

Ramps to the House & Slopes in the Garden: Will the Wheeled Walking Aid, Manual Wheelchair or Power Wheelchair Make It?

Medical Aids Subsidy Scheme

6 March 2024



Queensland
Government



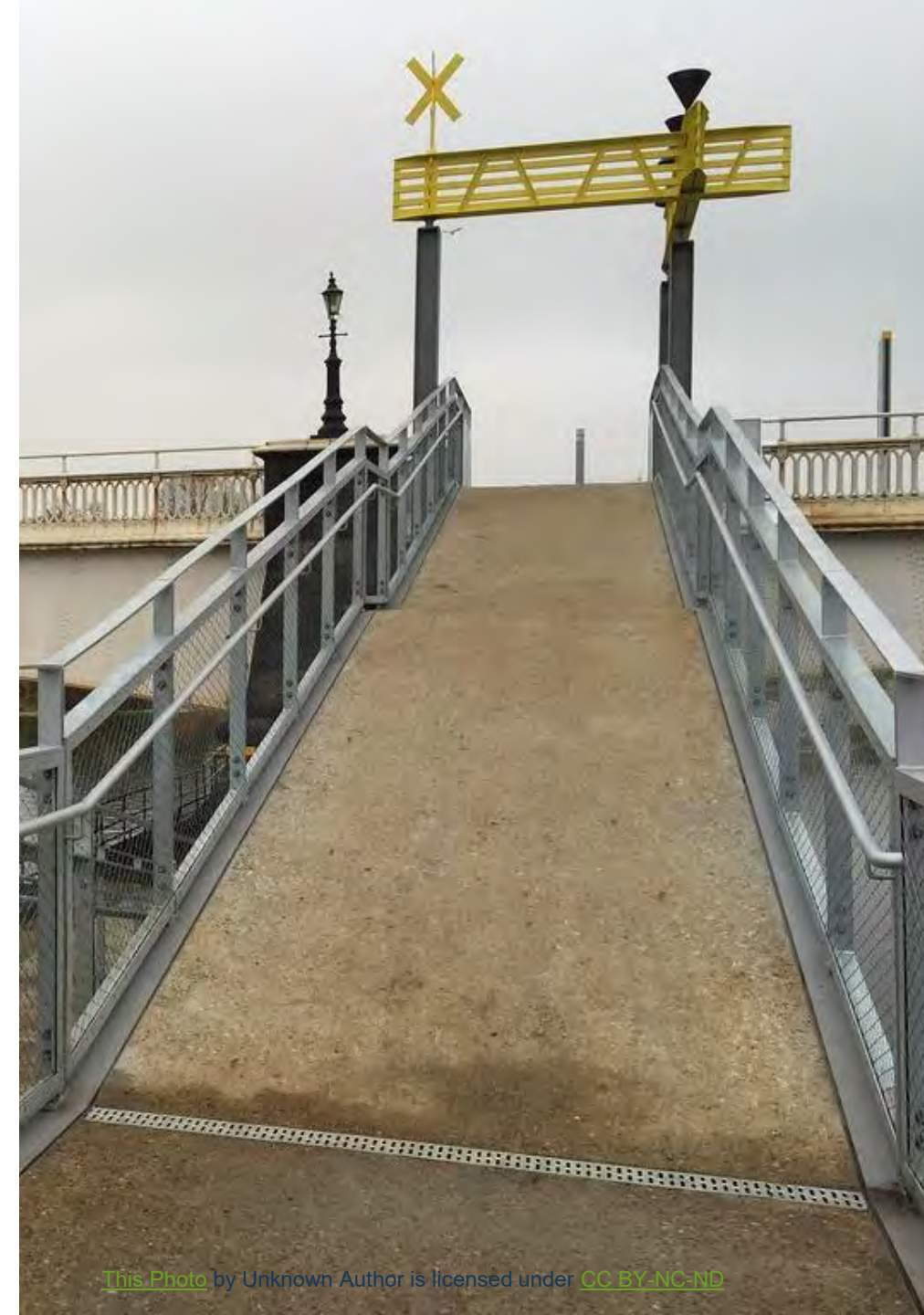
Session outline

- Consequences
- Understanding gradients
- Measuring gradients
- Standards
- General guidelines
- Person-centred considerations
- AT-centred considerations
- Environmental considerations

What happens if we get this wrong?

- Traumatic brain injuries¹
- Concussion¹
- Fractures¹
- Spinal cord injuries¹
- Soft tissue injury
- Skin injury
- Overuse injury
- Inability to access an area

1. Opalek, J.M., Graymire, V.L., & Redd, D. (2009). Wheelchair falls: 5 years of data from a level I trauma center. *Journal of Trauma Nursing*, 16(2), 98-102.





Disaster scenarios

- Tipping out of wheelchair going down slope¹
- Footplates / castors catch at start/end of ramp (e.g., ascending a 45° curb) and flip out of chair¹
- Starts to go backwards when walking up slope with wheeled walker
- PWC mid-wheel lifts off ground and gets stuck
- MWC or wheeled walker user unable to control speed downhill

1. Corfman, T.A., et al. (2003). Tips and falls during electric-powered wheelchair driving: effects of seatbelt use, legrests, and driving speed. *Archives of Physical Medicine & Rehabilitation*, 84(12), 1797-1802

BEFORE



AFTER



A case report¹

67yo

PWC – Permobil
Chairman 2K Stander

Femur fracture

1. Edlich, R.F., et al. (2010). A case report of a severe musculoskeletal injury in a wheelchair user caused by an incorrect wheelchair ramp design. *Journal of Emergency Medicine*, 38(2), 150-154.



Understanding gradients

Gradient	Degrees
1:20	2.86
1:14	4.09
1:12	4.76
1:10	5.71
1:8	7.13
1:6	9.46

[Slope calculator](#)



How to measure a gradient

Tape measure



Inclinometer

(Phone-based apps e.g., Clinometer, Apple Measures)



Water or laser level



Image source:

Tape measure by [Unknown Author](#) is licensed under [CC BY-NC](#)

[Inclinometer photo](#) by Unknown Author is licensed under [CC BY-SA-NC](#)

[Laser level photo](#) by Unknown Author is licensed under [CC BY](#)



When you have a level surface to measure the ramp / slope against

Measure the rise



Measure the run



1800mm

180mm

Rise
Run

$$\frac{1800\text{mm}}{180\text{mm}} = 10$$

Gradient = 1:10

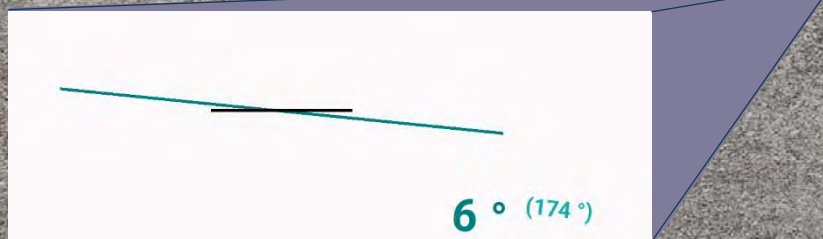
Degrees = 5.71

When you don't have a level surface to measure the ramp / slope against

Use an inclinometer (easily downloaded on most smartphones)

Use it on its side or flat

On uneven ground, use a straight 'stick' underneath





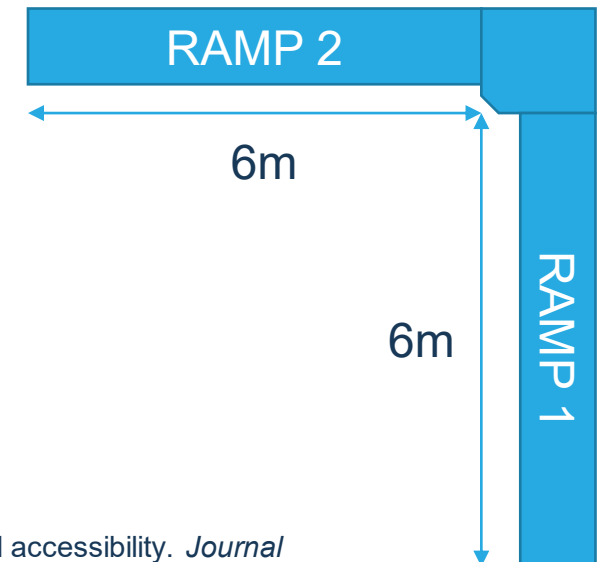
“Bubble” level
type apps where
you can see
incline and
cross-fall at the
same time

**Don't forget to measure
thresholds / lips**



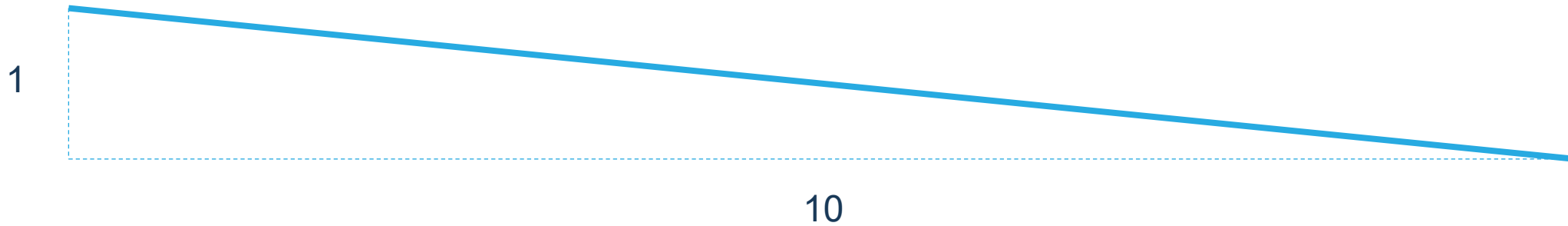
Can users tell a steeper gradient?¹

- Experimental study with manual and power wheelchair users
- Unable to distinguish differences in steepness of 2% (1.15°) or less (e.g., 1:10 vs 1:12)
- MWC users able to distinguish differences in steepness of 3% (1.72°) or greater
- PWC users generally couldn't distinguish slope difference 3% (1.72°)
- Similar for cross-slopes



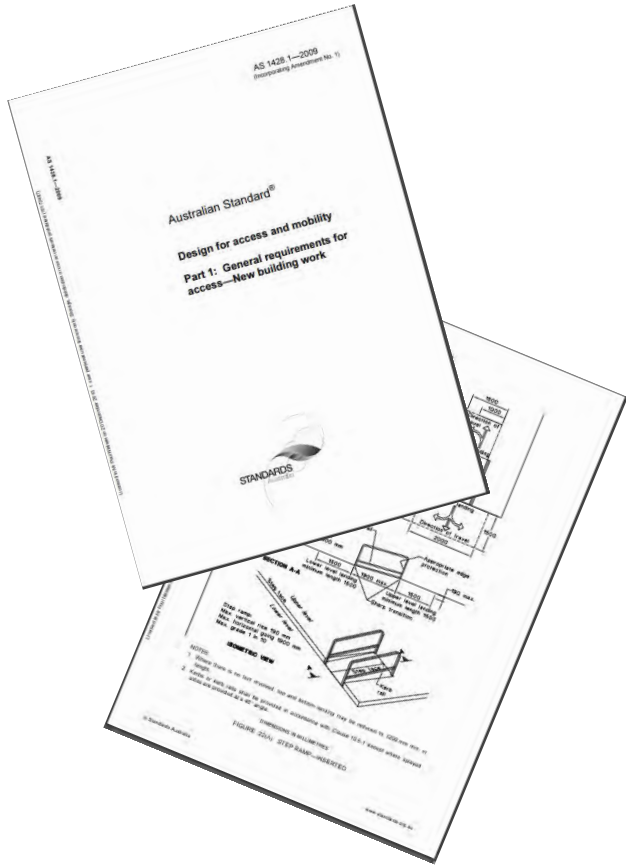
1. Vredenburgh, A.G., et al. (2009). Evaluation of wheelchair users' perceived sidewalk and ramp slope: effort and accessibility. *Journal of Architectural & Planning Research*, 26(2), 145-158.

POLL: How steep is this slope?



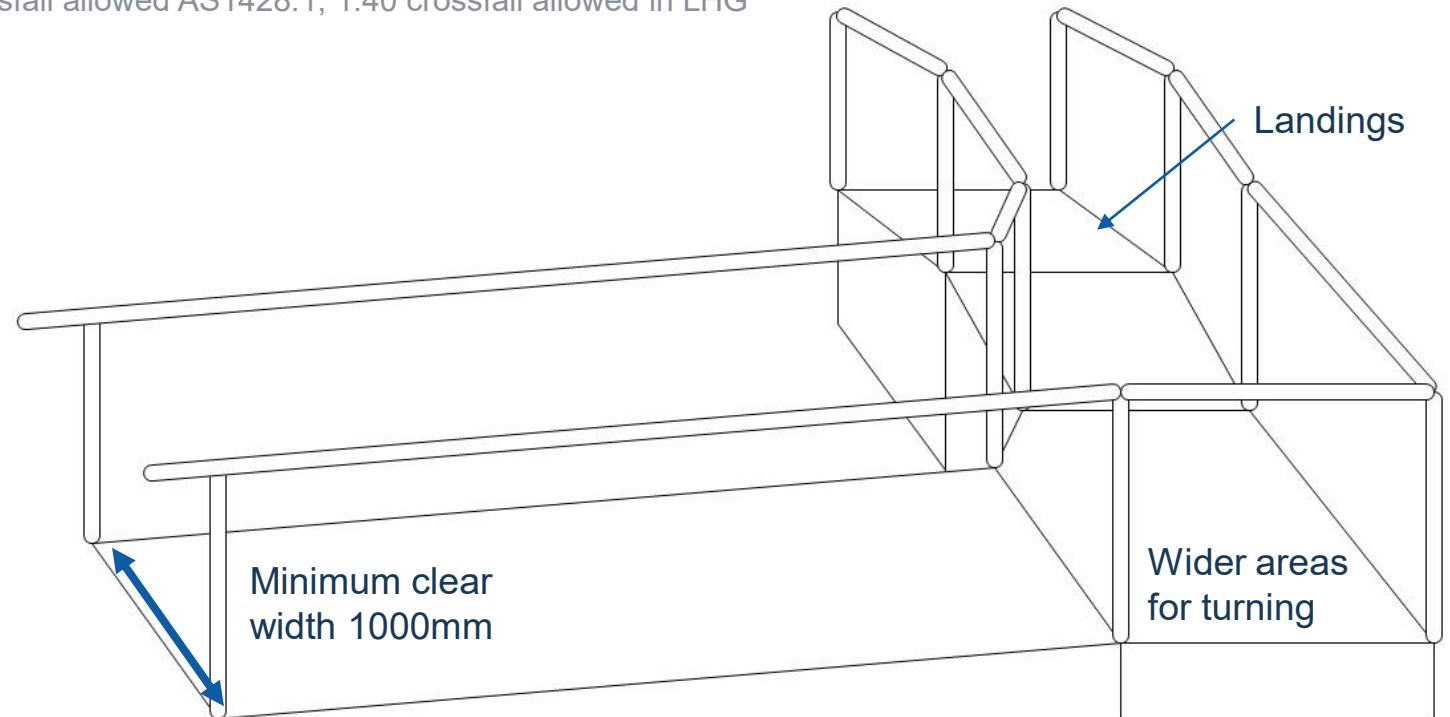
Standards & Guidelines

Standard	Application
AS 1428.1: 2021 Design for access and mobility, Part 1: General requirements for access – new building work	New <u>public</u> buildings
AS 3856.1: 2021 Hoists and ramps for people with disability – vehicle mounted, Part 1: Product requirements	Vehicle access ramps for <u>occupied</u> wheelchairs
AS 3695.2: 2019 Wheelchairs, Part 2: Requirements and test methods for electrically powered wheelchairs (including mobility scooters)	Minimum gradient that PWC must be capable of transversing, depending on classification, to be compliant
AS 4299: 1995 Adaptable housing	Voluntary housing standards (ramps refer to AS 14281.1)
Livable Housing Design Handbook 2022	Non-mandatory guidelines for housing accessibility (becoming mandatory for new homes in Queensland)



Scenario	Maximum gradient
Ramps up to 15m long	1:20
Ramps up to 9m long	1:14
Step ramp up to 190mm high	1:10
Threshold ramp up to 35mm high	1:8

Note: no crossfall allowed AS1428.1, 1:40 crossfall allowed in LHG



AS 1428.1 2021

/ Liveable Housing Guidelines (LHG)

AS 3856.1: 2021

- Maximum gradient 1:6
- Slip resistant finish
- Edge barriers (min 75mm high recommended)





[Image: Invacare Esprit Action power wheelchair](#)

AS 3695.2: 2019

PWC / scooter

- Should be able to climb its manufacturer rated gradient at >2km/h
- Should not exceed more than 125% its maximum horizontal speed on a downhill

Class	Descriptor	Minimum slope
Class A	Compact, manoeuvrable wheelchairs not necessarily capable of negotiating outdoor obstacles	3° (~1:19)
Class B	Wheelchairs sufficiently compact and manoeuvrable for some indoor environments and capable of negotiating some outdoor obstacles	6° (~1:10)
Class C	Wheelchairs, usually large in size, not necessarily intended for indoor use but capable of travelling over longer distances and negotiating outdoor obstacles	10° (~1:6)

Extract from Quickie Q400 User Manual

Manufacturer's manual may advise as suitable for steeper slopes that exceed minimum requirements for class

Model	Q400 series	
Type / configuration	Q400 M	
Mid wheel drive	Q400 M	
Maximum user weight		
In combination with Sedeo Lite	136 kg	300 lbs.
In combination with Sedeo Pro	136 kg	300 lbs.
EN12184 class:	B	

Description	Metric system values		Imperial system values & alternative	
	Minimum	Maximum	Minimum	Maximum
Total length (including legrests)				
Mid wheel drive				
Q400 M Sedeo Lite Central footplate	1100 mm	1130 mm	43.3"	51.2"
Q400 M Sedeo Pro Swingaway hangers	1280 mm	1280 mm	50.4"	50.4"
Total width				
Q400 M 13" Drive wheels	610 mm	620 mm	24.0"	24.4"
Total weight				
Basic configuration, no batteries				
Q400 M Sedeo Lite	130 kg	138 kg	287 lbs.	304 lbs.
Q400 M Sedeo Pro	130 kg	138 kg	287 lbs.	304 lbs.
Total weight influencers				
Batteries				
50 Ah AGM (C20) (Set of 2)	27 kg		+ 59.5 lbs.	
60 Ah GEL (C20) (Set of 2)	43 kg		+ 94.8 lbs.	
80 Ah GEL (C20) (Set of 2)	50.2 kg		+ 110.7 lbs.	
Transport weight of the heaviest part	24.2 kg		53.3 lbs.	
Dynamic stability: Maximum safe slope				
Q400 M Mid wheel drive	8°		14.0 %	
Min. braking distance at maximum speed	1100 mm	3100 mm	82.7"	
Static stability				
Q400 M Sedeo Lite Down	14%		13%/26%/23%	
Q400 M Sedeo Pro Down	14%		13%/26%/23%	
Range of action				
NB: The following aspects have an effect on the range of action: Obstacles, rugged terrain, dirt, snow, ice, freezing point and frequency				
6 kph				
8 kph				
10 kph				
Climbing				
Q400 M				
Max				

Dynamic stability: Maximum safe slope
Q400 M Mid wheel drive

8°

14.0 %

Description	Metric system values		Imperial system values & alternative	
	Minimum	Maximum	Minimum	Maximum
Maximum battery dimensions (l x b x h)	260 x 172 x 210 mm		10.2 x 6.8 x 8.3"	
Battery capacity	50 Ah / 60 Ah / 80 Ah		50 Ah / 60 Ah / 80 Ah	
Maximum permissible charging voltage	24V		24V	
Maximum charging current	12 A (rms)		12 A (rms)	
Connector type	Controller manual		Controller manual	
Insulation	Class 2 double insulated		Class 2 double insulated	

MASS summary for power wheelchairs

Gradient Ratio	Gradient in Degrees	MASS Perspective on Best Practice
1 : 4	14.0	Historically, absolute maximum permitted gradient for assisted (potentially winch) vehicle access. Although permitted, recommendation to avoid. [Ref [Ref AS 3856.1: 1998]
1 : 5	11.3	Typical ramp gradient for vehicle access, with accompanying risk assessment (as reported by wheelchair accessible vehicle modifier)
1 : 6	9.5	Current acceptable gradient for portable ramp to facilitate vehicle access. [Ref AS 3856.1: 2021] 10 degrees - Minimum rated slope for Class C PWC (usually large in size, not necessarily intended for indoor use but capable of travelling over longer distances and negotiating outdoor obstacles). [Ref AS 3695.2: 2019]
1 : 7	8.1	Consider with appropriate risk assessment.
1 : 8	7.1	For disabled access, kerb ramps not exceeding 1520mm long/190mm high [Ref AS 1428.1: 2021] For abled access to private residence [Ref Part 11.2 of the ABCB Housing Provisions]
1 : 9	6.3	6 degrees - Minimum rated slope for Class B PWC (sufficiently compact and manoeuvrable for some indoor environments and capable of negotiating some outdoor obstacles). [Ref AS 3695.2: 2019]
1 : 10	5.7	For disabled access, step ramps not exceeding 1900mm long/190mm high. [Ref AS 1428.1: 2021]
1 : 11	5.2	
1 : 12	4.8	PWC intended for minimal outdoor use likely to have higher allowable safe slope. Check manuf. spec.
1 : 13	4.4	
1 : 14	4.1	For disabled access, new ramp yet to be constructed. [Ref all cited references]

Veering away from standards and guidelines

When these apply

- ✓ Private residence, and
- ✓ Existing residence (not new build), or
- ✓ Outside standards (e.g., garden slopes), plus
- ✓ Based on individual assessment and clinical reasoning

Where did 1:12 come from?



- Some MWC user could easily do 1:8
- Many older women with MWC couldn't do 1:12
- Some cane users couldn't make the distance

One final word of caution. It is important to note that the requirement of a maximum slope of 1:12, or 1-inch rise for 1-foot length, coincides with the English Standard measurement system. Therefore, ramps that are 1:12 should be easy to understand and practical to construct. Yet, it is still common to find ramps that do not comply with this requirement. If the construction industry has difficulty with a slope based on a 12-inch rule, how can we expect compliance with something that is not a standard increment measure, such as 1-inch rise for 14-inches in length? Therefore, until evidence to the contrary is overwhelming, common sense dictates that the technical requirement for ramps should remain at 1:12. ¹

General concepts



1:6



1:8



1:10



1:12



1:14

1. Chow, J.W., et al. (2009). Kinematic and electromyographic analysis of wheelchair propulsion on ramps with different slopes for young men with paraplegia. *Archives of Physical Medicine & Rehabilitation*, 90(2), 270-278.
2. Sanford, J.A., Story, M.F., & Jones, M.L. (1997). An analysis of the effects of ramp slope on people with mobility impairments. *Assistive Technology*, 91(1), 22-23.
3. Kim, C.S., Lee, D., Kwon, S., & Chung, M.K. (2014). Effects of ramp slope, ramp height and users' pushing force on performance, muscular activity and subjective ratings during wheelchair driving on a ramp. *International Journal of Industrial Ergonomics*, 44, 636-646.
4. Choi, Y.O., Less, H.Y., Lee, M.H., & Kwon, O.H. (2015). Effects of ramp slope on physiological characteristics and performance times of health adults propelling and pushing wheelchairs. *Journal of Physical Therapy Science*, 27(1), 7-9.
5. Kim, C.S., Lee, D., & Chung, M.K. (2012). Effects of ramp slope on usability when a wheelchair is propelled by attendant. *Proceeding of the Human Factors & Ergonomics Society 56th Annual Meeting*, 629-633.
6. Lenker, J.E., Damle, U., D'Souza, C., et al. (2016). Usability evaluation of access ramps in transit buses: preliminary findings. *Journal of Public Transportation*, 19(2), 109-127.
7. Vredenburgh, A.G., et al. (2009). Evaluation of wheelchair users' perceived sidewalk and ramp slope: effort and accessibility. *Journal of Architectural & Planning Research*, 26(2), 145-158.

Case study: Bea

- Family sourced a 1:10 ramp
- Advanced rheumatoid arthritis with long hospitalisation
- Prescribing a TDX SP2 PWC
- Will she make it?



Considering cross-fall

- 3.72° increases MWC user glenohumeral peak force by 4.1x¹
- 2° doubles MWC user effort²
- 1.4° increases MWC user glenohumeral peak force by 1.4x²
- Often noticeable above 6 degrees for all users²
- Standards
 - AS1428.1:2021 No crossfall
 - NZS4121:2001 < 1:50 (1.15°)³
 - LHG < 1:40 (1.43°)

1. Holloway C S, Symonds A, Suzuki T, Gall A, Smitham P and Taylor S 2015 Linking wheelchair kinetics to glenohumeral joint demand during everyday accessibility activities 37th Ann Int Conf of the IEEE Eng in Med and Biol Soc (Milan) pp 2478-2481

2. Cooper, R.A., et al. (2011). Manual wheelchair propulsion over cross-sloped surfaces: a literature review. *Assistive Technology*, 23, 42-51.

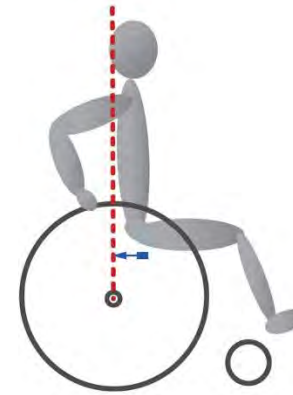
3. Flemmer, C.L. (2022). Improving the built environment for manual wheelchair users: a review. *IOP Conference Services: Earth & Environmental Science*, 1101 032031.

Image from: <https://www.coppelltx.gov/1107/Accessible-Intersections>

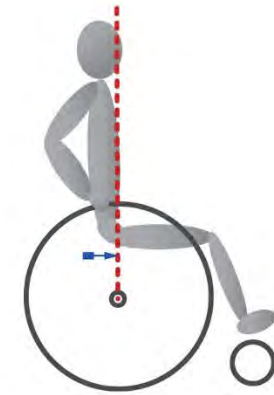


Tolerating cross-fall

1. Axle position / wheelchair camber
2. Weight distribution of product (height, wheel base, weight)
3. Anthropometrics of user
4. Sitting balance of user



Rear Wheels
REARWARD Position



Rear Wheels
FORWARD Position

Image source:
[Motion composites](#)





Managing thresholds / lips

- Living Housing Guidelines recommend max lip of 5mm
- Public transport internationally guidelines often accept lips / gaps no greater than 20mm x 20mm
- Highly affected by wheel size, AT dimensions and power
- User may not tolerate bumps

Case study: Ashton

- Independently mobilising around home
- Wants to play in garden
- Slopes of up to 8° ($\sim 1:7$) in garden
- No fixed paths
- Will he make it?

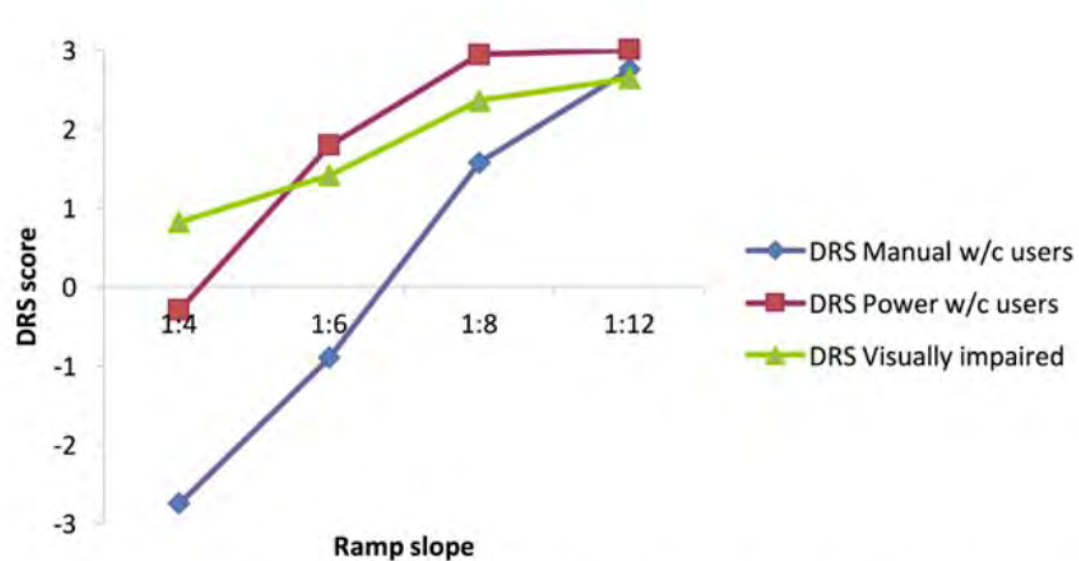


Person-centred characteristics

- Can they propel it?
 - MWC users can often tolerate longer ramps from 1:14 (weaker), 1:12 5°(moderate)¹, 1:10 ~6°(strong)²
 - Shorter ramps (e.g., steps thresholds) can be steeper¹
 - If a carer, 1:12 and forward up, forward down³
- Postural control / balance / gait
- Shoulder pain (for manual wheelchair users)
- Backpack⁴
- Anxiety
- Wheelchair training

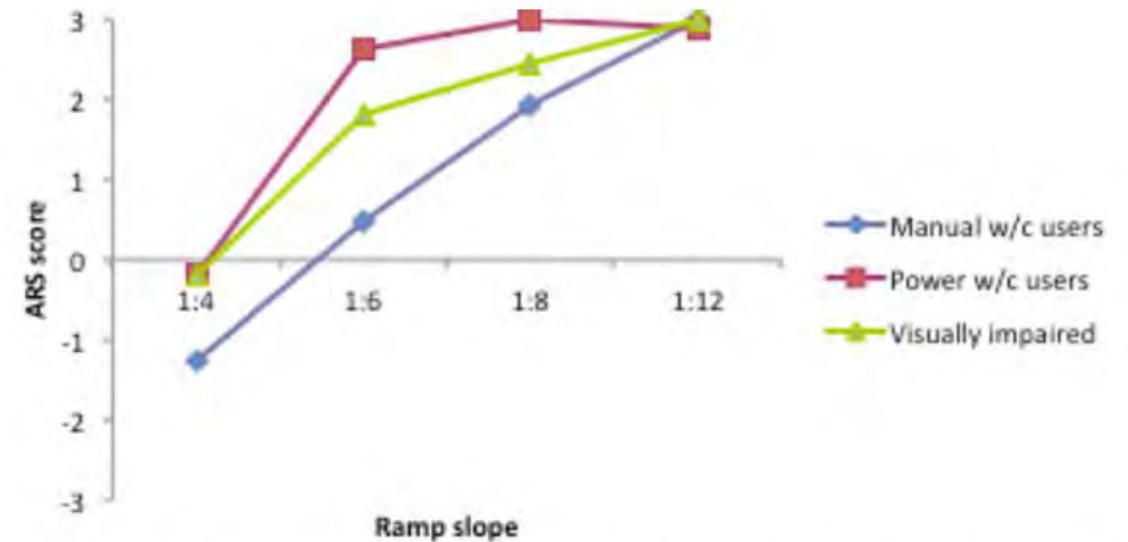
1. Kim, C.S., Lee, D., Kwon, S., & Chung, M.K. (2014). Effects of ramp slope, ramp height and users' pushing force on performance, muscular activity and subjective ratings during wheelchair driving on a ramp. *International Journal of Industrial Ergonomics*, 44, 636-646.
2. Choi, Y.O., Less, H.Y., Lee, M.H., & Kwon, O.H. (2015). Effects of ramp slope on physiological characteristics and performance times of health adults propelling and pushing wheelchairs. *Journal of Physical Therapy Science*, 27(1), 7-9.
3. Kim, C.S., Lee, D., & Chung, M.K. (2012). Effects of ramp slope on usability when a wheelchair is propelled by attendant. *Proceeding of the Human Factors & Ergonomics Society 56th Annual Meeting*, 629-633.
4. Lee, K.R., et al. (1994). Wheelchair-related accidents caused by tips and falls among noninstitutionalized users of manually propelled wheelchairs in Nova Scotia. *American Journal of Physical Medicine & Rehabilitation*, 73(5), 319-330.

Impact of slopes on difficulty and acceptability



Positive DRS ratings indicate relative ease of task; negative ratings reflect relative task difficulty.

DIFFICULTY



Positive ARS ratings indicate relative acceptability of task; negative ratings reflect relative unacceptability of task.

ACCEPTABILITY

1. Lenker, J.E., Damle, U., D'Souza, C., et al. (2016). Usability evaluation of access ramps in transit buses: preliminary findings. *Journal of Public Transportation*, 19(2), 109-127.

When do slopes get hard?¹

Percentage of participants indicating “no anticipated disability” traversing 24m of slope

Running slope	Motorized	Manual
1 : 11.4 5%	90.0% (70)	69.2% (169)
1 : 9.5 6%	85.7% (14)	63.9% (36)
1 : 8.1 7%	93.7% (16)	81.6% (38)
1 : 7.1 8%	87.5% (16)	48.6% (37)
1 : 6.3 9%	87.5% (8)	26.3% (19)

1. Vredenburgh, A.G., et al. (2009). Evaluation of wheelchair users' perceived sidewalk and ramp slope: effort and accessibility. *Journal of Architectural & Planning Research*, 26(2), 145-158.

Wheelchair skills training

- Ramp training using conventional training or immediate video feedback is similar¹
- Clinician may benefit from wheelchair skills training education (4.5hrs better than shorter sessions)²

1. Wang, Y.T., et al. (2015). Immediate video feedback on ramp, wheelie, and curb wheelchair skill training for persons with spinal cord injury. *JRRD*, 52(4), 421-430.
2. Giesbrecht, E.M., et al. (2015). Preliminary evidence to support a “boot camp” approach to wheelchair skills training for clinicians. *Archives of Physical Medicine & Rehabilitation*, 96(6), 1158-1161.



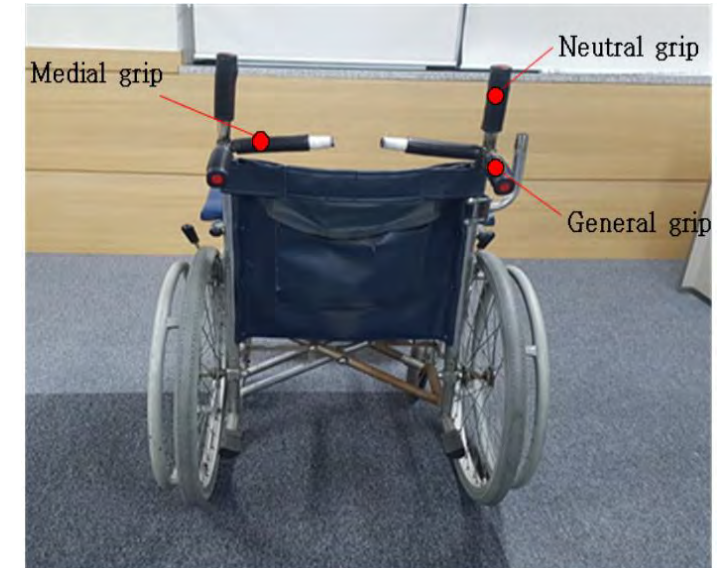


Case study: Colin

- Parkinson's
- Deconditioned after a fall
- Long-stay rehab
- 4-wheeled walker
- 1:12 ramp
- Takes his dog "Millie" out for walks
- Will he make it?

Assistive technology characteristics

- Manufacturer guidance
- Centre of mass / axle position
- Seat height (if elbow flexion isn't 60°, much more difficult on slopes)¹
- Clearances (e.g., footplates)
- Grip of the wheels / castors
- Wheelchair handle grips (neutral grip more biomechanically efficient)²
- Availability of tilt (PWC)



Will I make it?



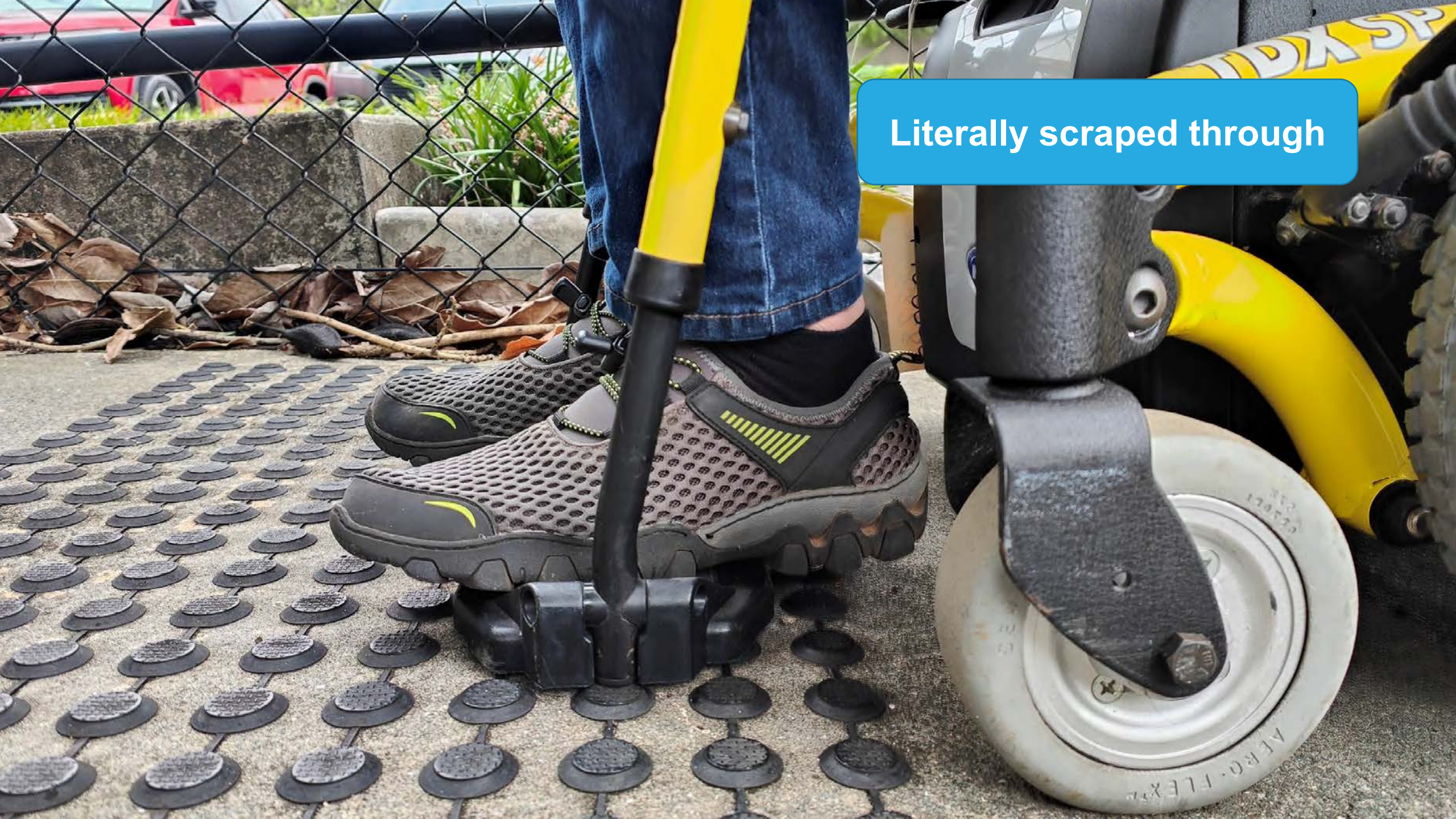


61mm

48mm

246mm

$\frac{246\text{mm}}{61\text{mm}}$
=
4.03
1:4 or 13.9°



Literally scraped through

But I made it up and down
this slope
 $6.9^\circ \sim 1:8$



**But feels like I
might tip / slide
out**

**A bit more
backrest recline
and cushion
wedge could feel
safer**





**Much nicer next door, even with the cross fall
6.9° ~ 1:9**



Anxious about
the drop

Just cleared the
47mm lip on the
way up with my
48mm absolute
clearance on the
footplates





And made it
back up thanks
to the front
castor
suspension so
that the mid-
wheels remain in
contact with the
ground

Environmental characteristics

- Will it grip?
 - Surface type (e.g., concrete, carpet, tile, metal, wood, rubber)¹
 - Slip resistance value (e.g., R-value)
 - Impact of weather e.g., mud, dew
- Impact of terrain (e.g., remote, rural)
- Weight/power ratio of carer to client (e.g., controlling a manual wheelchair down a slope)²
- Edge protection (e.g. rails, lips, wings)
- Gaps / lips / sliding door tracks

1. Hurd, W.J., Morrow, M.M.B., Kaufman, K.R., & An, K-N. (2014). Influence of varying level terrain on wheelchair propulsion biomechanics. *American Journal of Physical Medicine & Rehabilitation*, 87(12), 984-991.
2. Kim, C.S., Lee, D., & Chung, M.K. (2012). Effects of ramp slope on usability when a wheelchair is propelled by attendant. *Proceeding of the Human Factors & Ergonomics Society 56th Annual Meeting*, 629-633.

Slip resistance

BCA Table D2.14 SLIP-RESISTANCE CLASSIFICATION

Surface conditions		
Application	Dry	Wet
Ramp steeper than 1:14	P4 or R11	P5 or R12
Ramp steeper than 1:20 but not steeper than 1:14	P3 or R10	P4 or R11
Tread or landing surface	P3 or R10	P4 or R11
Nosing or landing edge strip	P3	P4

Testing slip resistance



Oil wet ramp test Image source: [CSIRO](https://www.csiro.au)



Pendulum test Image source: [SafeEnvironments](https://www.safeenvironments.com)

Self-propelled

Attendant-propelled

Power

What if the ramp or slope is just not safe?

- New ramp
- Lifts
- Stairlifts
- Alternative routes
- Lowering or raising floors
- Sloping interior floor

MASS Education



Queensland
Government

Upcoming MASS CPD - 2024

DATE/TIME	TOPIC
Thursday 4 th April 8am – 12 noon	In-Person Workshop: Intermediate skills in power wheelchairs, seat and mounts (cost = \$40) Workshop registration
Thursday 2 nd May 9am – 12 noon	In-Person Workshop: Pressure Cushion Prescription (cost = \$10 - \$15) Workshop registration
Friday 3 rd May 9am - 12noon <u>or</u> 1 - 4pm	In-Person Workshop: Introduction to adjusting & maintaining equipment (cost = \$25) Webinar registration (morning offering) Webinar registration (afternoon offering)
Wednesday 15 th May 1.00 – 2.00pm	Assistive Equipment and People with Dementia Webinar registration
Thursday 6 th <u>or</u> Friday 7 th June 9am - 4pm	In-Person Workshop: Introduction to wheelchairs and seating (cost = \$40 - \$60) Webinar registration (Thursday offering) Webinar registration (Friday offering)

External education on home and environmental modification

Provider	Topics & modes
<u>Home Design for Living</u>	Book: An occupational therapist's guide to home modification practice Webinars & online workshops (minor and major mods)
<u>OT Australia</u>	Workshops (minor and major mods) – face-to-face
<u>InclusiveOT</u>	Workshops (minor and major mods) – face-to-face
<u>Access Institute</u>	Workshops (minor and major mods) – online (includes CPPACC4020 and CPPACC5016)

Certificate of attendance



Complete the [webinar feedback form](#) to receive a certificate of attendance.

THANK
YOU

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