Velomobiles and Urban Mobility: Opportunities and Challenges

Geoffrey Rose and Alex Liang

Abstract As the transport challenges facing urban areas intensify, innovative solutions are required to address the social, economic and environmental impacts arising from overreliance on private motor vehicles. Velomobiles offer a range of advantages but do not feature on the radar screen of urban transport policy makers. This chapter explores the challenges and opportunities of increased adoption of velomobiles as an urban mobility option. A scan of existing velomobiles is used to define typical characteristics of these vehicles and place them into perspective against relevant travel options before they are assessed in the context of typical vehicle regulations and facility design guidelines. The opportunities and challenges associated with greater adoption of velomobiles in the context of urban travel are examined through the lenses of technology adoption and the sociotechnical framing of independent travel options. Shared mobility is identified as one potential way of broadening the base for velomobile adoption in urban areas.

Keywords HPV/human-powered vehicles • Velomobiles • Vehicle classification • Infrastructure design guidelines • Shared mobility

1 Introduction

As urban populations are growing in many cities, the pressure on urban transport systems is intensifying. Those pressures are compounded by the reliance on car-based mobility—the prevailing transport monoculture in many cities [1]. The emphasis on in-active transport, and the inevitable traffic congestion and emissions, results in lower productivity and considerable negative external costs that are not directly born by users [2, 3]. Responses to these challenges within the transport industry have presented opportunities for disruptive technologies. Disruptive technologies influence and add value to established markets, often displacing older

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technologies or methods. In the transport sector, such technologies may influence the mode choice of individuals which will have implications for the social, economic and environmental impacts arising from the transport system.

Many light electric vehicles are examples of potentially disruptive technologies [4] in the context of urban transport where these technologies have the potential to disrupt the dominant role of private automobile ownership and use in urban mobility. Examples of disruptive transport technologies include shared mobility such as car sharing and bike sharing [5] as well as emerging motorised personal mobility devices (PMD) such as electric-power-assisted bicycles [6], electric scooters, Segways and other self-balancing motorised devices. Laws and regulations have a large impact on the adoption and usage of various disruptive technology options. The focus of this chapter is on velomobiles, which are one form of PMDs.

A Web search of the images of a ‘velomobile’ will bring up a range of images of two- or three-wheeled vehicles with their shape suggesting consideration of aerodynamics. One example is shown in Fig. 1.

A definitive definition of a velomobile is problematic and as noted by van de Walle [7, p. 69]:

even the people closely involved with velomobiles cannot accurately define a velomobile and there are plenty of discussions on what exactly constitutes a velomobile. Although a velomobile is very different from a bicycle, enthusiasts usually describe a velomobile in relation to the (recumbent) bicycle.

Non-enthusiasts who see a velomobile and are not sure at first what it is and might reach the conclusion that it is essentially:

a special bicycle an expensive, heavy, complex, large and difficult to park bicycle with extra wheel(s) and a body on top of it. van de Walle [7, p. 81]

The platform Wikipedia [8] and [7] offer the following definition which picks up key attributes and characteristics:

A velomobile, is a human-powered vehicle (HPV) enclosed for aerodynamic advantage and/or protection from weather and collisions. They are similar to recumbent bicycles and tricycles, but with a full fairing (aerodynamic or weather protective shell).

Fig. 1 Side and front view of a velomobile (own image)

While there is no doubt that velomobiles are human powered, there is growing interest in electric-assisted velomobiles. Other authors note the relevance of luggage-carrying capacity [7] which does not feature in the Wikipedia definition. The issue of safety is considered later, but it is not clear that the design of velomobiles, except perhaps for those aspiring to world record speed titles where rider safety is an explicit consideration, inherently provides any substantial amount of collision protection. The shell/body is provided primarily for aerodynamics and weather protection rather than structural integrity in the case of a collision.

Cox [9] noted that “Within the existing framework of transport options, the velomobile has a heavily circumscribed market as a symbol of the social elitism amongst cyclists” and added that “If the velomobile is itself a marginalised form of cycle, then it is difficult to envisage a greater future role than its current limited market”.

While a decade and a half have passed since those words were written, they still hold true today. Yet velomobiles offer obvious opportunities from the perspective of enhancing the sustainability of our urban transport systems. They have low energy requirements, have passenger-carrying capacities that meet the needs of most trips in urban areas, have a smaller spatial footprint than a conventional motor vehicle and provide exercise and associated health benefits for the user.

The aim of this chapter is to explore the challenges and opportunities of increased velomobile usage in the context of urban travel. The approach is broken into three distinct components. First, an international scan of existing velomobiles is used to identify typical characteristics of these vehicles and place them into perspective against relevant travel options. Second, velomobiles are assessed in the context of typical vehicle regulations and facility design guidelines and finally the opportunities and challenges associated with greater adoption of velomobiles in the context of urban travel are examined. A short conclusions section wraps up the chapter.

2 Velomobile Characteristics

Velomobiles have varying attributes and their characteristics are ultimately dependent on the design and function of the vehicle. Velomobiles may be designed as an alternative mode of transport, for the purpose of attaining maximum speeds or as a recreational vehicle. An appropriate starting point is to appreciate the typical characteristics of velomobiles, including their physical geometry or spatial footprint as well as the speed profiles and operating characteristics of these vehicles. Table 1 summarises indicative values for a range of parameters. The focus here is on the general trend across different types of vehicles rather than focusing on the measurement accuracy of one particular parameter for a specific vehicle.

In general, velomobiles have a greater spatial footprint compared to road bikes, e-bikes and recumbent bicycles as given in Table 1. The dimensions of both human-powered and electric-assisted velomobiles vary greatly as velomobiles are

Table 1 Typical characteristics of various mobility devices (*HP* = Human-powered, *EA* = Electric assist. *Source* Manufacturer’s web sites)

	Road bike	E-bike	Recumbent trike**	HP velomobile	EA velomobile
Width (m)	0.61	0.61	0.83–0.88	0.56–1.02	0.76–1.5
Length (m)	1.5–1.8	1.5–1.8	1.71–2.08	1.98–2.85	2.17–3
Turn radius	Low	Low	Med 1.45–3 m	Med-high 1.5–6.5 m	Med-high 1.5–6.5 m
Weight (kg)	6.8–17	23	14.5–21.8	15–80	32.5–120
Eng. power*	N/A	<250 W	N/A	N/A	<250 W

*Engine power limit under Australian and European regulations. Other countries may vary due to different regulations

**Catrike and Terratrike recumbent trikes

designed for different functions and design requirements [10]. Smaller and lighter velomobiles are generally used for racing purposes whilst mid-size and large-size velomobiles are more suited as a mode of transport [11]. Some designs incorporate two seats or additional room for storage space and therefore have larger spatial footprints.

There are velomobiles that can travel at very high speeds. The world record of a human-powered velomobile is 144.17 km/h [12]. The high speeds are due to a low centre of gravity and an aerodynamic shell of the vehicle [13]. Table 2 shows a comparison of speeds between bicycles and velomobiles. An average healthy adult can deliver 100 W of power on a bicycle and maintain that for approximately one hour. By contrast, 250 W is the power output of a well-trained cyclist. It is evident that velomobiles can travel at higher speeds with the same amount of energy input

Table 2 Speed comparison between typical bicycles and velomobiles (*Std* = standard, *BP* = best practice)

	Poorly maintained bike*	Good regular bike**	Std velomobile***	Racing bike****	BP velomobile*****
Flat road, 250 W	23.5 km/h	29 km/h	41 km/h	37.5 km/h	50 km/h
Flat road, 100 W	15 km/h	20.5 km/h	28 km/h	27 km/h	34 km/h
5% uphill, 150 W	6.5 km/h	9.7 km/h	8.6 km/h	11.6 km/h	9 km/h
Power require to ride 30 km/h	444 W	271 W	115 W	137 W	79 W

*Typical bicycle used for short distance transportation with rusty chain, underinflated tires, bad riding position, no gearing. Rough indication only

**Bicycles for transport, including fenders luggage, upright rider position

***Flevobike Alleweder

****UCI compliant bike, deep racing posture, cycling clothes

*****Velomobile.nl

Table 3 Kinetic energy generated for bikes and velomobiles

	Good regular bike*	Racing bike**	Standard velomobile***	Electric-assisted velomobile****
Flat road, 250 W	5004 J	4781 J	39,924 J	95,313 J
Flat road, 100 W	2500 J	2479 J	18,620 J	44,073 J

*Average weight of bicycle from Table 1, speeds from Table 2
**Lowest weight of bicycle from Table 1, speeds from Table 2
***Average weight from Table 1, speeds from Table 2
****Average weight from Table 1, speeds assumed to be of best practice velomobiles from Table 2

compared to bicycles, with the exception in uphill situations. Electric-assisted velomobiles are especially useful on steep hills.

Kinetic energy management is recognised as a critical factor in the context of road safety [14] since it is associated with the potential for injury in the event of a crash. Using the data from Tables 1 and 2, the kinetic energy generated for velomobiles and bicycles has been estimated and is given in Table 3. Kinetic energy is calculated as mass times velocity (speed) squared. Regular bicycles and racing bikes generate similar amounts of kinetic energy as the former are heavier and slower and the latter are faster but lighter. Standard velomobiles produce considerably higher amounts of kinetic energy compared to bicycles with the same amount of energy input due to higher speeds and increased weight. The difference in kinetic energy is even greater for electric-assisted velomobiles due to the same reasons.

3 Opportunities and Challenges

As noted in the introduction, urban transportation systems currently face substantial challenges. In that context, velomobiles are a potentially attractive option to enhance the sustainability of urban transport systems. They are space and energy efficient in operation and can be emission free (if batteries for power assistance are charged from renewable energy). From a sustainability perspective, there is an added benefit in terms of resource consumption. Velomobiles consume far less resources in manufacture than a motor vehicle given that 27 velomobiles are comparable in mass to one small car [7, p. 74]. The ability to travel at higher speeds without great effort, which is even more evident for electric-assisted velomobiles, improves comfort and efficiency when compared to bicycles and recumbents. The weather-resistant body shell of velomobiles also adds comfort for the rider. Some variants of velomobiles are also capable of storing luggage which adds utility benefits, whilst others can also carry a passenger. These properties reflect some of the benefits that private motor vehicles provide, whilst still delivering the environmental and health benefits of a bicycle. Despite these many benefits,

velomobiles remain a marginalised mode, with demand low and small-scale manufacture resulting in high production costs.

Innovative approaches to design and manufacture may present opportunities to lower production costs. This could include ‘growing’ body components for velomobiles from bamboo [15] or a combination of modular design, open sourcing, material recycling or additive manufacture [16]. However, there is an inevitable link between costs and demand. Production costs will not fall through economies of scale till production volumes increase. Yet that will not happen till demand increases but that demand is suppressed by high prices.

To date, the velomobile has engaged technology enthusiasts and visionaries, groups which characterise the early adopters of technology [17]. The challenging step in the context of technology adoption is going beyond those early adopters to engage the pragmatists who make up the early majority and that leap has been characterised as ‘crossing the chasm’ and calls for flexible and innovative product development and manufacturing alongside marketing to achieve more substantial product-market fit [17].

As yet there is little sign that velomobiles are building anywhere near the sort of momentum required to cross the chasm and achieve broader market appeal. Van de Walle’s (2014) seminal work on the interrelatedness of social and technical aspects of velomobiles, a concept that he articulates as the sociotechnical frame of this technology remains relevant in that context today. Van de Walle conceptualised a change in the evoliner social frame which traditionally sees a linear progression from the bicycle to the assisted bicycle to the motorcycle to the motor car. His matrix frame seeks to position the bicycle to velomobile mobility transition as comparable to the motorcycle to motor car transition. In the context of contemporary thinking about urban mobility, those pairs reflect low and high negative external costs or externalities (Fig. 2). Externalities arise due to, e.g., congestion or emissions and are costs that impact on third parties but are not reflected in the prices paid by users [18].

Fig. 2 Matrix of personal mobility options. *Source* Modified from [7]

One technology, which has made progress in crossing the chasm, is the electric-power-assisted bicycle even though van de Walle's assessment in 2004 was not optimistic:

practice tells us that the users of 'assisted bicycles' remain marginal actors to the bicycle sociotechnical frame. The assisted bicycle is in a similar process as the recumbent bicycle to become accepted as legitimate variant of a new bicycle sociotechnical frame, modified from the old established one that excluded the assisted bicycle. [7, pp. 72]

The electric-power-assisted bicycle, or e-bike, has grown substantially in market share in the last decade and a half [19] and is being viewed positively for the opportunities that it present to enhance urban transport options [6]. Concerns have been expressed about the impact on e-bikes on levels of physical activity. However, the results of recent research are very positive indicating substantial increases in physical activity for users who switch from a car and limited net losses from those switching from cycling because of increases in overall travel distance [20]. Whilst in some respects, the e-bike highlights that opportunities remain from mobility options to gather traction, and there are other factors which are likely to act as barriers to growth in velomobile adoption and use.

Velomobiles typically meet the regulations associated with bicycles or Pedalecs [21]. Consequently they face lower regulatory barriers than if their characteristics meant they were reclassified as quadricycles, mopeds or motor vehicles since they would therefore need to meet tighter design regulations. In Australia, as in Europe, they are classified as bicycles so long as the auxiliary power is less than 250 watts, and the maximum power-assisted speed is restricted to 25 kph. However, velomobile riders would be required to wear a bicycle helmet in Australia which is one jurisdiction that has mandatory helmet legislation. Even though some velomobiles can travel at high speeds, they would be forbidden from operating on urban freeways in many countries including Australia.

As velomobiles are classified as bicycles, the facility design guidelines that apply to bicycles need careful consideration. Velomobiles are generally wider than bicycles but can still fit in standard bicycle lanes and shared-use paths, although the manoeuvring space and lateral clearance is lower [22]. Cycling infrastructure is typically designed for bicycles which have a smaller spatial footprint compared to velomobiles. Although it is legal to operate velomobiles in the same locations as bicycles, it may be difficult to move efficiently or safely due to their physical characteristics and the existing infrastructure. A typical velomobile will fit in a bicycle lane but the standard lateral clearance that is used for manoeuvring, which is provided for regular bicycles, may not be adequate for velomobiles. Shared-use paths allow individuals to travel in both directions which may be a concern because of the increased width of velomobiles. Existing infrastructure may not be adequate to cater for velomobiles overtaking other users of the shared-use path or the concurrent use of a mixture velomobiles and bicycles.

Safety is also an important consideration since collisions may have serious consequences. Velomobiles are capable of travelling at higher speeds than bicycles and with significantly less effort as given in Table 2. Hence, one potential barrier

for velomobiles is likely to be real or perceived issues with safety. Little is known about the safety performance of velomobiles although examination of single vehicle velomobile crashes in Germany highlights speed as a contributing factor [23].

The weight of velomobiles is generally greater than bicycles and recumbents, particularly electric-assisted velomobiles. Speed and weight both influence the amount of kinetic energy which would need to be dissipated in the event of a crash. Managing the dissipation of kinetic energy in that case is critical in determining the risk of serious or fatal injuries [14, 24]. Crash rates are not solely a function of higher speed but rather increases in variances of speed [25], and hence, there could be greater concerns where there is a mix of users such as pedestrians, cyclists and velomobile riders. The braking regulations for bicycles also apply to velomobiles but may not be suitable due to the greater speeds of velomobiles. This raises potential safety issues as velomobiles may need brakes to be of higher capabilities to ensure that the rider can stop in the event of an incident.

Since the existing infrastructure is geared towards bicycles, bicycle paths and shared-use paths which may be under designed for the speed and braking capabilities of velomobiles. Bicycles are able to make sharper turns as they have a smaller turn radius and travel at lower speeds. Velomobiles may require larger curve radii, and additional sight distance may need to be provided along shared-use paths to create a safe environment for all users. Of course, this is dependent on where velomobiles are ridden and travel surveys do not currently provide insight in that context because of the low incidence of velomobile use in the population. Their classification as bicycles means they can legally be ridden on bicycle facilities. However, incompatibilities can arise between their performance characteristics (e.g., maximum speeds) and the design characteristics of those facilities, for example, in relation to the horizontal curve radii which are designed on the expectation of lower maximum speeds.

One other area which may present a barrier to greater adoption relates to parking. While classified as bicycles, the larger spatial footprint of velomobiles makes them incompatible with common bicycle parking infrastructure. This is partially illustrated by the example provided in Fig. 1 where the capacity of the bicycle parking hoops is reduced by the parked velomobile. The suspension systems of velomobiles can be designed to facilitate vertical parking and storage [13] and that may present other opportunities to overcome parking challenges.

The infrastructure issues raised above are potential barriers to use, but the challenge of stimulating demand remains. Cox [9] highlighted the need to explore the possibilities for sociable velomobiles to encourage adoption. Reflecting emergence of the shared economy, some commentators see shared mobility, such as car sharing and bike sharing [5], as one of the three pillars to underpin the transition to a sustainable transport system along with electrification and automation [1]. In that context, the emergence of shared mobility options based on a velomobile may assist in helping this innovative form of urban mobility to gain momentum. One example is Veemo (Velometro Mobility), a one-way sharing network of three-wheeled, electric-assisted velomobiles being developed in Vancouver [26]. Veemo brings together a new vehicle with a shared vehicle mobility platform to offer a new option

in the context of shared mobility. Systems such as that may help to ‘normalise’ velomobiles within the context of urban mobility. This is analogous to what systems of shared electric scooters have done in cities around the world to normalise this type of mobility option which has helped to stimulate private ownership of e-scooters where users perceive that to be a regular part of their urban mobility system. The emergence of shared velomobile systems may help to advance the normalisation of velomobile technology in the context of urban travel.

4 Conclusion

Velomobiles have the potential to provide a mode choice alternative in urban environments since they provide some of the benefits of both bicycles and motor vehicles. Human-powered and electric-assisted velomobiles have varying physical and operational characteristics. In comparison with bicycles, they have a larger spatial footprint, can travel faster with less energy and are heavier. They have the advantage of still being classified as bicycles (depending on their characteristics). Therefore, the same regulations and laws that apply to regular bicycles currently apply to velomobiles. There are many implications for velomobiles regarding existing infrastructure and facility design guidelines as these are designed to cater for the performance envelope of regular bicycles. High speeds and a larger spatial footprint, combined with the lack of appropriate infrastructure, raise safety issues both on road and on shared-use paths. The challenge as new velomobile entrepreneurs emerge is determining whether the community and the transport profession will continue to regard them in the same category as bicycles particularly when the spatial footprint makes them incompatible with many existing bicycle facilities. Current regulatory frameworks which are based on vehicle descriptions rather than performance-based standard present a risk for disruptive technologies like velomobiles. The short-term risk for even current velomobile developers is that regulatory responses to other innovative modes may have unintended consequences for the use of velomobiles by placing new restrictions on where and when current, but less common vehicles, are permitted to operate. The emergence of velomobiles as the basis for systems of shared mobility may be a valuable stimulus for velomobile adoption. Shared-use systems could play a part in helping velomobile technology to cross the chasm to wider adoption and emerge as a more mainstream urban travel option.

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