VIENNA 2018 TRA
TRANSPORT RESEARCH ARENA
A digital era for transport
solutions for society, economy and environment

Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria

2-wheel personal rapid transit: Self-driving vehicles for maximum sustainability

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Abstract

The topic of this paper is a concept for socially and ecologically sustainable passenger transportation in rural and suburban areas, based on the idea of driverless cabin motorcycles running on an own, segregated guideway network. It describes the functioning principle, characteristics of vehicles and route network and possible effects on cross-modal competition and intermodal travel chains. Finally, estimations upon costs and resource consumption as well as regulatory aspects are discussed.

Keywords: Transition to Automation; Energy Efficiency; Accessibility / Affordability; Passenger Transportation; Rural and Suburban Areas; Robotaxis; Carsharing; Public and Intermodal Transportation

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1. Introduction

1.1. Traditional public transport in rural and suburban areas

In the last decades, efforts for more sustainable mobility were successful primarily within urban agglomerations and in long-distance rail passenger transport. In contrary, in rural and suburban regions the individual car remains clearly predominant and even in cases, where sustainable transport modes gain rising demand, this is insufficient to reduce individual car traffic significantly given a growth of total transport performance. One of the main reasons for poor success of sustainable mobility solutions outside the cities is the dependence of public transport on the density of population and mobility demand, causing a downward spiral: The operational performance of public transport is limited by low ridership, leading to poor occupancy if too few passenger-kilometers are distributed over too many train- or bus-kilometers. A small quantity of public transport can be arranged either as a poor network density, long intervals or frequent stops and detours, giving the choice between long walking time to the next stop, long waiting time for the next train or bus or long riding time. Furthermore, the overall passenger mobility of a region splits up across a huge number of origin-destination pairs and on the majority long interchange waiting times arise because even in case of an integrated clock-face timetable, the distance between interchange hubs is much longer, than the road network density and usual distances between villages. At the same time, in rural areas public transport competes with individual cars, which are by far less affected by congestion or lack of parking facilities, than in urban conditions.

1.2. Existing intermodal solutions for non-urban areas

Intermodal and other innovative solution attempts of the past can be roughly divided into the following groups:

- Reducing the use of the individual car to those purposes, where it is “really necessary”: Park & Ride is broadly applied, but as far as people still have to own a car, it has rather the contrary effect to use public transport only where “really necessary”, mostly for commuting toward congested urban areas, whereas for various trips within the region it is more convenient and seems often cheaper to use the own car.
- Providing mobility for those without car and/or driving license: On-demand paratransit can improve quality of their life significantly, but it is usually not comprehensive enough to be competitive to the use of an individual car. Covering mobility needs of the majority of the population by on-demand services would probably be not only very costly, but also ecologically similarly inefficient as the own car.

1.3. Opportunities and threats for sustainable mobility originating from autonomous driving technology

Autonomous driving technology obviously offers opportunities to support multimodal mobility behavior and to make the residual individual car traffic more sustainable:

- Operation without driving license reduces the number of people with restricted mobility options.
- The main obstacle for car-sharing networks in rural areas is the enormous need for redistribution of vehicles which accumulate in the morning in towns and next to public transport terminals and spread in the afternoon across the region. This problem could be solved by driverless redistribution.
- The use of driverless mobility services instead of individual car ownership can also solve the problem of poor occupied, excessive car size: Whereas it is reasonable to own a 5-seat-car because of occasional trips with friends, robotaxi users would hardly order an unnecessary big vehicle when riding alone.
- Driverless rental vehicles are not only a rival, but also a support for conventional public transport: First, they resolve the problem of high fixed costs of car ownership at low perceived costs of car usage. Second, you can depart in the morning by public transport being sure to have a possibility to ride home even much later than expected.

Anyway, there are as well several reasons for skepticism and concern:

- All the positive effects mentioned above require the highest level of automation (SAE 5), enabling really driverless operation on the whole road network. It is still quite inestimable, when this will be achieved at reasonable costs, so there might be decades when driverless mobility services cannot be established yet, but public transport already suffers from the popularity of partly automated cars, allowing the driver to read, work or sleep at some parts of the trip.

- Some obstacles for efficient car-sharing operation might remain despite the development of driverless vehicles: High size independent vehicle costs, e.g. for safety features, might make the concept of one-seat rental cars unfeasible. Driverless mobility services might not achieve the breakthrough because of relatively high visible costs per kilometer, even if they would lead to less total mobility costs compared to car ownership.

Facing severe uncertainties about the future development of autonomous cars and mobility services, it is the challenge for sustainability-oriented transportation planning to develop integrated concepts strengthening the opportunities and mitigating the threats.

2. Description of the 2-wheel personal rapid transit concept (2-wheel PRT)

2.1. Functioning principle

The basic idea of 2-wheel PRT is the use of driverless vehicles on a route network which is separated from any conventional, human steered traffic (at least out of town), including grade-free crossings between the 2-wheel PRT and the existing road network. Segregation from conventional vehicles has two positive effects:

- First, it allows us to break the weight spiral: crashworthiness standards require higher car body weight, requiring more engine output, leading to more engine weight, requiring the car body again to carry more weight. On conventional public roads, these passive safety requirements will remain effective for autonomous cars too as long as human steered cars exist.

- Second, automated operation becomes easier, if size and shape of the other vehicles is known, their behavior is predictable and car-2-car- as well as car-2-infrastructure communications can be applied comprehensively and there is no need for overtaking as all vehicles run at the same speed.

At first sight, it seems to be obviously infeasible to double the existing road network with additional traffic routes for automated vehicles. On closer consideration, it is rather some kind of solvable chicken-or-egg-dilemma: Redundant road networks are infeasibly expensive if they are constructed for conventionally heavy vehicles. In turn, vehicles must be heavy when using existing conventional roads together with conventional vehicles because of conventional crashworthiness requirements. Furthermore, costs for the 2-wheel PRT network are kept low not only by low axle load (decreasing the pavement stress roughly by the fourth power), but with the usage of self-steering 2-wheeler technology (see Fig. 1): The vehicles are cabin motorcycles, thus the intended width of the route's paved surface is only 0,5 m, even narrower than the vehicle itself.

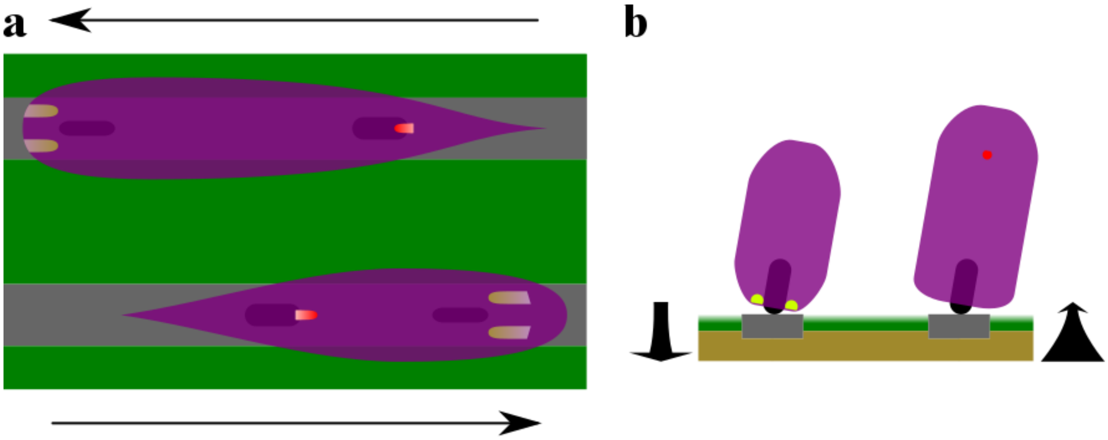

Fig. 1 top view (a) and front/rear view (b) of vehicles and pathway. Lower (a) resp. left (b) vehicle: standard vehicle, upper (a) resp. right (b) vehicle: enlarged vehicle.

2.2. Technical feasibility of autonomous cabin motorcycles

This contribution focuses on the perspective of transportation planning, not vehicle engineering. However, there are technological developments, showing that self-steering or self-balancing motorcycles are in general feasible:

- The Yamaha Motobot, a humanoid robot riding a conventional motorcycle (see Yamaha [2016])
- The Honda riding assist, enabling a motorcycle to run driverless at low speed (see Honda [2017])
- Various self-balancing unicycles, proving that robots fulfil extraordinary balancing challenges rather better than humans (see Wikipedia [2017 - 2])

In the course of further research and development, there are anyway some specific challenges in order to create a reliable means of transport: First, bad road surface conditions particularly in winter must be considered and second, the self-balancing mechanism shall be capable to compensate some movements of passengers within the vehicle without capsizing or getting off the paved part of the route. Desirably, the balancing mechanism should be robust enough to allow the use of the vehicle without seatbelts. Third, either some reliable technology for detection and/or deterrence of crossing animals, or fences and grade-free wildlife crossings, will be required.
Apart from the narrow paved pathway surface, 2-wheel vehicles reduce the minimum curve radius (higher lateral acceleration acceptable for passengers) and facilitate the reduction of aerodynamic drag as 3- oder 4-wheelers require some minimum width for stability reasons. For parking (including slow and rearward movements) the vehicles are to be equipped with retractable auxiliary rollers.

2.3. Vehicle characteristics

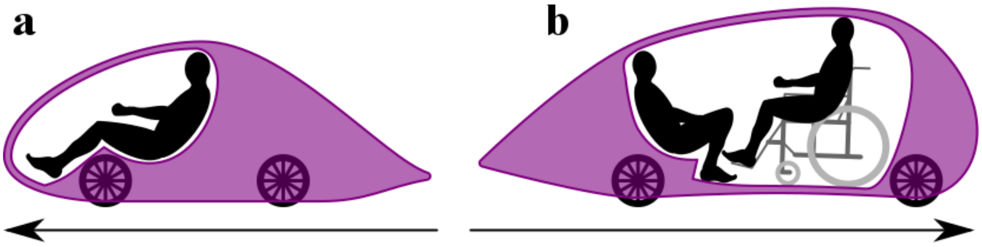

Fig. 2 side view of the standard vehicle (a) and the enlarged vehicle (b)

It is intended to offer two different vehicle types: Whereas the standard vehicle (Fig. 2 a) accommodates only one passenger, the enlarged vehicle (see Fig. 2 b) is big enough for a standard wheelchair and an additional passenger accompanying the wheelchair user or for a family of 3-4 people, depending on the children’s age. The enlarged vehicle could accommodate one passenger in a lying position too.

The 2-wheel PRT vehicles are battery-electric powered. As they are used solely within a vehicle rental system, a battery exchange system could be established easier, than based on user-owned vehicles. Additional costs and complexity of a battery exchange system are to be balanced with the advantages of elimination of recharging breaks (vehicle change or waiting time required on range-excessing trips, vehicles and rental stations blocked during recharge) and more flexibility to manage the charging process according to the requirements of the electricity grid and the maximum use of renewable energy.

The main characteristics of both vehicle types are estimated as displayed in Table 1:

Table 1. Characteristics of the 2-wheel PRT vehicles

	Standard vehicle	Enlarged vehicle
Length	3,6 m	4,2 m
Width	0,75 m	0,82 m
Height	1,4 m	1,69 m
Weight without passengers	150 kg	300 kg
Thereof battery weight	20 kg	40 kg
Battery capacity	3,3 kWh	6,7 kWh
Range	100 km	130 km
Engine output	5 kW	9 kW

2.4. Route network

The 2-wheel PRT route network is consistently designed out of backbone and feeder sections (see Fig. 3): Backbone sections are projected completely grade-free and passing around built-up areas, allowing the vehicles to run over the most part of the trip distance at constant speed. Grade-free construction is facilitated by low weight, width and clearance height of the vehicles. Feeder sections are only used at the beginning and the end of a trip between origin resp. destination (usually within built-up area) and the next backbone route.

Thanks to lower speed limits, threats originating from conventional vehicles are within built-up areas by far smaller, than out-of-town: Roughly the half speed means only a quarter of braking distance and kinetic energy. Therefore, for the feeder sections within built-up-areas, there are several alternatives considered:

- Full grade separation as the most cautious variant would require grade separation by underpasses, seeming rather unrealistic from the point of view of construction efforts and urban aesthetics.
- A high level of safety at acceptable time losses could be achieved by traffic lights at crossings with the conventional road networks, eventually additionally protected by railway-type barrier booms. Between the crossings, the 2-wheel PRT roadway can be protected by fences.
- As soon as the autonomous driving technology matures sufficiently at affordable costs, mixed operation on the conventional roads could become feasible, maybe first on selected routes or with specific restrictions e.g. concerning turning on crossings. From the point of view of passive safety, mixed operation in town without application of crashworthiness standards would be comparable to conventional urban cycling. Door-to-door service would on one hand increase the popularity of 2-wheel PRT thanks to the avoided walking distance to the next rental station as well as accessibility for people with reduced mobility. On the other hand this might have significant negative impact on public health due to reduced physical activity.

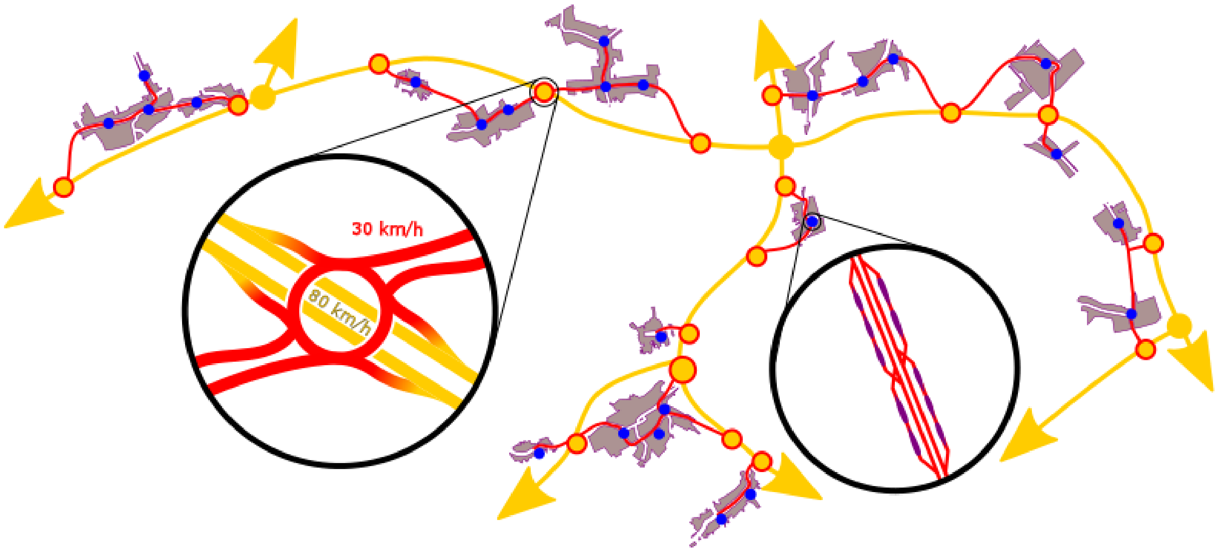

Fig. 3 Network structure of 2-wheel PRT: backbone sections (yellow lines), feeder sections (red lines), rental stations (blue dots)

In order to reduce the network length to a feasible extent, in all variants without mixed operation 2-wheel PRT does not serve every address, but users get on and off the vehicles at rental stations which are accessed by foot or bike. Depending on local building structures, in-town-sections can be arranged on grass-strips between pavement and buildings, by conversion of parking lanes or by changing two-way-streets into one-way-streets.

The intended speed level is about 80 km/h on backbone sections and on feeder sections out of town. Within built-up areas the 2-wheel PRT vehicles shall ride at about 30 km/h. Junctions are intended to allow 80 km/h along the backbone sections or when branching between them, but only 30 km/h when branching off onto a feeder section. As the vehicles run nearly the whole journey continuously at their maximum speed, an optimum ratio of average speed on one hand and resources for achieving higher speed (required engine output to overcome aerodynamic drag rising by the third power of speed, more battery weight, more complicated steering and suspension…) is achieved.

3. Fields of application, intermodal chains and cross-modal competition

3.1. Short- and medium distance trips in rural and suburban areas

The most important field of application for 2-wheel PRT are trips outside urban agglomerations in a distance range, where the overall travel time in public transport is dominated by the walking time to the station, the waiting time for the next connection, waiting times when interchanging and time losses for many intermediate stops. The lower limit of this range is defined as the distance, where walking or cycling the whole trip takes the same or just a little more time, than walking to the rental station (if there is no door-to-door service), renting a vehicle, riding, returning the vehicle and walking to the destination. As the intended density of rental stations shall ensure a walking distance of 200-300 m for the vast majority of the population, the use of 2-wheel PRT will probably start at about 750-1000m. The other end of the range of this main application field depends on the concrete origin-destination pair: Along main public transport axes with short intervals and relatively high speed, it might be about 20 km, in adverse conditions for public transport it might be a multiple of this.

3.2. Trips within urban areas

Large, densely built-up urban areas are not suitable for 2-wheel PRT as the framing conditions do not correspond to those, 2-wheel PRT is optimized for:

- Very good alternatives in the field of public transport, walking and cycling
- Less importance of travel speed, higher importance of capacity, network density and reliability
- Few space available for new transport infrastructure
- Sensitive urban architecture and heritage protection

3.3. Intermodal division of work in rural-suburban-urban relationships

Small town centers in rural and suburban areas can be accessed either directly via a 2-wheel PRT route passing through them, or by a short walk if there is not enough space for a pathway directly through a densely structured town center, but in some of the streets nearby. In case of small to medium cities (10.000 – 50.000 inhabitants) without an own public transport network serving for trips within the city, it would be conceivable to create some 2-wheel PRT corridor, perhaps underground or elevated, in order to enable direct access to the city center. Above this city size, trips between city and region are to be performed intermodally:

- A possible solution consist out of extensive 2-wheel PRT rental stations with interchange to tram or metro terminals at the outskirts of the city. In this case, the rural and suburban 2-wheel PRT seamless connects to urban public transport, designed primarily for intra-city trips.
- The demand for interchange could also be distributed over more stations, if there are high-performance suburban rail passenger services connecting the core city to a limited number of suburban stops with high demand potential originating from population density around the stop as well as from intermodal interchange. This solution is particular useful, if suburban express trains run at short regular intervals, facilitated by the elimination of local trains with short stopping distance.

3.4. Long-distance trips

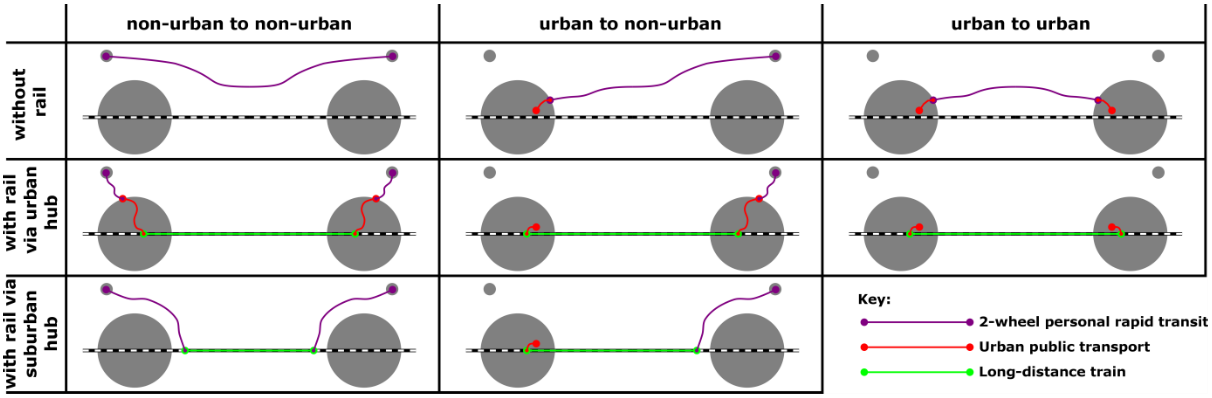

Fig. 4 Unimodal and intermodal options for long-distance trips between different urban and/or non-urban (rural or suburban) destinations.

For assessing the competitiveness of long-distance rail services against a long-distance-use of 2-wheel PRT, it is important to differentiate according to settlement structures of origin and destination: Conventional main railway stations, usually located in centers of big cities, are not accessible directly by 2-wheel PRT, so travelling from a non-urban origin to a non-urban destination would require at least four interchanges (left column, middle row in Fig 4). On the other hand, in order to travel between urban destinations using 2-wheel PRT, the first and last mile must be covered by urban public transport as well (right column, upper row in Fig 4). A significant increase in efficiency of intermodal trips could be achieved with suburban stops of long-distance trains as they are directly accessible by 2-wheel PRT, eliminating at least one, but often several interchanges (lower row in Fig 4).

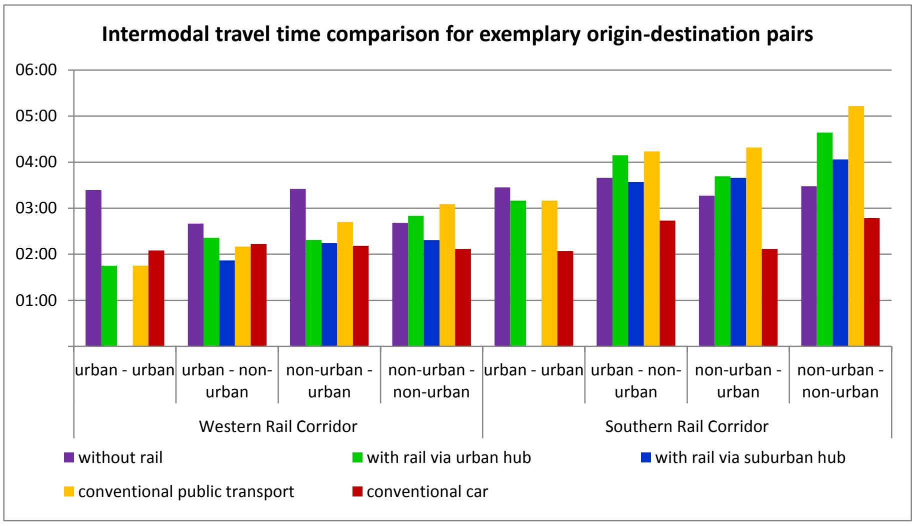

Fig. 5 Travel time comparison between unimodal and intermodal long-distance trips for exemplary origin-destination pairs.

As a first approximation of competitiveness based on the different circumstances described in Fig. 4, travel times for exemplary itineraries in Austria were calculated. These exemplary trips do not differ only between urban and non-urban, but also in travel speed characteristics: One set of origin-destination-pairs is located along the western rail corridor between Vienna and Upper Austria, which had been modernized during the last decades, offering an average beeline speed of up to 122 km/h, the other origin-destination-pairs are located along the southern rail corridor between Vienna and Styria with no higher beeline speed than 55 km/h. At each end of the respective corridor an urban and a suburban or rural address was chosen randomly[2]. The non-urban destinations are optionally accessible via urban hubs or via suburban hubs. Whereas the non-urban destinations in the Vienna region and Upper Austria are rather good accessible suburban towns, the non-urban destination next to in Styria (applies for the southern corridor) is a rather remote village. Travel times by conventional car and the combination of long-distance rail and local public transport were compared as well.

The results of the travel time comparison, shown in Fig. 5, can be interpreted as follows:

- The achievable travel speed of long-distance trains, generally determined by the quality of track infrastructure, is crucial not only for the competitiveness of long-distance rail travel over long-distance-use of 2-wheel PRT, but also for the sustainable modes together compared to conventional car traffic.
- The consistent implementation of long-distance train stops at suburban interchange hubs would significantly reduce travel times in the intermodal chain of 2-wheel PRT and long-distance rail travel.
- Even the comparison for the itineraries along the southern rail corridor is to some extent biased in favor of the use of rail services: First, the routes between the considered destinations are all more or less parallel to the rail corridor, served by direct trains (except some connections via suburban hubs). There

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[2] Origins, destinations and other assumptions for travel time comparison:
- Vienna Region: Wien Bürgerspitalgasse (urban), Schwadorf Florianigasse (non-urban)
- Upper Austria: Linz Hauptstraße (urban), St. Georgen / Gusen Wimmingerstraße (non-urban)
- Styria: Graz Rechbauerstraße (urban), Arnfels 194 (non-urban)
- Train stations: Wien Hbf, Linz Hbf, Graz Hbf (urban), Vienna Airport, St.Valentin, Leibnitz (suburban)
- Urban sections in Vienna by metro, in Linz and Graz by tram
- 5 Minutes for every interchange, 80 km/h for the whole trip except 30 km/h on the first and last km
- 5 Minute break for battery or vehicle change every 75 km
- Distances and conventional travel times retrieved from VOR / ITS Vienna Region (2017)

would be obviously many origin-destination relationships requiring several changes or long detours, leading to a worse result for the intermodal connections. Second, intermodal connections with the use of long-distance trains are provided usually at intervals of 30-120 minutes, whereas passengers can start their trip at any time when using only 2-wheel PRT or about every 5-10 minutes when combining it with urban public transport.

- Even a significant longer travel time can be more convenient, if the passenger can travel asleep during a long ride without interchanges. The potential use for overnight travel is an argument for the application of a battery change system, facilitating long-distance rides without interchanges or breaks for recharge.

3.5. Further modal choice criteria

Travel time is an important, but not the only modal choice criterion. Another one, though quite difficult to judge about, is comfort of travel: On one hand, the interior of a long-distance train is of course more spacious and you can have a walk or use the toilet or maybe a restaurant car while travelling. Particularly for families or groups that do not fit into a single vehicle, it would be more enjoyable to travel together. On the other hand, 2-wheel PRT offers privacy, maybe one of the main reasons among car users not to take the train.

Last but not least, even the most time-saving mobility option might be uncompetitive if it is too expensive. The economic aspect of division of labor between 2-wheel PRT and public transport is not only a question of the average cost level (see 4.3), but also of cost structures: Public transport, especially trains, has a big minimum efficient scale and every bus- or train-kilometer with poor occupancy means additional uncovered costs. In contrary, an appropriate utilization of a 2-wheel PRT route can be accumulated throughout the day and some adequate demand for a rental station may spread not only over the time, but also over various destinations. As 2-wheel PRT vehicles are mostly one-seaters, the occupancy of an individual drive is by nature high. Therefore, not only areas of low demand, but also periods of low demand will rather be served by 2-wheel PRT, than by conventional public transport. If the total required 2-wheel PRT route infrastructure is required to ensure comprehensive territorial coverage and sufficient capacity at peak hours as its main task, marginal costs for additional services like long-distance rides would be much lower, than the average infrastructure costs per passenger-kilometer.

On the other hand, there are as well similarities concerning the cost structure of conventional public transport and 2-wheel PRT: In both cases, there are high fixed costs per maximum peak capacity (number of vehicles resp. seats available at peak hours) and the long-distance segment offers more favorable conditions than commuter traffic because demand is less concentrated within peak hours and peak directions.

3.6. Total effect on public transport usage

All things considered, there are two opposite effects of 2-wheel PRT on public transport usage: On one hand, short-distance bus and train services outside metropolitan areas could be replaced nearly completely and also for a relevant share of long-distance trips, 2-wheel PRT would be more popular, than trains. On the other hand, 2-wheel PRT has the potential to multiply multimodal travel behavior compared to a currently very low level particularly in rural and suburban regions. But also in urban areas, many people own a car primarily for access to non-urban destinations. Thus, the target group as a whole would grow, but the market share of public transport within it would decline. At the same time, public transport would become more efficient: Less network density but more trains per hour on the remaining network after elimination of local trains with frequent stops having poor daily mileage, but blocking disproportionally much track capacity for fast passenger trains and cargo trains.

4. Costs and resource consumptions of 2-wheel PRT[3]

4.1. Energy efficiency

The electricity consumption of 2-wheel PRT per passenger-mileage is not only lower than that of electric cars of conventional size and speed, but also below the specific electricity consumption of public transport (see Fig. 6 a). If applying the average EU electricity mix, 2-wheel PRT has the same carbon dioxide emissions as a diesel powered car consuming about 1,15 – 1,4 l / 100 km.

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[3] For detailed assumptions and references concerning the cost and energy calculations see Buschbacher [2017]

4.2. Demand of raw materials

The small, light vehicles do not only require less energy for movement, but also when being manufactured. This concerns the car-body with low crashworthiness requirements as well as the battery: Low electricity consumption, but also the possibility to solve range limitations by battery exchange or changing of vehicles lead to a required battery capacity of the standard vehicle of about one-tenth of usual electric cars (see Wikipedia [2017 – 1]), reducing accordingly the demand for rare minerals and conflict resources.

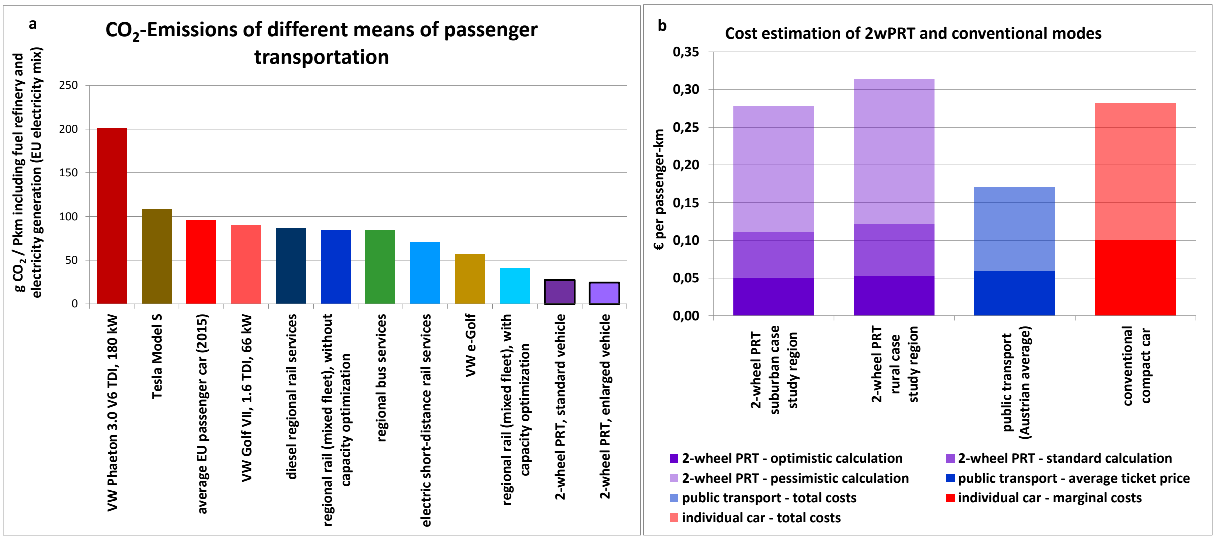

Fig. 6 CO_2-Emissions of 2-wheel PRT compared to electric or combustion-driven conventional cars and public transport systems (a), average costs of 2-wheel PRT, conventional public transport and individual car traffic per passenger-km (b)

4.3. Cost estimation

Cost estimations for 2-wheel PRT were made based on two exemplary regions in Austria, relying on data published within the research project “SynArea” (see SynArea Project Team [2015]). Facing a big variety of very uncertain input variables, an optimistic, a standard and a pessimistic assumption was made for each of them, leading to a wide range of final average costs per passenger-kilometer as shown in Fig. 6 b: If the optimistic assumptions turn out to be true, 2-wheel PRT would be immediately competitive against conventional public transport as well as individual car traffic and through the replacement of regional public transport government spending could be reduced or reallocated to other public sectors. Following the standard calculation, a multimodal lifestyle based on the use of 2-wheel PRT and public transport would be still much cheaper, than unimodal mobility behavior focusing on the own car. Anyway, the current level of public transport fares, heavily influenced by cheap season tickets for commuters and pupils, could be achieved only by public subsidies. If the pessimistic assumptions apply, 2-wheel PRT seems not to be economically feasible nationwide based on current internal costs of mobility, but maybe in areas of particularly good framing conditions, with the consideration of external costs of conventional means of transport or when applying efficiency-oriented fares leading to optimal capacity utilization instead of the simple comparison of average costs per passenger-km.

The share of route infrastructure costs in the total costs is between 6% and 27% depending on the calculation scenario and the exemplary region, so the construction of an own route network is worth the effort, if the advantages of the segregation between 2-wheel PRT and conventional traffic reduces all other costs by at least this percentage.

5. Regulatory aspects

Compared to other innovative products, 2-wheel PRT requires significant involvement of public bodies due to the following reasons:

- In order to realize a useful route network, land (usually farmland and forests) must be purchased where it is needed and there is inevitably some influence on land use. Despite all efforts for amicable solutions, government support from zoning plans up to expropriation will be necessary.

- At least the route network, but maybe also the operation of 2-wheel PRT has characteristics of a natural monopoly with high fixed costs at low marginal costs: Direct competition between several redundant networks is obviously senseless, but without competition, market failure is expectable.
- In the field of transportation, governments often pursue specific public interests as e.g. low fares for specific user groups or comprehensive territorial coverage regardless to demand.
- With interoperability problems in conventional transport modes in mind, there should be a strong public interest in comprehensive compatibility and seamless usability throughout different countries and operating companies.

Similarly to other modes of transport and other network industries, several regulatory models are worth considering:

- Integration or unbundling of infrastructure and operation: The construction and maintenance of the route network can be done by other entities, than the operation of the 2-wheel PRT vehicles similarly to the European railway liberalization, or both can be integrated into one organization as usual urban tram or metro companies.
- If infrastructure and operation are unbundled, several operators can compete on the same network. This might cause inefficiency through redundant capacities (similar to ATMs of different banks or transmission masts of different mobile communication operators), but it could also reduce costs through competition.
- In those areas without competition (at least infrastructure, but maybe also operation), there are several options for the public, how to influence quality, quantity and price:
    - Similar to roads or urban public transport in many cities, infrastructure or services can be provided in-house by a public authority or a public-owned company.
    - Similar to public transport, waste collection or water supply in some countries, services and/or infrastructure construction and maintenance can be tendered and finally awarded to the supplier with the best ratio of price and quality. Gross cost contracts would facilitate the integration into public transport fare collection systems, leading to more convenience for intermodal trips and the opportunity for a common demand management.
    - If it is intended that the operator shall cover all costs directly by fares, but some aspects of price (e.g. reduced fares for needy user groups) or quality (e.g. territorial coverage) shall be still influenced by the public, the operator can work on the base of a service concession defining such conditions in exchange for the exclusive right to operate the system.
    - If profitable operation of 2-wheel PRT is expected to be feasible, but the number of competing operators within the same area seems to be limited, concessions could be auctioned similar to frequency bands for mobile communication operators.
    - In case of unbundling of infrastructure and operation, different modalities and also different contract periods can be applied. Depending on expected profitability and intended service quality, fees for the usage of the infrastructure can vary from zero (similar to the secondary road network) to cost-covering or demand-managing amounts.
- Technical standardization as well as regulated cooperation between operators is necessary not only if there are several competing operators within a given region, but also between neighbouring monopolists in order to avoid the necessity for interchanges at borders of regions or states. This would be of particular importance, if 2-wheel PRT is used significantly for long-distance and overnight travel.

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