.

One limitation of our study is that it is based on a relatively limited sample. Previous qualitative studies of PWC drivers have also only involved a limited number of interviewees (Torkia et al., 2015). In future, it would be beneficial to carry out further substantial investigations from a holistic perspective, involving PWC drivers and issues they experience in various urban and traffic environments, over time. To conclude, it is important to gain a more in-depth understanding of how PWC drivers experience, and develop skills and awareness of risks and difficulties, in traffic environments. This could be achieved by taking PWC users' knowledge and experience into account, making them active participants in inclusive research, including traffic planning and accident prevention (Charlton, 1998).

CRediT authorship contribution statement

Catharina Henje: Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Project administration. **Gunilla Stenberg:** Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing. **Jörgen Lundälv:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Funding acquisition. **Anna Carlsson:** Conceptualization, Methodology, Formal analysis, Writing - original draft, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Declarations of interest

The data in this study was collected as part of a previous study supported by the PWC manufacturer Permobil. However, that study itself was entirely independent, Permobil was not involved in any stages of the research process. The researchers were also not restricted to studying individuals using Permobil wheelchairs.

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