

# Data based safety analysis of personal electric vehicles (PEVs)

## 基于数据的个人电动汽车 (PEV) 安全分析

aka personal or powered mobility devices (PMDs), personal light electric vehicles (PLEVs), 又称个人或动力移动设备 (PMD)、个人轻型电动汽车 (PLEV). Full post available at [Peace-maker.com](https://www.peace-maker.com) & [Personaltransportideas.org](https://www.personaltransportideas.org) (Made using the SimpleMind app.) 完整贴文可在上面的网站参阅

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Author's summary: The aim of this map is to compare the safety of different portable transport tools and help us understand more how we can make them safer. The information is based on objective research data or observable features rather than subjective views. However, I did collect the views of experienced users, as in numerical surveys, would be especially useful - especially given the distinct lack of high-quality research in some areas. In particular more research is needed with regard to electric unicycles, electric skateboards & other newer less traditional devices. Also to note there are some key elements that research is unlikely to ever fully capture in data, such as one's level of expertise, mindfulness, awareness, focus and compassion to other road users while riding. Safety may not always be completely a matter of choice, but thankfully the data clearly suggests that safety can be enhanced by us making sensible choices.

作者摘要: 本图旨在比较不同便携式交通工具的安全性, 并帮助我们更好地了解如何使其更安全。信息基于客观的研究数据或可观察的特征, 而非主观观点。然而, 我认为收集经验丰富的用户的意见, 例如进行数值调查, 将特别有用——尤其考虑到某些领域明显缺乏高质量的研究。特别是在电动独轮车、电动滑板车和其他较新的传统设备上进行更多研究。值得注意的是, 研究不太可能完全捕捉到一些关键要素, 例如骑行者的专业水平、专注力、意识、注意力和其他道路使用者的同情心。安全可能并不总是完全取决于选择, 但值得庆幸的是, 数据清楚地表明, 我们可以通过做出明智的选择来提高安全性。

### Perceptions 认知

- e-scooter users regard motor vehicles as too fast & unpredictable, so they often ride on the pavement. However, only half of e-scooter riders feel the pavement is suitable for riding on. Most think cycle paths & quiet streets are more suitable. 电动滑板车用户认为机动车辆速度太快且难以预测, 因此他们经常在人行道上骑行。然而, 只有一半的电动滑板车骑行者认为人行道适合骑行。大多数人认为自行车道和安静的街道更适合。  
European Commission (2021) Road safety thematic report
- pedestrians & cyclists feel safer if e-scooter users ride at a maximum speed of 15 km/h & pedestrians feel safer if e-scooter user overtakes at a maximum speed of 10 km/h. However, this was seen as too slow by e-scooter riders 当电动滑板车使用者以最高15公里/小时的速度骑行时, 行人和骑行者会感觉更安全; 当电动滑板车使用者以最高10公里/小时的速度超车时, 行人会感觉更安全。然而, 这被电动滑板车骑行者认为太慢了  
Elisabeta Dimilova, Matúš Sucha, Karel Rečka, Narelle Howarth, Astak Fyhi, Pontus Walgren, Peter Silverman, and Freya Sjöström, 2024
- pedestrians least comfortable (by far) sharing pavement with large sit down style electric mopeds. 2nd least comfortable with EUCs (electric unicycles, aka e-wheels, monowheels). Most comfortable sharing with people walking or running and conventional wheelchairs 行人最不舒适的(远不及)共享式电动轻便摩托车。第二不舒适的是电动独轮车。最舒适的是跑步者和传统轮椅。  
Brian Casey, Langford, 2013
- enhanced safety perception if ebike user is able to keep up with traffic rather than being constantly overtaken 如果电动自行车使用者能够跟上车流而不是不断被超车, 安全感知会增加。  
Brian Casey, Langford, 2013
- See also 另见: Zhenyong Shao, Yan Xing, Yunhui Wang, Susan Han, 2014
- electric scooters & bikes riskier than non-electric conventional ones 电动滑板车和自行车比传统自行车更危险  
Adrian N. Fernandez, Kevin D. Li, Hiren V. Patel, Isabel Elaine Allen, Umar Ghaffar, Nizar Hakam, Benjamin N. Breyer, 2021
- "e-cyclists were eight times more likely to have a crash than e-scooterists" 电动自行车骑行者发生事故的可能性是电动滑板车骑行者的八倍  
Felicity Pallas, 2025
- "Those with e-scooter injuries are more likely to be treated and released (85%) than those with e-bike (81%) or bicycle injuries (79%)" 电动滑板车受伤者比电动自行车(81%)或自行车(79%)受伤者更有可能接受治疗并出院(85%)  
Hannah Younes, Robert Noland, Leigh Ann Von Hagen, 2024
- e-scooters = higher odds of head, thorax & higher survival rates e-bikes = higher odds of spine injuries & ED admission 电动滑板车=头部、胸部受伤的几率更高, 生存率更高。电动自行车=脊柱受伤和急诊入院几率更高  
Marcel Niemann, Karl F. Braun, Ellen Otto, Michael Tiefenbrunn, Jonas Wäster, Ulrich Stöckle, Stefan S. Ahmad, Sven Märdian, Frank Graef, 2023
- injured e-scooter users were more often intoxicated, had a lower rate of helmet use, were younger, and crashes often occurred at night 电动滑板车受伤者更常醉酒更年轻, 头盔使用率更低, 那天晚上  
Hannah Younes, 2025
- injured e-scooter users were not more likely to suffer severe injuries than bicyclists and e-bike users 受伤的电动滑板车使用者遭受严重伤害的可能性并不比骑自行车和电动自行车使用者高。  
Hannah Younes, 2025
- hoverboard less safe to ride without a helmet compared to EUC & scooter. Scooter least unsafe without a helmet (but still very unsafe). 电动滑板车不戴头盔的危险性最低(但仍然非常危险)。如果戴头盔, 电动独轮车比其他两种设备更安全。  
Caroline Deck, Nicolas Bourdier, Frank Meyer, 2025
- EUCs, Segways, pedestrians and cyclists: modelling generally found the self-balancing devices resulted in lower head injury severities than the equivalent pedestrian or bicycle collisions 电动独轮车、赛格威、行人和骑自行车者: 模拟分析普遍发现, 自平衡装置造成的头部损伤程度低于同等情况下行人或自行车碰撞造成的头部损伤程度。  
Jun Xu, Shi Shang, Guohua Yu, Hongsheng Qi, Yunpeng Wang, and Shuai Xu, 2016

### Injury data 伤害数据

- skateboards had higher injury rates compared to scooters & e-scooters (8.72 per 100,000 individuals) & skateboards also had higher fracture rates (35.39 per 100 injuries). 与滑板车和电动滑板车相比, 滑板的受伤率更高(每10万人中有8.72人受伤), 滑板的骨折率也更高(每100例受伤中有35.39例骨折)。  
European Commission (2021) Road safety thematic report
- head injuries are the most common type of injury for micromobility users 头部损伤是个人电动车使用者最常见的损伤类型。  
Hannah Younes, 2025
- head injuries are by far the most common injury related to e-scooters 头部损伤是电动滑板车相关伤害中最常见的一种。  
European Commission (2021) Road safety thematic report
- risk of emergency department visits & fatality are same for e-scooter riders & cyclists, but hospitalization more likely for e-scooter riders. A trip on a motorcycle or moped is 5 times more likely to lead to a fatality compared to a journey on an e-scooter. Over 80% of e-scooter rider fatalities resulted from crashes involving a heavier motor vehicle. 电动滑板车骑行者和自行车骑行者就医急诊和死亡的风险相同, 但电动滑板车骑行者住院的可能性更高。与电动滑板车相比, 摩托车或轻便摩托车的出行致死率高出5倍。超过80%的电动滑板车骑行者死亡事故是由涉及重型机动车辆的碰撞造成的。  
European Commission (2021) Road safety thematic report

### hypothetical modelling & simulations 假设性建模与模拟

- Pro Lapierre Urban 3.4 e-bike outperforms Xiaomi Mi e-scooter & Inmotion V5F in braking. Acceleration & control during evasive manoeuvres about the same but euc had a higher roll rate so is more manoeuvrable but maybe less steady 在制动性能方面, Pro Lapierre Urban 3.4 电动自行车优于小米米家电动滑板车和 Inmotion V5F。加速和避让时的操控性能大致相同, 但电动独轮车的侧倾率更高, 因此操控性更好, 但稳定性可能稍逊一筹。  
Claire Naude, Elizabeth Riatt, Bastien Canu, and Thierry Serie, 2025
- "e-scooters required much lesser handlebar torque which makes them more manoeuvrable compared to bicycles" "电动滑板车所需的车把扭矩要小得多, 因此与自行车相比, 它们更灵活。"  
Milan Paudel, 2020
- e-scooter best maneuverability, but lacked in safety due to bad braking performance 电动滑板车操控性最佳, 但由于制动性能差, 安全性不足。  
Lucas Billette and Christian Sverin, 2022
- e-bike and the e-scooter good rider comfort & stability 电动自行车和电动滑板车骑行舒适稳定。  
Lucas Billette and Christian Sverin, 2022
- Segway = Least safe at high speeds, comparable at lower speeds 赛格威: 高速行驶时安全性最低, 低速骑行时安全性尚可。  
Lucas Billette and Christian Sverin, 2022
- conclusion: limit speeds of Segway 结论: 限制赛格威的速度  
Lucas Billette and Christian Sverin, 2022
- generally larger diameter wheels = smoother & safer over bumps & potholes 一般来说, 车轮直径越大, 行驶在颠簸和坑洼路面上就越平稳安全。  
Lucas Billette and Christian Sverin, 2022
- arms free to indicate 手臂自由地表示  
Lucas Billette and Christian Sverin, 2022
- no deck = less ground clearance issues 没有甲板 = 更少的高地间隙问题  
Lucas Billette and Christian Sverin, 2022
- less mechanical moving parts & hinge points compared to bikes & scooters 与自行车和踏板车相比, 机械活动部件和铰链点更少。  
Lucas Billette and Christian Sverin, 2022
- immediate forward jump up/possible 通常可以立即向前跳下  
Lucas Billette and Christian Sverin, 2022
- can prevent vehicle rolling away 可以防止车辆溜车  
Lucas Billette and Christian Sverin, 2022
- add safety tools in easy reach 在触手可及的地方放置安全工具  
Lucas Billette and Christian Sverin, 2022
- at low speeds allows instant safe dismount while rolling 低速行驶时, 可在滚动过程中立即安全下车。  
Lucas Billette and Christian Sverin, 2022
- allows instant lifting over or up obstacles such as kerbs & stairs 可瞬间举升越过或举升过路缘石和楼梯等障碍物。  
Lucas Billette and Christian Sverin, 2022
- allows far quicker learning phase 可以大大缩短学习阶段  
Lucas Billette and Christian Sverin, 2022
- naturally self-balancing; motor failure = roll to a stop 自然自平衡; 电机故障 = 滚动至停止  
Lucas Billette and Christian Sverin, 2022
- extra contact point with ground (traction backup) 与地面有额外接触点(牵引力备用)  
Lucas Billette and Christian Sverin, 2022
- one foot can be quickly put on ground enhancing traction & stability 一只脚可以快速放在地面上增强牵引力和稳定性  
Lucas Billette and Christian Sverin, 2022
- can be avoided by using a EUC letter, but with larger heavier wheels can be risky to the rider 使用电动独轮车字母可以避免, 但带有更大更重的车轮可能会给骑行者带来风险。  
Lucas Billette and Christian Sverin, 2022
- lights (higher up than on a EUC) 灯(位置比电动独轮车更高)  
Lucas Billette and Christian Sverin, 2022
- bell or horn 转向灯  
Lucas Billette and Christian Sverin, 2022
- indicators 转向灯  
Lucas Billette and Christian Sverin, 2022
- likely useful when approaching pedestrians to help put them at ease 在接近行人时可能有用, 有助于让他们安心。  
Lucas Billette and Christian Sverin, 2022
- EUCs also allow this but usually takes longer; likely need to stoop or unfold trolley handle. 电动独轮车也可以做到这一点, 但通常需要更长时间; 可能需要弯腰或展开拉杆。  
Lucas Billette and Christian Sverin, 2022
- with many EUCs best to also deactivate self-balancing before lifting 对于许多电动独轮车, 在抬起之前最好先关闭自平衡。  
Lucas Billette and Christian Sverin, 2022
- nixed blessing may also create overconfidence in new riders 有利有弊; 也可能让新手骑行者产生过度自信。  
Lucas Billette and Christian Sverin, 2022
- EUC balance relies on functioning motor & gyroscope chip & speed to be below maximum (respect the beep!) 电动独轮车的平衡依赖于正常工作的电机和陀螺仪芯片, 并且速度必须在最大值以下(请尊重提示!)  
Lucas Billette and Christian Sverin, 2022
- one wheel = one contact patch & zero redundancy (Inmotion E20 & some other EUCs have two tyres, but a scooter's wheels are spaced further apart & are in the line of travel) 一个轮子 = 一个接触点且没有冗余 (Inmotion E20和一些其他电动独轮车有两个轮胎, 但踏板车的轮子间隔更大, 并且在行驶方向上前后排列)  
Lucas Billette and Christian Sverin, 2022
- EUC users can also place a foot on ground but usually not as easily - depends on pedal height 电动独轮车用户也可以把一只脚放在地上, 但通常不那么容易——取决于踏板高度。  
Lucas Billette and Christian Sverin, 2022

### Safety related performance & features 安全相关性能和功能

- Advantages of EUCs (electric unicycles, self balancing wheels, monowheels) 电动独轮车(电动独轮车、自平衡轮、单轮车)的优势  
Lucas Billette and Christian Sverin, 2022
- Observable safety-related physical attributes of EUCs & scooters (not based on research data or subjective user reviews) 电动独轮车和电动滑板车的可观察安全相关物理属性(并非基于研究数据或主观用户评价)  
Lucas Billette and Christian Sverin, 2022
- Advantages of scooters 踏板车的优点  
Lucas Billette and Christian Sverin, 2022
- two or more wheels 两个或更多的轮子  
Lucas Billette and Christian Sverin, 2022
- handicaps 车把  
Lucas Billette and Christian Sverin, 2022
- installing reflectors or increasing the wheel size 安装反光装置或增大车轮尺寸  
Marco Dozza, Alessio Violin, and Alexander Rasch, 2022
- replace narrow, hard wheels with wider softer wheels & improve shock absorbers to reduce chances of falling over bumps or potholes. A wider platform for greater stability. 用更宽、更软的车轮替换狭窄、坚硬的车轮, 并改进减震器, 以减少在颠簸或坑洼处摔倒的可能性。更宽的平台可提高稳定性。  
European Commission (2021) Road safety thematic report
- modification of the frame can improve stability & handling of the many small wheel PMDs 对车架进行改造可以提高许多小轮个人移动设备的稳定性和操控性。  
Milan Paudel, 2020
- roll or pedal to start (prevents acceleration from accidental pressing of throttle) 通过滑行或踩踏启动(防止因误按油门而加速)  
Regulations and Safety for Electric Bicycles and Other Low-Powered Vehicles, 2017
- audible sounds (respondents often startled because electric motors are nearly silent) 可听见的声音(由于电动机几乎无声, 受访者常常会受到惊吓)  
Ulif Sandberg, Luc Goedert, and Piotr Moduszewski, 2010

### Safer design 更安全的设计

- WEAR A HELMET! 戴头盔!  
Yuping Li, Qi Chen, Qiang Ma, Haolong Yu, Yujia Huang, Lei Zhu, Hengzhi Zhang, Chen Li, and Guangyu Lu, 2022
- Reduce speed 降低速度  
Yuan Huang, Qing Zhou, Caroline Koepfer, Quan Li, and Bingting Nie, 2020
- Master your device before riding in public spaces 在公共场所骑行之前, 先熟练掌握你的设备  
Austin Epidemiology and Public Health, 2019
- Pedestrian empathy: remember that others are likely far less trusting of your device than you are 体谅行人: 请记住, 别人对你的交通工具的信任程度很可能远低于你自己的信心。  
Austin Epidemiology and Public Health, 2019
- Stay clear: Don't drink alcohol or take intoxicating substances before riding & stay away from cars where possible 保持清醒的心: 骑行前不要饮酒或服用致醉物质, 并尽量远离汽车。  
European Commission (2021) Road safety thematic report
- enforced helmet wearing, driver's licences for e-bikes, data collection & safe-riding credit system 强制佩戴头盔、电动自行车驾驶证、数据收集与安全骑行积分系统  
Yuping Li, Qi Chen, Qiang Ma, Haolong Yu, Yujia Huang, Lei Zhu, Hengzhi Zhang, Chen Li, and Guangyu Lu, 2022
- helmet wearing depending on speed, maximum speed & size for vehicles on footpaths, age limits & driver licensing for higher speed devices 头盔佩戴根据速度、在人行道上车辆的最大速度与尺寸、年龄限制及高速设备的驾驶证要求  
Regulations and Safety for Electric Bicycles and Other Low-Powered Vehicles, 2017
- Taipei model: two-wheeled micro electric vehicles need insurance & must pass vehicle inspections to obtain a license plate 台北模式: 两轮微型电动车需购买保险, 并且必须通过车辆检测才能领取车牌  
Department of Transportation, 2024
- Singapore model: clear categories of vehicle types. For PMDs: maximum width of 70cm, max. speed 25kmph & 15kmph on footpaths, weight up to 20kg & must be approved by approved by the Land Transport Authority (LTA) 新加坡模式: 明确车辆类型分类, 对个人移动设备(PMD): 最大宽度70厘米, 最高速度25公里/小时(在人行道上15公里/小时), 重量不超过20公斤, 且必须获得陆路交通管理局(LTA)批准  
"Guide to E-Scooter and PMD Laws for Singapore Riders - SingaporeLegalAdvice.com", 2024
- rental scooters' time dependent pricing system could be complemented or replaced with price-per-kilometre travelled, price per journey, or even a monthly subscription 租赁滑板车的计时定价系统可补充或替换为按公里计价、按行程计价, 甚至按月订阅  
Alexandre Santacreu, George Yannis, Ombine de Saint Léon, Philippe Crist, 2020
- regulations on phone use, limits on the maximum blood-alcohol concentration allowed for riders 关于使用手机的规定、骑行者允许的最高血液酒精浓度限制  
Marco Dozza, Alessio Violin, and Alexander Rasch, 2022

### Good habits 良好习惯

- Author's own ideas can be seen here: "building or improving cycling infrastructure can help keep e-scooter riders from riding on the sidewalk" 建设或改善自行车基础设施可以帮助避免电动滑板车骑行者在人行道上骑行  
Juliane Anke, Madlen Ringhand, Tibor Petzold, and Tina Gehrlert, 2023
- PMD users express a clear preference for cycle paths so allow PMDs on cycle paths. But upgrade design standards & make them wide enough to accommodate various vehicles. The surface must be smooth & well maintained, with repairs done as quickly as possible. PMD用户明确偏好自行车道, 因此允许PMD使用自行车道, 但需升级设计标准, 使自行车道足够宽以容纳各种车辆, 路面必须平整且维护良好, 维修应尽快完成。  
Alexandre Santacreu, George Yannis, Ombine de Saint Léon, Philippe Crist, 2020
- "scooters, and e-monowheels, which have reduced braking capacity compared to electric bicycles, require protective measures such as speed limits and carefully designed lanes to mitigate risks" 滑板车和电动独轮车制动能力低于电动自行车, 需要采取保护措施, 如降低速度限制和精心设计车道以降低风险。  
Claire Naude, Elizabeth Riatt, Bastien Canu, and Thierry Serie, 2025
- child cyclists would only be allowed to use e-bikes once they were old enough to be denied access to footpaths 儿童骑行者只有在达到依法禁止在人行道上骑行的年龄后, 才被允许使用电动自行车。  
Regulations and Safety for Electric Bicycles and Other Low-Powered Vehicles, 2017
- geofencing & pedestrian airbags (for mopeds & ebikes) 地理围栏与行人安全气囊(针对轻便摩托车和电动自行车)  
Elise Ahnsson & Theresa Ahnsson, 2025
- expanded traffic training for children at secondary school to include other personal mobility devices. Also driver training for motorists (most e-scooter fatalities are a result of a crash with a motorised vehicle) 在中学阶段扩大儿童交通培训, 包括其他个人移动设备; 同时对机动车驾驶员进行培训(大部分电动滑板车死亡事故为与机动车碰撞造成)  
Alexandre Santacreu, George Yannis, Ombine de Saint Léon, Philippe Crist, 2020
- police officers to promote e-scooter safety behaviour. 警察推广电动滑板车安全行为  
Elisabeta Dimilova, Matúš Sucha, Karel Rečka, Narelle Howarth, Astak Fyhi, Pontus Walgren, Peter Silverman, and Freya Sjöström, 2024

### Safety enhancing Policy 安全提升政策

- Allocate protected space for micromobility and keep pedestrians safe 为微型出行分配受保护的空间, 并确保行人安全。  
To make micromobility safe, focus on motor vehicles. 要让微型出行更安全, 应重点关注机动车辆。  
Regulate low-speed e-scooters and e-bikes as bicycles. 将低速电动滑板车和电动自行车归类为自行车。  
and higher-speed micro-vehicles as mopeds. 将高速微型机动车辆归类为轻便摩托车。  
Collect data on micro-vehicle trips and crashes. 收集微型车辆出行和事故数据。  
Proactively manage the safety performance of street networks. 主动管理街道网络的安全表现。  
Include micromobility in training for road users. 在道路使用者培训中加入微型出行。  
Tackle drunk driving and speeding across all vehicle types. 在所有车辆类型中解决酒后驾车和超速问题。  
Eliminate incentives for micromobility riders to speed. 消除激励微型出行骑行者超速。  
Improve micro-vehicle design. 改进微型车辆的设计。  
Reduce wider risks associated with shared micromobility operations. 减少与共享微型出行运营相关的更广泛风险。  
Alexandre Santacreu, George Yannis, Ombine de Saint Léon, Philippe Crist, 2020

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