Elevated Small Vehicle Highways (SVH)

Abstract

Automobile like scaled down elevated urban Small Vehicle Highways (SVH) and Small Vehicle Limited Access Thoroughfare (SVLAT) arterials are introduced and compared to urban automobile arterials. Daunting challenges are noted as every issue ever discussed for urban automobile arterials must be re-considered for scaled down small vehicle arterials. The importance of urban automobile arterials are noted as these roadways move disproportionately large amount of traffic compared to the roadway length. Noted also is that arterials are non-existent for transportation modes excluded from Limited Access Thoroughfares and other arterials. Feasibility for scaled down aterials is explored philosphically from several important perspectives in detail. It is found spacing of highways may be 8.72 km (5.4 miles) or greater due to willingness of transit riders to commute more than a mile on a bicycle. For throttle controlled lanes roadway capacity is likely similar to automobile roadway capacity per lane. The resultant high capacity, lower weight and smaller scale will in some cases such as bridges result in lower costs than automobile bridges. Other issues discussed include: auxiliary uses for structure, transportation equity, transportation interfaces, new technology integration, automated roadway, knowledge gaps, system design alternatives, potential high value highway applications, and elevated roadway examples. Sketches are used to show how the systems might fit into a relatively narrow street and to show how systems might be configured where physical space is less limited. 40 conclusions are developed including some derived from other conclusions. Conclusions include: lower cost examples, potential for congestion relief, higher efficiency, faster mode speed, perceived better safety, and an opportunity to re-balance transportation equity. The final conclusion is a recommendation to fund development and demonstration of this concept.

Keywords: bicycle, highway, arterials, electric bicycle, small vehicle, limited access thoroughfare.

Introduction

“The twentieth century has been dominated by the growth of automobiles and they (automobiles) have shaped the land use of cities, especially in wealthier developed nations.”[1] Automobile transit ways are highly evolved and include arterials, collectors and local roads.[2] Transportation planners are are advised to never argue against the car(automobile).[3] Active form of transportation is marginalized in the USA. [4] In the USA, smaller vehicles which are individually operated similar to the automobile including bicycles, electric bicycles, electric motorcycles, electric scooters, velomobiles and small cargo vehicles are all excluded from automobile Limited Access Thoroughfare(s) (LAT). Smaller vehicles are not only excluded from automobile arterials, but also, have no arterials in most areas.

This article investigates the likely features and results of mirroring the automobile roadway system by adding elevated scaled down arterial roadways, Small Vehicle Highway(s) (SVH), above city streets. Since the goal is to recreate urban automobile functionality at a smaller scale, the proposed for SVH are mostly compared to urban automobile arterials. Automobile minor arterials and collectors are likely places to add elevated SVH systems. The principals for designing SVH follows directly from automobile highways therefore the highways should have similar design details which are scaled to the smaller vehicle. The goal is to recreate the functionality of the urban automobile for small electric vehicles while simultaneously promoting active forms of travel without interrupting automobile flow of traffic. A secondary goal is to add capacity by creating a parallel transportation system. It likely this scaled down system can be created for a lower overall societal cost than the cost for automobiles.

Herein the automobile is referred to as the automobile, however this terminology can be misleading. If the proposal is adopted, smaller than automobile vehicles may evolve and have the same functionality as the automobile. A more accurate definition for the scaled down automobile might be, ‘small vehicles that can operate in estimated 1.5 m (4.5 ft) lanes with tare weight of 340 kg (750 lbs)’. The parameters of lane width and tare weight are not cast in stone at the outset of this proposal, rather these these are floated as trial balloons to facilitate discussion.

This article explores the myriad impacts cause by changing one parameter, roadway scale. If this parameter were to be changed at the onset of a city’s planning and design the change might be a relatively simple one. However changing roadway scale in an operating city populated with people who have been en-cultured with a different transportation legacy is anything but simple. The opportunity to envision a future city design that is shaped by a new transportation optimization is even more complex.

SVH can easily be thought of as a scaled down urban automobile highways with extensive provisions for pedestrians and manual bicycles. Much like a scaled down railroad, SVH will be less costly per mile to install and operate given the same conditions. The smaller scale contributes to feasibility of elevating the highway above city streets. The undesirable effects of the automobile will be retained but at a smaller scale. The positive effects can also be retained such as level of service, safety, speed of traffic sorting and on demand service. The challenge for planners and designers will be to compromise these effects in a way that maximizes value for the expenditure in a particular locality.

The article is primarily focused on comparing the differences between the current state of art for urban automobile travel and the proposal. This is a daunting task as every issue ever discussed for automobile highways must be reconciled for SVH. Therefore issues are prioritized in the article to those which seem the most important. A high level view is that the aforementioned smaller vehicles generally: cost less, weigh less, use less energy, cause less pollution, travel slower and use less parking space than the automobile transportation system being compared. It is expected economic activity can re-orientate around small vehicle transportation mode much like it has other transportation systems if we can achieve safer, faster and more convenient travel options for a given locality.

There is a wealth of information including government regulations detailing design parameters for automobile, bicycle and pedestrian transit ways. Small vehicle modes mentioned above are mostly capable of using bicycle lanes therefore the body of research into bicycles can be helpful. However there are no studies found discussing characteristics for small vehicle arterial roadways elevated above city streets, therefore parameters are derived to illustrate likely features.

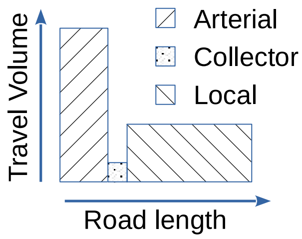
Automobiles urban trips can involve a functional combination of local, collector and arterial roadways over a highly optimized network. Existing small vehicle transportation networks only have functional local and collector type roadways for small vehicles, no arterials are present. The percentage of automobile roadways devoted to each roadway function are summarized in Table 1 which also presents the small vehicle functional modes of travel, showing that arterials and collectors are mostly non-existant. Principal + minor automobile arterials carry up to 65% of the traffic yet represent no more than 25% of the overall roadway miles. It would not be unreasonable to expect planning optimization to result in similar ratios for elevated small vehicle arterials should the benefits be equivalent with the automobile.

Table 1 Typical automobile distribution of urban road type and usage by percent compared to available roads for small vehicles and pedestrians from Exhibit 1-7 AASHTO Green Book. [2]

	Principal + Minor Arterial	Collector	Local Road
Travel Volume (%)	65-80	5–10	10-30
Length (%)	20-25	5-10	65-80
Active Transportation	No Bicycles, no sidewalks	Bicycles lanes on some, sidewalks	Bicycles allowed, sidewalks
Small Vehicle	Few or no arterials.	Some collectors.	Widely allowed.

Figure 1 graphically represents the data above. The graphic clearly shows the automobile arterial moves the most traffic with the least miles of roadway. 65-80% of the traffic is moved by 20-25% of the roadway length. In retrospect it is obvious why the automobile is dominant over smaller vehicles, it is the only transportation mode with arterial roadways capable of rapidly moving large amounts of traffic. It is possible scaled down arterial roadways installation will be the enabling factor to cause small vehicle usage to grow to rival or even surpass the automobile in some urban environments.

Figure 1 Graphic of Table 1 showing relative importance of arterials for moving traffic.



“The US Interstate Highway System, which includes 2.6 percent of all roadway lane miles in the U.S., carries 26 percent of the nation’s vehicle travel.” [5] The US interstate system is mostly rural but also provides some of the most important arterials in urban areas of major cities. It can be expected urban elevated Small Vehicle Limited Access Thoroughfares (SVLAT) can provide a similar function within optimized small vehicle urban transportation network. In effect the lack of small vehicle arterials is likely a ‘missing link’ in urban transportation networks which favors automobiles over smaller automobile like transportation modes.

Proposing the cost benefits elevating roadways for bicycles is not a new idea. A New York Times article in 1896 proposed a bicycle path over a railway and compared cost to the cost of a subway. [6] As was typical for print of the time, no practical details were provided.

Conclusion

1. Automobile arterial roadways move more capacity per length than other roadways.

2. Small vehicle arterial roadways rare or non-existent.

The greatest need for SVH is to service all vehicles/modes excluded from conventional urban arterials. Vehicles using throttle controlled motive power rather than human power operate similar to the automobile. Pedestrians and manual bicycles represent the opposite end of the spectrum where motive power is dependent on the human effort expanded, creating larger speed differentials. Active forms of travel, pedestrians and bicycles, are to be encouraged due to health and livability benefits. [7] Designing a state-of-art system to accommodate all vehicles excluded from automobile arterials while prioritizing active forms of travel presents a unique and complex challenge.

Study Methodology

This study is an outgrowth of other research by the author into the likely outcomes of adding SVLAT systems to cities. This work to prepare this article starts with surveying what is known to develop characteristics for comparison. The comparisons are used to logically develop conclusions. These conclusions are then used to develop other conclusions or illustrate the comparison. In effect this article is a basic study package which can serve as a starting point for subsequent more focused studies.

Due to author convenience this article relies heavily on design standards promulgated by US authorities and uses US examples. In no way does this convenience imply the US is the preferred location for projects. Cultural factors and economic needs override practical considerations often when considering new transportation systems.

The analysis works around practical constraints. Without funding there can be no detailed studies. Therefore the work to describe likely outcomes is limited to that which can be completed on the author’s desktop.

Due to the extreme amount of literature discussing existing transportation, the literature search cannot be a comprehensive overview of the state of art. What this article does is to extract pertinent data to support comparison of the existing system with the novel system. The first priority for data is codes and standards. Research articles are used to describe important observations regarding characteristics of the current transportation network. Books are used mostly to describe transportation networks form an overview perspective.

This article is intended to provide data, analysis and perspectives to support a decision process whether to invest funds in an alternative transportation system.

Research results are provided by One Search tool at Kraemer Family Library University of Colorado Colorado Springs and AI tool Aria. It is not intended this search is reproducible as much novel work has gone into development of search terms and some of the searching was done years ago.

Geometric factors of existing transportation systems

Many geometric characteristics of US roadways are codefied into law through various resources. Table 2 summarizes physical characteristics of current state of art for various vehicles. While Class 3 and more powerful vehicles are throttle controlled similar to the automobile, human powered modes utilize human motive power as a result have more speed variation. The summarized data is subsequently used for logical development of observations and conclusions.

Table 2 Select Physical characteristics of transit ways operation for pedestrians and vehicles.

	US LAT	**Micro car**	**Pedelec Cargo**	**Bicycle**	**Pedestrian**
Preferred lane width	12 ft [B, AK]	1.5 m (4.5 ft)	1.5 m (4.5 ft) [BV]	1.5 m(5 ft) to 2.2 m (7 ft) 2 side-by-side [BW]	
Maximum Lane Height	16 ft [AK]			2.5 m 100” [B]	
Design Weight	39,594 kg (80,000 lbs) [C]	100 kg (220 lbs) – 500 kg (1100 lbs)			
Speed	55-80 mph US [find]	Up to 75 kph (45 mph)	50 kph	E-bike 12-18 mph, manual bicycle 4-18 mph. [BV]	Walking speed up to 1.0 m/sec, 3.6 kph. [A] i
Preferred lane construction	Slower modes excluded	Faster/Slower modes excluded	Faster/Slower modes excluded	Faster/Slower modes excluded	Faster modes excluded
SVLAT Cooridor	Excluded	Max weight, can use Class III, 50 kph speed limit.	Uses Class III below 28 kph	Uses Class III below 28 kph	Uses Pedestrian only lanes
15 minute (SV)LAT commute	25 km (15 miles)	12.5 km (7.5 miles)	12.5 km (7.5 miles)	6.25 km (3.75 miles)	Not estimated.

[8] [9] [10] [11] [12] [13]

Table 3 Fuel efficiency for select transportation modes.

	US LAT	**Twizzy**	**Bicycle**	**Pedestrian**
Electric	Automobile: 30 kwh/100	9.65 kwh/100 miles	1.9 kwh/100 miles	None

	US LAT	Twizzy	Bicycle	Pedestrian
Efficiency	miles]			

[14] [15] [16]

Conclusion

3. Smaller electric vehicles are more fuel efficient than electric automobiles.

Recommendations for reducing carbon emissions include strengthening the sustainable transportation system by promoting eco-friendly and energy efficient modes of transportation. Transport sector, and therefore, urban mobility, is a key factor for economic growth and sustainablity. [17]

Accessibility

Accessibility is promoted by active forms of transportation such as walking and manual bicycling. To a lesser extent accessibility is promoted by electric bicycles and electric scooters. These active forms of travel utilizing Pedelecs and human motive power also contribute to better health. [18] [18] [19] Manual mode accommodation serves transportation, accessibility and egress purposes. Incorporating accessible transportation in the basic design philosophy of SVH will promote accessibility all along the highway. Wide sidewalks will encourage walking or running while providing access for emergency or egress purposes.

Accessibility by way of public transport has been found to have higher economic value than automobiles. [20] Reasons for this may be related to the costs and complexities of automobile parking. In comparison a person is an immediate pedestrian when exiting mass transit. SVH by accommodating smaller more easily parked vehicles will on a continuum perform more like mass transit than the automobile. However, SVH operates similar to automobiles therefore some automobile deficiencies will be retained. Further study is needed to clarify retained automobile deficiencies and how this might be best managed.

Feasibility

On the face, feasibility for constructing scaled down highways is assured by seeing the answer to the questions below.

- Can we build scaled down highways? YES
- Will scaled down highways move significant amounts of traffic? YES
- Can we build elevated scaled down highways over city streets? YES
- Is there space above city streets for scaled down highways? YES

- Are small electric vehicles commonplace and low cost i.e. electric bicycles, electric scooters? YES
- Are there many of streets above which scaled down highways can be installed? YES

However practical feasibility when dealing with large scale changes to city planning is anything but easily understood since we must consider culture, future impacts, economics, routing options and changing public opinion. Therefore it is necessary to take a deeper dive into the subject of feasibility. This article is not intended to prove local feasibility, but to identify variables for further study.

Average SVH Mode Speed

Average modal speed takes into account the entire trip. From the moment a person decides to start the trip, until when the trip ends. This can include many interactions and modal shifts along the way. For the automobile distance from the start location to parking location may not be insignificant. The time to navigate local roads before joining traffic along arterial roadways can be an important factor. Mass transit has many more steps including wait times to transfer or to get on the ride. Small vehicle commuting has the advantage of more convenient parking, or even no parking when using folding bicycle or walking. In highly congested cities provisions for small vehicle parking can be less costly to provide.

For the user average modal speed represents a cost of travel a particular distance. The average mode speed is a measure of the range of travel possible for a given time expenditure in an urban environment.

Average speed for a given trip is highly dependent on the trip and the characteristics of the urban environment. For example a trip comprised of travel from a house located on an arterial highway down an arterial to another location on the arterial highway will be different from a trip that includes walking to the parking spot, driving from parking spot-> local road -> collector road then repeating in reverse. Determining average modal speed with modern tools for all users of existing transportation modes can be a costly process. In addition, SVH have not been built, therefore the model results cannot be tested. Any untested result using a mathematical model is suspected for accuracy. Therefore this article focuses on the arterial speed to guage how useful elevated SVH arterial might be in comparison with other modes.

Urban automobile streets can be highly congested and contain many impediments for free flowing traffic. Elevated SVH in comparison can provide non-stop traffic flow through congested parts of the urban environment. Therefore, SVH should be located in areas of highest congestion. These highly congested areas are often concentrated areas of trip origination and destination. Areas of high trip origination and destination are urban residential apartment blocks, work locations, entertainment venues and shopping areas.

Conclusion

4. By locating SVH in areas of highest congestion the comparative mode speed can be higher for SVH.

Electric bicycles have been shown to overcome some barriers associated with traditional cycling including range, grade and speed. [21] Designing for different classes of electric bicycles becomes an imperative for the dual goals of cost minimization and increasing average modal speed for small vehicle commuting.

SVH systems are envisioned to have lower speeds than automobile highway systems. Slower speeds has merit when considering sustainability. [22] However higher speeds allow longer range for a given time investment. Setting SVH speeds limits in a particular area is likely to be an ongoing debate.

Currently small motorcycles (some are electric) can navigate the LAT system and are within the size and weight class of vehicles proposed for SVH. Small motorcycles are allowed to ‘lane split’ in some jurisdictions, [23] Lane splitting demonstrate motorcycle capability to navigate narrower lanes. Microcars can navigate smaller lanes than automobiles. [24] Continued development may allow small LAT capable automobiles to use SVH.

Small throttle controlled vehicles such as some electric bicycles, electric motorcycles and some small electric vehicles can be designed to travel almost any speed. However classifications for these vehicles recognize Class 3, [25] a class of vehicle travelling 47 kph (28 mph). While it is not clear what maximum speed throttle SVH should be designed for travel, it is easiest to focus discussions in this paper on the Class 3 designation.

US Federal Highway Administration recommendations limit local urban street speeds be 50 kph (30 mph). [26] Vehicles traveling these streets must navigate street lights, roundabouts, and stop signs. These traffic features create impediments to travel. A non-stop highway above city streets moving at the maximum speed of traffic below will have an average modal speed along the highway higher than the traffic below. Since the initial and final stages of the trip are similar at least some trips on SVH will be faster than trips along the street below.

Average modal speed for pedestrians and bicycles along a non-stop corridor will similarily have a higher modal speed than pedestrians and manual bicycles navigating city streets with traffic signals. This can result in the same result, the same or greater average modal speed than those navigating the street below.

Conclusion

5. For all but the shortest trips, non-stop travel through city is more rapid than stop lighted travel at same speed limit.

Some travel modes may benefit from SVH more than others, however the amount of benefit is difficult if not impossible to quantify. The utility of small folding electric bicycles highlighted to illustrate extent of benefits. The time required to get moving on the folding electic bicycle can be less than the time to get to a parked car. A folding electric bicycle can have a higher speed along the SVH than riding on the street below. A folding bicycle can also be taken on the train to destination thereby reducing the travel time at the destination or along the SVH. Without understanding all SVH design details any estimate performed by modern trip generation tools is suspect.

However it is possible to understand that smaller vehicles with a smaller parking footprint can be accessed with less average time expenditure. This smaller land footprint can be reduced further by constructing automated parking devices.

Conclusion

6. Bicycle parking, due to small footprint, is typically more conveniently located than automobile parking. Small vehicles are likely to be similarly parked.

SVH Design Speed

This paper is written assuming SVH are to provide simultaneous non-stop service via independent corridors for 4 classes of transportation. This assumes the most complex case to reconcile therefore is more conservative than considering fewer corridors.

- Pedestrians
- Manual bicycles
- Class I electric vehicles, 15 mph speed limit
- Class 3 electric vehicles, 28 mph speed limit

The discussion is limited to these classes because these classes are defined in law. However it is by no means clear these classes should all be accommodated in all areas or these classes represent the best service compromise for small vehicle urban arterial roadways. On contrary, there are good reasons to question what the optimal vehicle mix is and the speed limits.

People prefer to commute no more than 30 minutes. [1] The dominance of the automobile, has created a desire to maximize automobile utility. Maximizing automobile utility while accommodating the 30 minute commute limit has created urban sprawl. We have achieved a state of automobile dependency in some areas. Cities and areas within cities have been categorized as fully automobile dependent, partially automobile dependent, and mixed transit/automobile dependency. This relative dependency has created variations of the built housing and work environment. One might say this diversity creates economic resilience as different organizational structures can work more efficiently in one environment versus another. However, this diversity also creates problems for transportation planners as techniques that work well in some areas do not work well in others. Likely SVH applications will be no different in this regard.

Optimal small vehicle arterial roadways may not be one design fits all cities nor even all areas within a city. In some highly congested areas, pedestrian access and manual bicycle access may be the only cost effective transportation corridors to add. In other areas, such as automobile dependent areas of US and Australia, the highest speed lanes might be best optimized at 75 kph (45 mph) to help expand service area.

Conclusion

7. Existing small vehicle regulations may not be the best compromise to maximize utility of SVH.

User Preference

If we build it will they come? This question encapsulates the importance of user preferences in transportation systems design. User preference is a feasibility factor for any transportation system. Perceptions about safety, convenience, economics and culture all factor into user preferences. User perceptions vary from city-to-city, country-by-country and person-by-person. The transportation designer is therefore required to find the best possible compromise for each design detail in order to encourage positive user perceptions. Human perceptions can be surprisingly refractory to change. [27] Therefore efforts to create a bespoke user experience for early elevated SVH installations is likely to pay dividends for many years to come.

If users do not have perceived needs met then the consumers of transportation system will opt for alternatives. User needs are complex and inconvenience can be traded for other convenience. Every person in an urban environment is a user of transportation networks. Therefore transportation networks must appeal to a majority of users as well as meet their needs.

User preference for the urban automobile has changed our cities to accommodate this preference. The core of the SVH proposal is to create urban highways that offer best in class automobile like service in urban areas where the automobile user is confronted with increasing congestion. Proposing smaller size and lower weight vehicles does not mean creature comforts or safety is sacrificed. On the contrary, the proposal implementation will encourage vehicle designers to design scaled down vehicles that appeal to current automobile user perceptions.

A study of Dutch style bicycle highways determined that the features of bicycle highways do attract users. The factors believed to be most important are; reduced interaction with motorized traffic, perceived safety and increased speeds. [28] It was also found this user preference for bicycle highways was weaker as distance from the corridor increased. A study of travel options in Munich concluded the share of walking and bicycling can be increased by infrastructure investments. [29] Human factors should be studied in the first implementations of SVH and the most valuable features copied into later designs to maximize positive perceptions for the novel approach.

Level of Traffic Stress (LTS) using Dutch design criteria has been used as a metric to rate cycle paths. [30] SVH ramps, roundabouts and elevated structures are new experienced environments especially if enclosed. Level of stress must be determined for SVH design parameters. An example of this could be the perceived stress of driving down a long enclose corridor with no windows. We might find strategic placement of windows could reduce stress significantly.

Other studies indicate user route preference is based on the perceived quality of the route. Some cultural differences are noted with cyclists from Greece more likely to select a slower route over those from Germany. “Implementing dedicated bike infrastructure along main streets appears to be a stable strategy, regardless of individual and local characteristics. From the user's perspective, the separated bike infrastructure, which brings order and predictability to streets, is preferred across all subdivisions." [31] These findings support a potential strategy of routing elevated SVH near to or over existing streets lined with commercial enterprises.

Study of human factors leading to rider stress for SVH environment is likely to improved the perceived value of the SVH product and increase probability of early success. Early identification and study of SVH human factors should be pursued for risk reduction purposes. Since SVH do not exist it may be helpful to build a virtual highway environment to test and correlate user perceptions with design variable changes.

Transportation amenities can be a reason for visiting an urban area. [32] The first SVH would be a novelty. However after novelty wears off, the availability of a transportation highway which utilizes low cost vehicles can promote enjoyment of a city's amenities. An ability to more easily park and walk could transform some of the most congested cities into desirable places to visit simply by making transition from riding to walking easier and more ubiquitous.

Conclusion

8. Users prefer perceived safer and more rapid routes.

9. Users prefer grade separation, SVH can meet user preference for grade separated lanes.

SVLAT System Capacity

Per lane capacity for non-stop highways can be difficult to estimate due to design differences. [33] However it can be philosophically understood that if the driver experience is the same with regards to controls and perceived highway design then the driver's reaction time to make decisions should be similar if not the same. A similar reaction time should translate approximately to the same gap in time between vehicles along the roadway. The average acceptable gap in time will thereby control the lane capacity for a particular stretch of roadway.

This theoretical development above describing a gap of time is taught in US driver's education classes and is sometimes described as a 2 second rule. [34] A system of counting car lengths for the highway speed is an application of this time gap rule. The net result for traffic following this rule is that highway lane capacity is not dependent on highway speed. Thereby to the first approximation, LAT highway capacity is similar to SVLAT highway capacity per lane, for throttle controlled lanes.

A corollary statement is that for SVLAT to have the similar highway capacity per lane as LAT highways it must have well designed throttle controlled lanes.

Conclusion

10. Throttle controlled non-stop lanes can have similar capacity regardless of speed.

Costs

Societal costs for existing small electric vehicles navigating traditional roadways is as little as 1/6th the cost of traditional automobiles. [35] Compared to automobile systems, parking requirements are much less for bicycles and can require as little as 1/6th of the land area for automobiles. [36] This results in lower parking costs for bicycles and small electric vehicles than traditional automobiles. For the special case of folding electric assisted bicycles or automated parking structures the parking land use can be even lower per vehicle. [37] [38] Irrespective of other perceived benefits, encouraging use of vehicles with reduced parking costs and reduced overall societal costs, can provide economic rational for increased spending on SVH arterials.

The selection of automobiles for US transportation has been compared to an arms race with people selecting larger and larger vehicles to drive. This arms race increases system costs and emissions which effects health costs. It has been shown congestion pricing simultaneously decreases all of the major automobile externalities by reducing vehicle sizes and congestion. [39] Installing SVH systems is expected to expand usability of otherwise low cost small vehicles therefore may have a similar impact as congestion pricing while expanding rather than limiting urban mobility.

Electric bicycles are produced in high volume and are available at a lower cost than automobiles. [40] Electric motorcycles are lower cost than automobiles Scaled down automobile like vehicles if put into high production will also likely have lower cost than automobiles due to lower weight and electricity demands. For the user, purchasing a scaled down vehicle to run exclusively on scaled down highways would be a lower cost than purchasing an automobile to run on automobile roadways.

Parking costs for automobiles have been self reported by low income participants to be near to zero out of pocket cost. [41] This does not indicate the costs are zero, but that the actual cost of parking is often hidden from the consumer. Smaller vehicles will have lower parking costs due to smaller size and less weight. Due to the small size requirement for parking, small vehicle parking can be located more convenient for the user. In some cases such as folding bicycles formal parking spots may not be required.

Conclusion

11. User costs are lower for smaller vehicle.

12. SVH arterial roadways improve service for otherwise low cost urban travel modes.

Some of societies most vexing problems, including sprawl, congestion, oil dependence, and climate change, are prompting states and localities to turn to land planning and urban design to rein in automobile use. Mathematical models have been developed to predict the impact of various planning decisions on automobile use. [42] However analysis of elevated urban SVH has not been found in any planning studies or academic papers therefore the transportation industry seems to be unaware of this theoretical option.

From Table 1, the envisioned traffic corridors for SVH systems is approximately ½ the height and 1/3 the width of traditional automobile highway corridors, allowing 6 times the number of lanes in the same volume. In addition, small vehicle corridors moving at slower speeds can have lower static and dynamic design loads per lane than LAT systems. [43] This combination of less load and fitting into a smaller volume can significantly lower bridge construction costs for the same amount of traffic. Also Microcars are available with a weight of 100 kg (220 lbs), adding two large sized 110 kg (242 lbs) people gives or 342 kg (754 lbs.) net weight. Microcars are automobile like vehicles that could potentially be designed to navigate both LAT and SVH.

Conclusion

13. SVH swept volume per lane is estimated to be 1/6th the volume of LAT systems.

14. Microcars compare 342 kg (754 lbs) with LAT design weight of 39,594 kg (80,000 lbs)

Due to the lower design loads and smaller scale, SVH corridors are expected to be built above ground mostly using steel structures. In comparison with elevated automobile highways, less material will be used per lane. Steel structures can typically be erected in a shorter time than traditional at grade urban automobile highways. This reduced material usage and reduced construction time can reduce SVH costs and reduce disruptions of existing transportation networks.

Congestion Relief

Congestion has been noted in history since the advent of roadways. [44] Historically congestion has been relieved by building new transportation capacity. However others have noted the futility of building ever more facilities for urban automobile transportation, or at least re-framing how we think about congestion relief. [45] Recent trend of transition from gasoline fueled to electric fueled vehicles is expected to increase congestion, multiple methods to relieve congestion on existing highways have been modeled. [46] [47] [48] What has not been reported is whether congestion can be cost effectively relieved by building scaled down highways over existing city streets for smaller vehicles. If congestion can be relieved by mode shifting due to building SVH at the smaller scale then all users of urban transportation systems in the local area will benefit from SVH installation.

The current transportation system may have reached a paradoxical situation where “All individuals minimize their commuting time and reach an equilibrium under which no person is willing to change their transportation mode.” [49] The result of reaching this paradox is increased congestion as no mode changes are possible. Herein is proposed a new mode which can allow escape from this paradox of optimization at least for a period of time. Considering that automobiles were first ‘brought to the masses’ by Henry Ford in 1908 and first mass produced in 1913, this length of time could be 100 years or more.

Herein is proposed a new paradigm to build arterials for a lower cost modes of travel and to build arterials above existing transportation networks, thereby adding significant capacity with minimal impact on surface land usage. This change represents a dramatic capacity addition to an already overstressed system and could create dramatic positive results.

Land use

Land use for USA roadways has been estimated to have a value of $4.1 Trillion in 2016. The same study went on to estimate "the average cost of expanding roadways exceeded the benefits by a factor of nearly three when accounting for land value." [50] The proposed SVH by mounting over city streets and using narrower lane width will see much less land usage for incremental capacity than traditional roadways.

Along the SVH corridor vertical supports to grade will be installed in locations which minimize disruption to street usages below. One idea is to use current light pole locations while relocating street lighting to the SVH structure. Designing SVH supports will be a complex process that must take into account structural needs of SVH, the street uses below and underground interference. Selecting the best alignment will be the primary tool of designers followed by changes in design to highway or infrastructure below. However complex, it can be reasonably stated that the net effect will likely be little interference with activities along the street below. In effect taking no critical land from the operating city along the corridor. Should traffic along the street below or nearby be reduced due to traffic relocation to the SVH, some of the land on the street below can be re-purposed to more desirable functions such as plant growth.

Conclusion

15. Column supported elevated SVH structures can use minimal surface land along the corridor.

Entrance and egress points will require usage of land footprint. Elevator and stair towers to access the SVH above will require some land where the tower impacts street level. Nearby buildings can provide space for elevators or stairs to the SVH thereby minimizing land usage. The building owners can benefit from increased traffic within the building.

Conclusion

16. Elevator or stair access impacts land usage at grade.

17. Use of nearby buildings for elevator and stair access can reduce land impacts along the corridor.

18. Elevator or stair access through nearby buildings can provide foot traffic within building.

Vehicle or pedestrian ramps will require surface land. These ramps can transition to the street below or to a less valued location nearby. Elevated secondary arterials can move ramp locations off the highway corridor significantly away from the most congested areas. Some ramps can be located in parking lots or parking garages thereby interfacing with commercial interests while reducing street level impacts.

Conclusion

19. Ramps can be located along corridor or significantly away with elevated feeders.

Technological Risk

While the bicycle pathway design recommendations are extensive for local and some highway modes the advent of SVH will require development of various standards. A good example is signage, Manual of Uniform Traffic Control Devices devotes more space describing automobile signage for highways than to signage for small vehicle highways. [51]

Wind can impact small vehicle operation. Wind can be concentrated by nearby buildings or concentrated by the SVH itself. Should the designs be fully enclosed the internal air movements caused by other vehicles can impact vehicle operations. Therefore aerodynamic studies are required to quantify aerodynamic effects for various scenarios. These studies are not technologically risky if completed in a timely manner and if recommendations are followed through.

Walkability has been coined as a term to describe how walking accessibility has been reduced by design in some residential areas. Residential plat designs confine walking to streets which can be configured to not allow driving through the neighborhood. [52] However walkability can have meaning in a large urban area where walking along a street can expose a person to crime or inconvenience if crosswalks have long light cycles. It is expected that SVH with continuous grade separated walkways can be well lit and camera surveilled to help improve urban walkability.

Designing camera surveillance for SVH with many access points is not trivial. The system will resemble city wide surveillance systems more than building surveillance. While these complex systems are workable, the designs can be enhanced by combining technology. One is to have pedestrian access control points by way of tap-to-enter, each person would then be identified prior to being allowed entry. Should it be feasible to charge a fee these access control points could be payment centers. Vehicles could be equipped with beacons on license plates. Beacons can be used to allow access through automated access control points. Beacons can also be used to monitor vehicle location for use in centralized vehicle control on automated roadways.

There is little technological risk with constructing the structure except with underground foundations. Underground foundation design in an already congested city will be be a significant challenge to manage. Underground investigations can cause relocation of supports, and therefore, create non-uniform span lengths.

Fire and emergency response assessments for SVH will be unique due to the unique building dimensions and unique loading. Battery fire risk is evolving due to extraordinary attention being directed at the subject. [53] Likely regulations and best practices need to be developed to address battery fire risks. “Battery safety is a rather complex and sophisticated problem.” [54] Fire risk can vary with battery chemistry. [55] Battery chemistry is a subject of ongoing development and performance assessments. Regulations are likely to be comprehensively required and can include vehicle designs, battery design details, fire suppression systems, egress design, building material selections, ventilation design and emergency access.

Should the SVH corridors be climate controlled and enclosed there will be issues to consider which may impact elements of design or operation that are not easily identified. Particle generation from tire wear is one factor to be considered. Climate control for such a large space will require unique designs. Small changes to materials selection such as windows, paint or illumination can have out-sized cost impacts in such a large building. Climate control can be all corridors or limited only to pedestrian and bicycle lanes creating a comfortable environment for walkers, runners or cyclists.

Conclusion

20. Climate control can be limited to pedestrian and bicycle lanes creating a comfortable environment for walkers, runners or cyclists.

Climate and Health Impacts

The health effects of cycling comprise a combination of exercise benefits, outdoor exposure, pollution exposure, and injury from accidents. Studies indicate that both traditional and Pedelec cycling create benefits for health and well-being. [56] [57] Some of these benefits are due to being outdoors which in the case of enclosed systems can be at the start and end of the trip.

Traffic-related air pollution is a main contributor to unhealthy urban ambient air quality, particularly in areas with high traffic volume. Specifically Isochemic Stroke incidence has been associated with living near to major roadway. [58] Primary prevention strategies to reduce traffic emissions include improving access to alternative transportation options (e.g., transit, rideshare programs, walking, and cycling). [59] Encouraging usage of efficient zero emissions vehicles by constructing arterial SVH within the urban area can encourage zero emissions vehicle usage throughout the city and thereby help contribute to positive health outcomes.

Health risk has been noted for riders of subway systems due to indoor air quality. [60] SVH can be constructed enclosed or open to the air. In either case study and characterization for pollution precursors will be desired.

It has been reported 250 European cities have low emission zones.[61] SVH provide arterial roadway service exclusively for zero emissions modes of transportation. Therefore SVH can be used in these low emission zones or to feed zero emissions vehicles to/from these zones.

SVH enclosure options will affect indoor pollution levels or exposure to outdoor pollution. Those areas fully open to the outdoor environment will be subjected to atmospheric pollution, precipitation and wind. Should parts of the SVH systems be fully enclosed, air intakes can be located either on the roof or the roof of a nearby building, which can reduce pollution exposure for people inside the corridor. [62]

Paris, for reasons of climate and city ambiance, in February 2024 implemented a nuanced policy that is intended to reduce or eliminate automobiles from the city core. [63] Elevated SVH concept could provide high volume small vehicle transportation to/from automobile free zones.

There are some reports of increased accident severity for children riding in light electric vehicles versus other vehicle types. [64] It is anticipated SVH systems will achieved highest level of accident prevention by achieving grade separation for various classes of vehicle and manual modes of travel. However due to increased potential for travel on local streets SVH may on balance increase small vehicle accident incidence rates. Further study is warranted.

A person might expect those cities with more bicycle usage have more bicycle/automobile accidents, but one study says those cities with more bicycles have a lower accident rate. The same study showed pedestrian fatalities are higher in areas of more bicycle usage. [65] The underlying causes of these counter-intuitive results warrants further study.

Conclusion

21. By creating new opportunities for active transport health impacts may be improved.

Availability of Urban Space

Physical interferences between the new highway and existing infrastructure within a city must be avoided or reconciled. One method to effectively demonstrate new infrastructure is to demonstrate installation using less than ideal assumptions. A sketch study (results shown in the following figures) has therefore been prepared assuming installation over a relatively narrow street while demonstrating installation of three classes of lanes: Pedestrian, Class 1 vehicles and Class 3 vehicles. While relocation of electric lines and traffic signals is expected, building interferences are to be avoided.

Figure 2 displays basic sketch study results for a relatively narrow street, Colfax between Pennsylvania and Pearl in Denver, Colorado. The study was performed for a single level highway accommodating 3 types of traffic: Class 1, Class 3 and Pedestrian. Traffic corridors for the study are 12' (3.66 m) square, mounted 24' (7.32 m) over an 80' (24.38 m) wide street.

It was found that three classes of traffic can fit into a single level configuration into the area available above this relatively narrow street utilizing current regulatory structure.

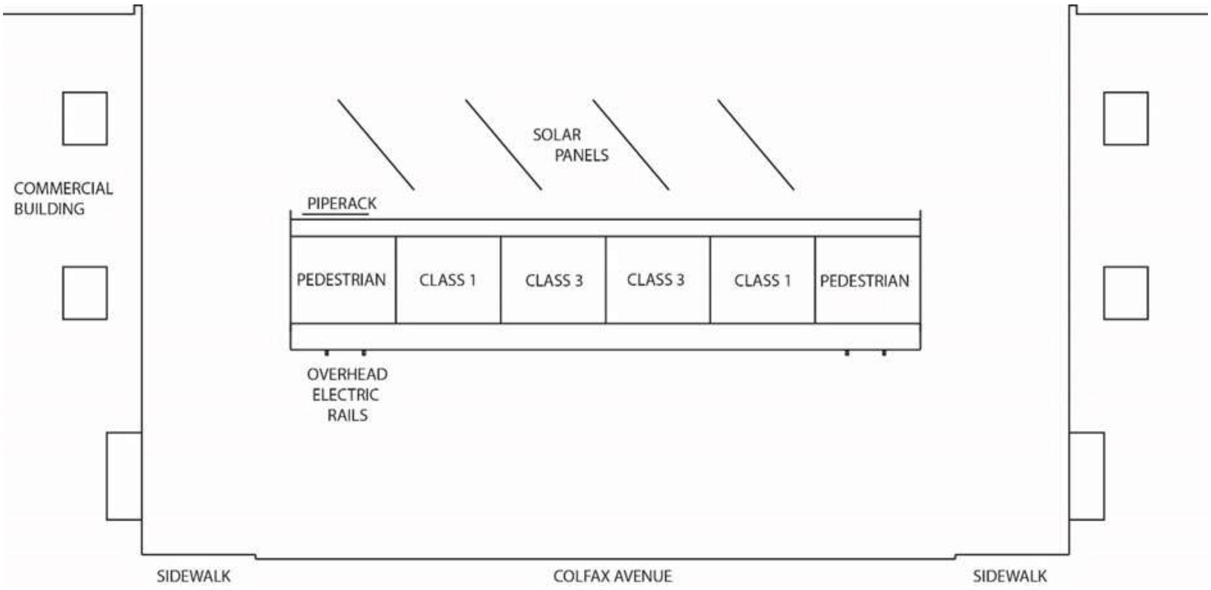


Figure 2: Two vehicle classes and pedestrian lanes over an 80' (24.38 m) wide street

Another key element is fit of intersecting non-stop highways over an intersection of existing roadways. Figure 3 shows two highways and traffic circles can be stacked 24' (7.32 m) over the top of an intersection and maintain a height of less than 100 feet (30.5 m). The fully electric Class 3 traffic circle is located higher than Class 1. Presumably, Class 3 electrics can navigate elevation change better than Class 1 manual bicycles.

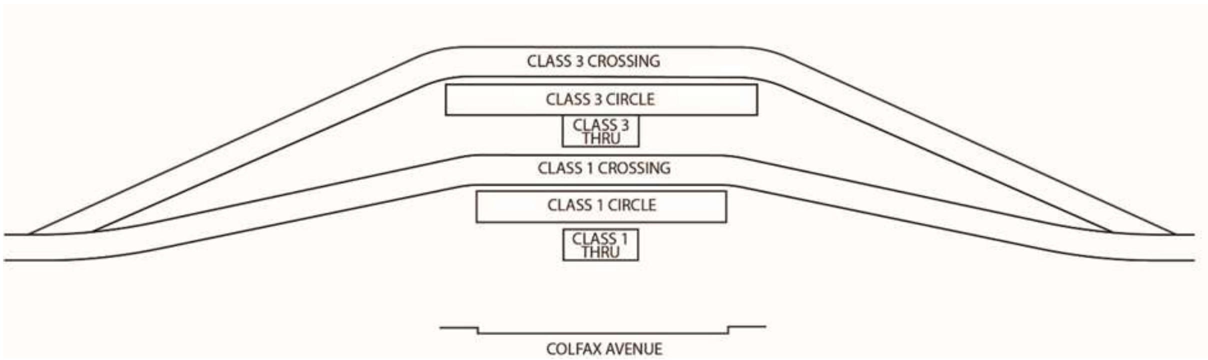


Figure 3: Two vehicle traffic circles over 80' (24.38 m) wide street.

Installing the SVH system over an existing street has therefore been conceptually demonstrated.

Conclusion

22. SVH can provide significant transportation capacity over relatively narrow streets.

SVH Highway Spacing

An important economic factor, therefore feasibility factor, is the required spacing between SVH and ramps. Wider spacing requirement will reduce overall system installation costs by reducing the number of arterial highways and ramps required. Work commuting often takes priority when considering transportation system feasibility. One US study indicates people will travel by bicycle up to 4.36 km (2.7 miles) from a mass transit stop to work location and that result is consistent with other resources. [66] [67] Presumably, that distance could be greater when using electric assisted vehicles. Therefore, since most SVH users will be driving or riding a vehicle, SVH have the potential to mitigate last mile issues associated with mass transit systems for work commuters.
The 4.36 km (2.7 miles) travel capability can also inform of required highway pitch spacing. Conceivably highways could be spaced every 8.72 km (5.4 miles), or greater, and still achieve full coverage for work commuting.

We are likely to find 8.72 km (5.4 miles) highway pitch spacing too wide for many urban uses. However, the wide spacing requirement indicates highway alignment may be flexibly chosen over many city streets without dramatically compromising utility. This flexible alignment can be exploited in the design phase and possibly save significant costs or provide accessibilty benefits than a less flexible requirement.

It is concluded there are many feasible alignments and ramp locations for SVH systems and these can be spaced wider than some transportation infrastructure alternatives due to most users using a vehicle.

Conclusion

23. SVH may be spaced 5+ miles and achieve full coverage for commuters.

24. Wide pitch spacing requirement creates opportunity to optimize roadway alignments.

Vehicle Design

According to Kelly Blue Book electric bicycles outsold electric automobiles in the years 2018 through 2022 in the USA. [68] Therefore vehicles exist in significant quantity for initial stages of operation.
Vehicles can be provided by system operator, some other operator or supplied by system users. In any case costs for smaller, lighter, lower speed vehicles can be less than that for significantly larger vehicles. Considering some of the challenges identified such as fire risk, indoor pollution and potential for fully automated highways, it is likely regulations need to be developed to assure vehicle designs provide uniform and acceptable level of safety.

Full self-driving is seen as a means to increase highway capacity and to reduce accident risk. Detailed studies to limit new Class 3 SVH or select lanes to fully autonomous usage could be undertaken. Wholesale modification of traditional highways for autonomous driving may be infeasible. However, it is prudent to consider if an entirely new highway such as SVH could be designed with novel features such as centralized monitoring/control, communications or fixed highway sensors to facilitate autonomous driving safety.

It will be prudent to consider, while there exists evolving concepts for velomobiles [69] and a UPS delivery van test project [70] , vehicle concepts can continue to evolve. In fact, it is reasonable to postulate SVH installation may encourage vehicle evolution by creating a desire for vehicle designs not yet envisioned. Accommodating these changes may involve lane modifications after the fact.
It is concluded that vehicle exist for SVH systems and design evolution is ongoing.

Conclusion

25. Vehicles exist for SVH and design evolution is ongoing.

Highway Infrastructure Construction

While infrastructure cost estimation for an entirely new structural category is not a trivial undertaking, costs could be relatively predictable since design and construction methods are well known due to occupancy and building height being similar to existing low rise commercial structures. The SVH structures being a public roadway will be designed with modern tools by professional engineers therefore should perform better than typical residential structures in hurricane force winds.[71] Being covered and possibly indoors may prove to be more survivable for extreme emergency access than nearby automobile roadways which are subjected to debris blockage.

Conclusion

26. SVH can be enclosed to help withstand extreme weather events.

The design of the SVH buildings must consider both commercial building codes and bridge design codes. The structure will have cyclic loading from traffic like a bridge, however the vehicle cyclic loads will be less due to lower speeds and less weight. Pedestrian walkway functional design are very similar to a commercial buildings. Some design margin may be cost effective for potential future alterations due to capacity additions or vehicle evolution. Detailed study of the design requirements is likely to require new standards be developed to accommodate unique combination of factors associated with SVH.

Factors which greatly impede a conceptual cost estimate include routing studies, underground characterization, and various technical issues identified by this study. New foundations can interfere with underground utilities. Underground interference mitigation can influence routing and above ground design details. Therefore each locality must be uniquely considered to undertake the design work. Undertaking this design work and reconciling the costs/benefits will require significant expenditure of time and resources.

Detrimental effects of elevated SVH

Elevated highways will present visual challenges in some areas. Especially those areas where the buildings or art installations were built to be viewed at grade from the street. Other areas such as modern high rises are located should provide less challenge for visual impacts. Generally SVH corridors will not exceed that of 5 story building therefore can be classified as low rise structures.

The elevated corridors will shade the sun from impact on nearby buildings or the streets below. The relative sparsity of the highways will minimize these impacts. However likely will be preferred to mitigate these impacts with lighting, route selection and corridor design.

Designs incorporating windows can create sun glare and might contribute in some cases to accidents along the street below. If recognized in the design phase, sun glare can be reduced by adding outside louvers or angling the windows.

One downside of the automobile is social isolation. SVH systems will promote individualized transportation alternatives therefore can contribute to social isolation. Rooftop entertainment venues, or rooftop parks [72] can transform a transportation asset into a destination itself. Encouraging nearby buildings to allow elevated access by transforming parts of the building into commercial space will create destinations. In addition it is possible to consider SVH traffic can be partially or fully routed through building interior space which if used as a destination has the potential to increase social interaction. SVH systems can contribute to social isolation same as the automobile. It is possible to focus on mitigating social isolation versus the automobile, for example by maximizing accessibility.

Auxiliary Uses for Structure

Significant value can be realized by utilizing the SVH structure for urban utilities. Identifiable uses include electrical or fibre-optic cable routing, pipe routing, package conveyors, solar collectors, and exercise corridors. While some of these auxiliary uses could be included at the time of initial build, providing space and load capability for future changes may be economical. Rack mounted utilities can be more easily repaired than underground utilities. Therefore, routing critical utilities over the engineered structure of the SVH can improve resilience to flood or wind events in lieu of overhead or underground routing.

Conclusion

27. SVH can provide alternative routing of critical utilities which can assist recovery from disaster events.

Transportation Equity for Disadvantaged Riders.

Key public groups are keen to see efforts are made to consider transportation equity for disadvantaged riders early in the development cycle. People can be disadvantaged due to lack of education, lower economic status or physiological limitations.

Various studies have attempted to tailor transportation planning around concepts associated with economic transportation equity. Should SVH systems be financed the same as original LAT systems, vehicles will cost less to purchase and operate. Therefore, the user will see less cost to use SVH.

Transportation equity is also a factor in choosing alignments. Providing urban mobility for working class participants can be considered in routing studies. Bicycle routing study methodologies to achieve workable alignments can provide some guidance to help avoid pitfalls. [45] [73]
The combination of understanding the shortcomings of existing transportation systems and the use of big data for routing selection of new highways creates an opportunity to align routing to achieve better economic transportation equity.

Conclusion

28. New highways allows economic transportation equity to be rebalanced.

As an entirely new roadway it is possible to consider the latest automation transportation innovative proposals such as full self driving. Full self driving has been noted as a desirable feature for physiologically disadvantaged users.

Virtually every service or vehicle running on LAT for disadvantaged users can be re-designed for SVH systems providing a high level of individualized service for all disadvantaged users.

Higher speed transportation mode, lower user costs, potential for automation and high capability of providing services for disadvantaged individuals indicates transportation equity may not suffer from SVH installation and could be beneficial to many users.

Transportation Interfaces

Transportation interfaces are those places where modal shifts occur. Below are listed some transportation interfaces.

- SVH pedestrian to street level
- SVH Pedestrian to building on elevated walkway
- SVH Class I to street
- SVH Class I to SVH pedestrian
- SVH Class 3 to street
- SVH Class 3 to SVH pedestrian
- Automobile Arterial to SVH Class 3
- SVH or pedestrian
- SVH to mass transit

Most of these interfaces are discussed in other sections of this article. However some are addressed in sections below.

Automobile Arterial to SVH Class 3 Interface

It is possible to design vehicles that meet both the criteria to travel along the traditional arterials and the SVH system, electric motorcycle is one such vehicle. Micro cars could be developed which also meet both criteria for weight, size and speed. Good speed control along SVH for these faster vehicles would be required to achieve acceptable perceived safety for SVH riders.

SVH to Mass Transit Interface

Rather than SVH systems fully replacing mass transit, there is a potential for long distance rapid mass transit to interface with the more local SVH systems. For automobile centric cities the automobile can travel along at LAT speeds for part of the trip. Class 3 vehicle speed is about ½ LAT speeds. Maximum speed for manual bicycles is about ½ that of Class 3 vehicles. Therefore the range for Class 3 riders is likely to be ½ that of automobiles travelling the LAT system.

This reduced range creates opportunity for trains or busses to provide intermediate range travel to bridge the gap between most small vehicles and the automobile. Thereby providing capacity to the mass transit suppliers and helping keep mass transit relevant. Albeit most relevant for intermediate travel, which is often marketed as express transportation.

Mass transit buses can also help provide capacity to SVH systems by bridging the gap between the urban environment and more remote communities. This can be as the system is built out or permanently configured due to geographic factors such as communities in the San Francisco Bay area of the USA.

SVH to Pedestrian Interface

Small vehicles need parking to transition from highways to pedestrian mode. This parking can be valet, provided by existing parking vendors, automated parking machines, local surface lots, or parking located on the SVH structure. In some cases such as bicycles a valet parking service can be located in nearby buildings elevated at the bicycling levels. Lockers can be provided for folding or regular bicycles as well as Microcars. Parking can be provided near to the corridor or farther away along SVH secondary arterials or collectors. The options can be as varied as people are creative.

In addition to parking, SVH drivers who become pedestrians need convenient access to the city amenities to complete the interface. Stair or elevator towers can facilitate access between SVH structure and the street level. Bridge connections can provide interface between buildings and the SVH structure for pedestrians and/or vehicles. Ramps can be configured to drop into parking structures or lots which allow transitioning into commercial buildings.

Consumer preference for 30 minute commutes has been discussed prior. Other trips may have a 15 minute driving preference. Reduced SVH speed vs automobiles will reduce effective range of SVH vehicles. This reduced range caused by reduced speed can be ameliorated by increasing the design speed of SVH or SVLAT highways. This design speed can be area by area, city by city or country by country decisions.

Conclusion

29. SVH operations could benefit through interfaces with automobile highways and mass transit.

30. Elevated SVH can have walkways to nearby buildings or be located inside buildings.

31. SVH maximum design speed may vary by urban area.

New technology integration

It is important to consider the potential for new technology in an entirely new network of highways. Technological topics recently discussed recently in popular literature include: full self driving, automated lane controls, centralized vehicle control, security, wireless charging and wireless communications.

Automated Roadway

One interesting topic is the potential to automate highways to deliver freight or use for automated mass transit. The highway could be equipped with lane controls that physically excluded entrance to lanes that are in use by automated vehicles. These exclusionary controls can be based on time of day or week thereby allowing automated vehicles exclusive access to select lanes and/or entire roadway. These exclusionary zones can be unidirectional or only in certain areas.

An example of time based exclusions is that certain lanes could be unavailable for human drivers for the low usage hours such as hours of 10:00-11:00, 13:30-14:30, and 21:00 to 5:00 hours. Road users would become accustomed to having more or less capacity at certain times of the day.

Conclusion

32. New highways could allow new technology such as automated highways.

Knowledge gaps

When introducing new systems to an existing urban environment the outcomes can be difficult to fully anticipate. However it has been proposed it is more productive to study likely outcomes of some new technologies rather than to take a laissez-faire” approach by only reacting to outcomes. [74] It is straightforward to discuss physical impacts of SVH and framing likely user behavior in terms of economic needs. Actual changes to travel behavior is complex sometimes resulting in counter-intuitive results.

Framing sustainability in terms of outcomes including induced demand, risky behavior and efficiency improvements can help planners stay in front of desirable and undesirable effects of new paradigms or systems. [75]

Existing literature does not recognize elevated small vehicle highways as an option to be separately analyzed. A good example of this is an article that discusses extensively rationale for adding bicycle highways into an urban area, but no mention is made about the impacts of the elevated option. [76] Therefore the transportation community is operating from a deficit of not considering all possibilities.

Traffic planning uses tools that have been compared to real world conditions both before and after changes. Since elevated SVH represents a technology for which there is no examples to measure, the accuracy of analytical tools is suspect until systems are built and analytical tools tested.

System design alternative

Figure 4 Cutaway view, showing possible one way arrangement of highways mounted 24’ above street level.

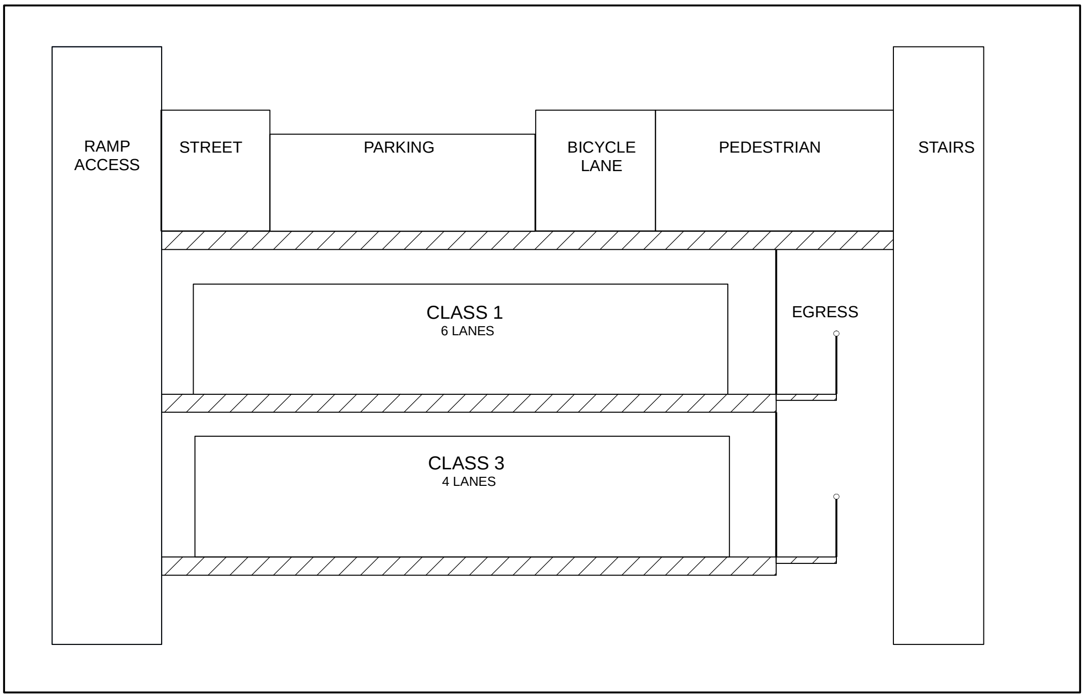


Figure 4 shows a one way arrangement of SVH using established urban automobile roadway design methodologies. This arrangement is three stories deep. The arrangement provides grade separation for four travel modes pedestrian, manual bicycles, Class 1 and Class 3 roadways. The arrangement also provides for modal switching by allowing top floor parking space. A roof can be added to this arrangement and the roof used for parking, entertainment or park land. A chase for stair or elevator access is shown. A ramp access way chase is shown to allow ramps between levels or to other highways. Crossing highways can be above or below the system shown. The street located on the top floor in Figure 4 is a local street exclusively for small 2, 3 and 4 wheeled vehicles.

SVH corridors shown in Figure 4 can be fully or partially enclosed. The stacked design will minimize the effects of atmospheric precipitation especially if the wind is restricted from blowing through. The corridors can be fully enclosed or seasonally enclosed to minimize effects of extreme climate.

Potential High Value Highway Applications

Potential high value applications give insight into how the new infrastructure can provide unique value proposition over other modes, and therefore, to illustrate factors which can create impetus for a first of a kind installation. This list is non-exhaustive. It is expected that where one or more of the high value factors exist the installation could have the highest impact. Ideal locations do not exist but those which can solve more than one major problem can more easily bear the cost of new technology.

Many large cities are built near to waterways which divide parts of the cities. Bridges and tunnels crossing these waterways are often included in congestion pricing schemes.[77] Due to historic shipping capacity needs, cities built near waterways often have high clearance bridges over navigable waters. Bridge construction costs for SVH are expected to be lower for the same volume of traffic than traditional automobile highway systems due to the scaling factors.

Transportation upgrades are often required as a part of the application process for world venues such as the Olympics or World Fair. These upgrades must be undertaken in an existing urban area where cost of subways or other transportation infrastructure is high and construction duration long. SVH alternative solutions could save significant cost, because of the features of above ground steel structures, reduced parking space, low design loads, elevated traffic corridors, wide coverage and high capacity.

In some coastal cities there are concerns with flooding and more so with climate changes or land subsidence. Increased intensity of storms or increases in static water levels have resulted in various proposals to mitigate impacts. An enclosed, elevated transportation network designed in accordance with modern codes and with consideration of recent climate changes could significantly alleviate some of these challenges.

Conclusion

33. Elevated SVH is more resistant to rising water than at grade roadways therefore can provide critical emergency infrastructure in areas prone to flooding or subsidence.

In many cities, transportation networks such as subways and urban LAT highways were installed years ago while the city economy has continued to grow, placing strain on these legacy transportation systems. The costs to upgrade these legacy systems can be prohibitive and often upgrades are limited in scope, unable to significantly improve transportation for more than a few years. [78] SVH may be lower cost in some areas and therefore more capacity may be added for the same expenditure compared to automobile highways. Considering that SVH can have higher speed than some other urban transportation modes in the local area, users may prefer to utilize SVH as a complete replacement for automobile, rail, bus, tram or subway systems in certain localities.

Urban design is a process of reconciling competing priorities for the same land area. Transportation systems access is a primary need and often overrides other needs. SVH has the potential to dramatically reduce surface transportation system demands by using underutilized space above existing transportation corridors. Modern traffic modelling methods can estimate the potential benefits of new technology for the users. Funding traffic modelling design studies, where SVH is an option, for congested areas is likely to reveal and quantify potential SVH benefits.

There is a significant positive correlation between city size and the cost of household travel. The internal mechanism is that city size affects the cost of household travel by increasing spatial distance and traffic congestion. [79] Map inspection indicates there are urban areas that are under-served by automobile highways. Most cities have areas where automobile highway arterials are not constructed, for example Manhattan Island where LAT stop at the island boundaries. In some of these areas adding capacity to underground or surface networks is impractical. These areas seem to be likely candidates to consider for initial installation of elevated SVH systems.

Elevated Roadway Examples

Elevated pathways exclusively for bicycles are known and informally appear to be an increasing trend to solve particular problems. [80] [81] [82] [83] Examples of elevated bikeways exist in Denmark, Germany, China, Netherlands, and USA.

Conclusions

In this article we present introduce the SVH system of elevated urban arterials and address important topics that come to mind either by research or by way of brainstorming. In the introduction we introduce concept that SVH is a scaled down automobile highway with scaled down automobile like vehicles are accommodated. The result is to create a system of urban arterials including SVLAT arterials which are designed to accommodate smaller vehicles excluded from traditional LAT. Arterials are known to carry a majority of urban traffic while having a minority of miles. The definition of an automobile is blurred by considering that in some localities we might prefer to accommodate enclosed vehicles that can navigate both automobile and small vehicle highways. The article also makes the point that small vehicles may not be able to compete in the urban transportation marketplace without arterial roadways similar to automobile arterial roadways.

In the course of discussions many concepts are explored and conclusions drawn. For convenience the most important conclusions are collated and numbered below.

1. Automobile arterial roadways move more capacity per length than other roadways.

2. Small vehicle arterial roadways rare or non-existent.

3. Smaller electric vehicles are more fuel efficient than electric automobiles.

4. By locating SVH in areas of highest congestion the comparative mode speed can be higher for SVH.

5. Non-stop travel through city is more rapid than stop lighted travel at same speed limit.

6. For smaller vehicles it is possible to design more convenient parking access than automobiles.

7. Existing small vehicle regulations may not be the best compromise to maximize utility of SVH.

8. Users prefer perceived safer and more rapid routes.

9. Users prefer grade separation, SVH meets user preference for separated lanes.

10. Throttle controlled non-stop lanes have similar capacity regardless of speed.

11. User costs are lower for smaller vehicle.

12. SVH arterial roadways improve service for otherwise low cost urban travel modes.

13. SVH swept volume per lane is estimated to be 1/6th the volume of LAT systems.

14. Microcars compare 342 kg (754 lbs) with LAT design weight of 39,594 kg (80,000 lbs)

15. Column supported elevated SVH structures use minimal surface land along the corridor.

16. Elevator or stair access impacts land usage at grade.

17. Use of nearby buildings for elevator and stair access can reduce land impacts along the corridor.

18. Elevator or stair access through nearby buildings can provide foot traffic within building or provide easy access to highway nearby.

19. Ramps can be located along corridor or significantly away with elevated feeders.

20. Climate control can be limited to pedestrian and bicycle lanes creating a comfortable environment for walkers, runners or cyclists.

21. By creating new opportunities for active transport health impacts may be improved.

22. SVH can provide significant transportation capacity over relatively narrow streets.

23. SVH may be spaced 5+ miles and achieve full coverage for commuters.

24. Wide pitch spacing requirement creates opportunity to optimize roadway alignments.

25. Vehicles exist for SVH and design evolution is ongoing.

26. SVH can be enclosed to maximize potential to withstand extreme weather events.

27. SVH can provide alternative routing of critical utilities which can assist recovery from disaster events.

28. New highways allows economic transportation equity to be rebalanced.

29. SVH operations could benefit through interfaces with automobile highways and mass transit.

30. Many methods are possible for interfacing between urban environment and SVH.

31. SVH maximum design speed should be studied for different urban area types.

32. New highways could allow new technology such as automated highways.

33. Elevated SVH is more resistant to rising water than at grade roadways therefore can provide critical emergency infrastructure in areas prone to flooding or subsidence.

By combining select logical statements above additional conclusions can be derived to create more value. Figure 5 shows how 1/6th lower society cost for electric bicycles, minimal land usage costs and significant capacity combine to lower cost of urban congestion relief. Derived conclusions are labeled DC with a number following (ie. DC 1). Conclusions by reference have the reference number and conclusions derived from article text are labeled with a C with a number following (ie. C 1).

Figure 5 Bridge costs for SVH are lower per traveller than automobile arterial bridges.

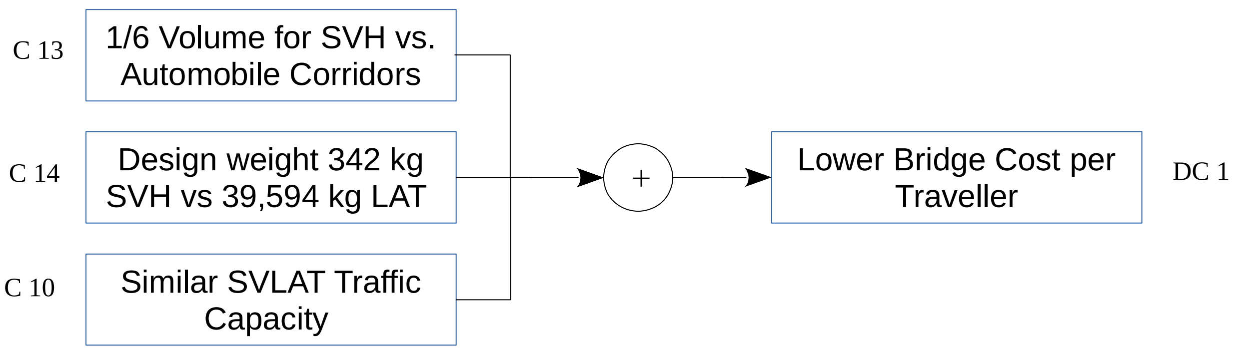


Figure 6 shows how combined design characteristics of smaller volume, lower design weight and similar highway capacity results in lower bridge cost per traveller for SVH vs. automobile roadways.

Figure 6 Shows why people may prefer to use SVH vs alternatives.

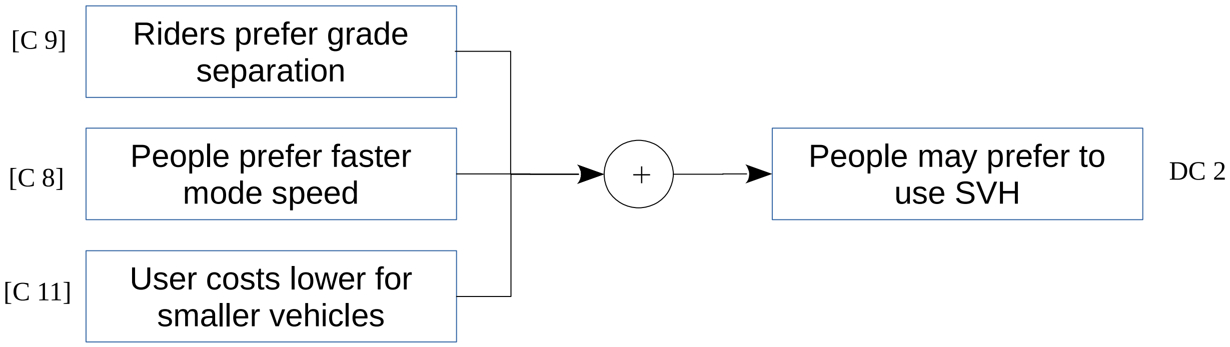


Figure 6 shows how features of SVH can cause users to prefer SVH. Grade separation is preferred, people prefer faster mode speed, and user costs are lower for smaller vehicles combine to support the proposition that SVH could be preferred in urban areas over the automobile.

Figure 7 New highways create new opportunities to upgrade urban travel experience. With improved features a bespoke experience is possible.

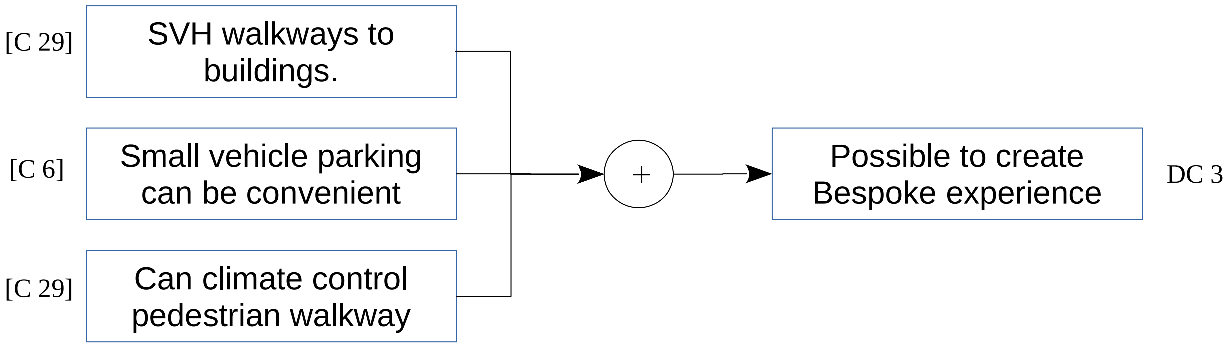


Figure 7 shows how the logical combination of connecting walkways to buildings, providing convenient small vehicle parking and adding climate control to pedestrian walkways can create a bespoke experience for pedestrians along the elevated SVH. This experience can be created in high value locations such as near urban high rises or alongside important entertainment venues.

Figure 8 Small vehicles arterials may transform urban transportation user demand.

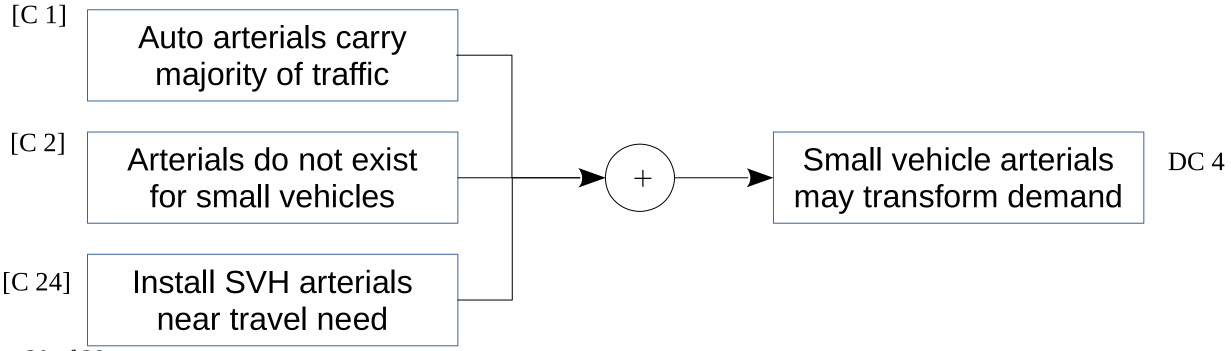


Figure 8 shows logic behind statement that ‘small vehicle arterials may transform (transportation) demand’. The combination of installing arterials near the travel need, adding aterials that do not exist and the fact that automobile arterials carry a disproportionate amount of traffic vs the roadway length creates this potential.

Figure 9 shows logic behind accessibility improvement through installation of elevated SVH.

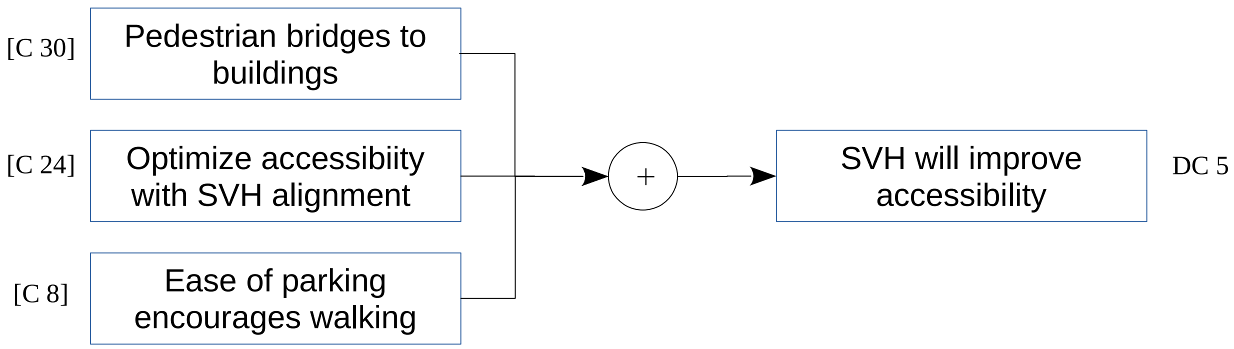


Figure 9 shows factors leading to the conclusion that accessibility will be improved. Pedestrian bridges between pedestrian walkways will create easy access to nearby buildings and businesses. Wide coverage means SVH can be flexibly located to provide the best location for access to business and entertainment venues without compromising overall utility. The ease of parking small vehicles with parking either built into the system, with automated parking options or parking in nearby structures give many options for transitioning from riding to walking mode.

Figure 10 Derived conclusions for potential of users preferring SVH, lower cost of congestion relief and improvements in accessibility combine to justify the final conclusion that research should be funded.

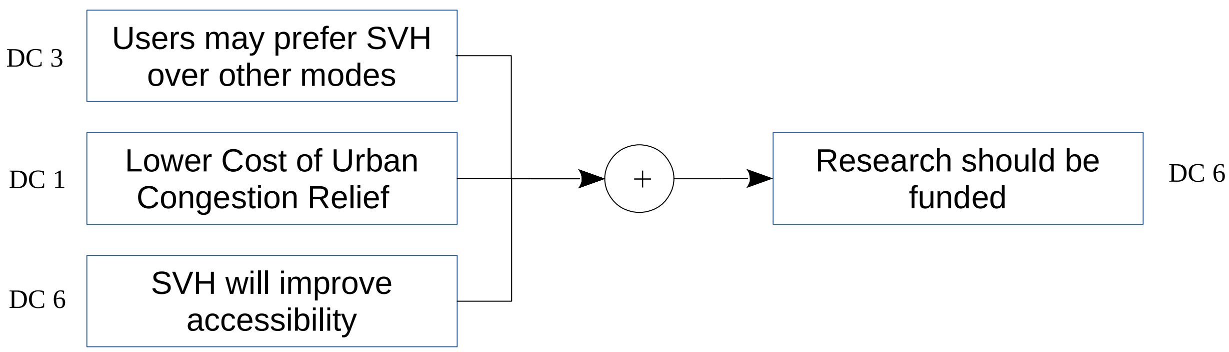


Figure 10 combines potential of three important derived conclusions of user preference, congestion relief and improved accessibility to recommend research funding. Any one of these factors should be sufficient to garner funding.

Recommendation and Summary

This article introduces urban elevated Small Vehicle Highway (SVH) and Small Vehicle Limited Access Thoroughfare (SVLAT) arterial concepts, which can be scaled down urban automobile arterial highways for small electric and human powered vehicles. Likely benefits, challenges, risks, uncertainties, interfaces, evolving technology and feasibility is discussed in detail with the goal to identify starting points for future research. These discussions introduce a myriad of highly complex topics, philosophically reconciles general understanding and illustrate potential debates in order to keep issues from suffering the fate of obscurity.

Transportation networks provide urban arterials for automobiles. However no urban arterials exist for small vehicles which are generally excluded from automobile arterials. The focus of this article is to discuss effects associated with adding elevated SVH which function as small vehicle arterials in the urban core.

Technical feasibility is assured by the simplicity of down scaling an existing system. However feasibility for a particular area or culture can be much more complicated and warrants a more in depth study. Since the concept is novel in academic literature, discussions are limited to philosphical comparisons. Important topics for study of feasibility are addressed including: Average SVH Mode Speed, SVH Design Speed, User Preference, SVLAT system capacity, Costs, Congestion is a Pervasive Condition, Land use, Technological Risk, Climate and Health Impacts, Availability of Urban Space Feasibility, SVH Highway Spacing Feasibility, Highway Infrastructure Construction Feasibility, and Detrimental effects of elevated SVH. These discussions are intended to help transportation planners understand for themselves if or when installation of the proposed highways may be feasible for a particular culture or urban environment. The discussion highlights challenges planners may wish to mitigate.

While the concept of scaling down is simple, there are a daunting number of issues. Every issue ever discussed for urban automobile highway arterials can be discussed for scaled down SVH arterials. Other topics discussed herein include: Auxiliary Uses, Transportation Equity for Disadvantaged Riders, Transportation Interfaces, New technology integration, Automated Roadway, Knowledge gaps, System design alternatives, Potential High Value Highway Applications, Elevated Roadway Examples. Documenting these topics is intended to give an overview of benefits and challenges. Identifying benefits and challenges early can help contribute to risk reduction by encouraging studies to be prioritized and scheduled.

The article develops and documents a large number of conclusions. Some of these conclusions are combined in subsequent logical derivations to illustrate more useful points of view.

The article illustrates a few corridor examples, Figures 2, 3 and 4, these examples follow directly from automobile highway design principals. The first two are constructed to support answering whether scaled down highway can have utility in space constrained urban cities. The third is intended to show how a system can be designed to accommodate user preferences in a less space constrained location where traffic counts may be high. The multi-story structure depicted in Figure 4 provides Class 1, Class 3, parking, manual bicycle, and pedestrian corridors.

Bicycle highways do exist. The most discussed in literature is the Dutch style Bicycle highways. These highways are installed in an area where open space exists between urban areas. The elevated SVH concept is intended to recreate the features and functionality of Dutch style highways in urban environments like that seen in the worlds largest cities. The overall effect of this addition is to provide urban arterial functionality for vehicles that are otherwise generally excluded from urban arterials.

By blurring the definition of an automobile the article reframes the question of what type of vehicle users may prefer for navigating city environments. The future cannot be known but if an open pathway is available for innovation, people will innovate.

The SVH concept is a type of philosophical framing with an exceptional number of outliers. The number of outliers grows when considering how the SVH concept might be practically applied within different cities and cultures. This complexity is as much a barrier as it is an opportunity. It has been philosophized we are in a paradoxical state with our highly evolved transportation networks where people cannot chose alternatives to relieve congestion therefore congestion can only increase. SVH with the large number of permutations can break us out of this paradox for a period of time.

With the far reaching potential for elevated SVH it would be tantamount to intellectual malpractice to not study elevated SVH further. Therefore the recommendation is to fund study of the concepts and further to fund a marque demonstration if no fatal flaw is discovered along the way.

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