**Are Elevated Urban Pedelec Highways Our Future? – A Conceptual Study**

D. T. Price\*

Colorado Springs, United States of America, 80905

\*Corresponding author, email: dtprice21@gmail.com

*A network of elevated non-stop small vehicle limited access thoroughfares (SVLATs) similar in function to existing bicycle highways is proposed for construction above existing transportation corridors. SVLATs can facilitate the movement of pedestrians, traditional bicycles, pedal-assist electric bicycles (pedelecs), and other small battery electric vehicles; which helps create an urban user experience that is currently only available to automobile users on urban highways. The resultant transportation mode could gain significant demand once effectively demonstrated, and this can lead to rapid general deployment. A literature review, capacity estimate, sketch study, a project management-based brainstorming process, and discussion of potential high value applications are presented as a comprehensive conceptual study of SVLAT development. The literature review indicates 1/6th lower societal costs and parking land use compared to those of electric vehicles, promotion of diverse active transportation modes at higher speeds, reduction in congestion, resolution of last mile issues, and integration with elevated malls that can help improve urban accessibility. The developed sketches confirm that adequate space exists above city streets to install SVLATs; further, the capacity estimate indicates that the proposed SVLAT network will add significant transportation capacity without permanently disrupting existing transportation networks. The potential auxiliary benefits of the SVLAT structure, such as electric rails, thermal piping, fiber optic cabling, electric cabling, solar panels, package conveyors, running paths, and/or rooftop entertainment venues, can help create additional value. The ability to enclose the SVLAT creates an opportunity to reduce pollution exposure and mitigate other atmospheric challenges as well. In addition, the construction of SVLATs will probably increase small electric vehicle usage in the surrounding city. Indeed, SVLATs can solve the “last mile” issues of mass transit and provide coverage for work commuting at least 4 km (2.35 miles) from the SVLAT highway, which can thus achieve full coverage with relatively sparse spacing.*

Practical Applications

A new small vehicle limited access thoroughfare (SVLAT) infrastructure is proposed for installation over city streets to provide nonstop traffic flow (highway) lanes for Pedelecs, bicycles, and pedestrians. This conceptual study examines the potential of this new infrastructure to resolve transportation challenges.

This proposed infrastructure can be viewed as an extension of an existing trend towards pedelecs and bicycles.

Societal costs and parking land use for bicycles are 1/6th that of electric automobiles. Further, bicycles can provide a 4 km (2.35 mile) coverage beyond the highway, which can help resolve the “last mile” issues. Moreover, significantly improved access within the urban city core can be expected given the subsequent construction of elevated indoor malls along the infrastructure.

Special cases are identified to illustrate how characteristics of the proposal may create additional value by solving particular problems. Cities constrained by waterways represent a special use case where SVLAT lower design weight and narrower lanes can reduce bridge costs when compared to alternatives. High-capacity entertainment venues are also identified as a special use case that can benefit from high capacity transportation and lower parking costs. Flood prone areas are identified because the elevated highway would be less prone to flooding.

Keywords: electric vehicles; expressway; pedelec; last mile; bicycle; highway; elevated

INTRODUCTION

Alterations to existing urban transportation infrastructure have been analyzed extensively to improve the accommodation of pedestrians, conventional bicycles, and pedal-assist electric bikes (pedelecs). The potential impacts of installing elevated nonstop highways over existing urban transportation corridors to accommodate pedestrians, conventional bicycles, pedelecs, and other small battery electric vehicles (BEVs) are examined in this conceptual study. This structure can realize a zero second-per-mile wait time urban highway, referred to as a small vehicle limited access thoroughfare (SVLAT). The proposed SVLAT can provide a level of urban transportation service that is currently only available to automobile users. Pedestrian and traditional bicycle access to this SVLAT can be optimized using high volume ramps, elevators and bridges. Although potentially revolutionary, this proposal can be viewed as a traditional incremental means to amplify the emerging pedelec trend that simultaneously encourages traditional bicycle and walking modes of travel. The space utilized for the proposed SVLAT is typically government owned and utilized for overhead utilities. The study is as comprehensive as the format allows with the intention to provide a benchmark for future studies and the analysis of this topic.

The design issues discussed in this paper include the optimization of the SVLAT network design parameters for prioritizing the movement of people over freight and for allowing cost-effective installations above city streets. The SVLAT superstructure is expected to be constructed from steel or other lightweight modules like conventional pedestrian walkways. The complex cost–benefit analysis is not performed at this stage as it is beyond the scope of a conceptual study.

#  SVLAT DEVELOPMENT

In this conceptual study, the proposed SVLAT was evaluated from the perspective of interested researchers, planners, and engineering stakeholders. Although other stakeholders are equally important, these three types are particularly well-suited to advance the state-of-the-art in the early stages of development. The objective of this study was to discuss the development of traffic corridors for emergent small e-vehicles such as pedelecs. Although transportation terminology and perspectives vary globally, this study is primarily conducted from a USA lexical and experiential basis because of the cultural experience of the author.

The traffic corridors evaluated in this study were intended as highways for Class 1 and Class 3 compliant vehicles, as described in the USA model legislation authored by the People for Bikes organization. People for Bikes (2022) does not promote the application of their model legislation to devices that do not resemble traditional bicycles; however, in this paper, these classes were used to refer to “any device that can safely coexist on the same pathway with a traditional bicycle-type vehicle.” Whether the transportation market for BEV SVLATs will consist primarily of Class 1 vehicles, Class 3 vehicles, or some combination of the two, is yet to be determined and can be expected to change over time. In addition, whether different corridors will be more suitable for pedestrian, traditional bicycle, Class 1 vehicles, and/or Class 3 vehicles continues to remain unclear. The study was developed to accommodate separate lanes for both Class 1 and Class 3 vehicle classes and pedestrians to evaluate the most complex case.

Class 1 and Class 3 BEVs are expected to require physical separation for safety, and therefore, separate Class 3 lanes are provided (though this does not preclude the use of these lanes by vehicles that can navigate higher speed transportation networks or heavier freight vehicles) and commutation between Class 1 lanes and pedestrian lanes is proposed using bollards to provide a physical yet porous barrier, which will allow users to walk their Class 1 vehicles along the pedestrian walkway to access parking and elevators. Traditional bicycles are accommodated in the Class 1 lanes, which provides the riders with a non-stop pedaling experience without requiring them to cope with cross winds or other adverse weather conditions. Finally, continuous pedestrian lanes allow users to walk nonstop without crossing streets, and it facilitates the construction/use of bridges from pedestrian corridors in nearby buildings to effectively realize an elevated indoor mall along the length of the SVLAT network. In some areas, the SVLAT will likely be enclosed and climate conditioned.

To develop the proposed SVLAT in this study, a literature review was first conducted by building on current understanding and addressing the relevant topics of interest to calibrate the discussion to existing research. The results of the literature review will help ameliorate the hypothetical nature of introducing an entirely new transportation system and underpin reasons why the proposed development of urban SVLATs can receive further consideration. The discussion also focused on factors that can impede progress, such as the indoor pollution caused by the tire wear and the previously observed rising accident rates for small BEVs, as an early identification of challenges and opportunities that can speed overall development.

Next, the practicality of the proposed SVLAT system was addressed by answering the critical question “Can a high-capacity SVLAT fit into the space above a congested commercial street?” Thus, sketches were developed to demonstrate the availability of installation space to fit the envisioned SVLAT. One approach to conservatively estimate the ability to fit a structure within an available space is to illustrate an unideal set of circumstances; in this study, this was accomplished by selecting a single narrow street and illustrating the installation of multiple classes of the SVLATs above. If we accept that there is adequate space, future efforts can shift to investigating how best to estimate the balance between the costs and benefits of SVLAT construction.

Furthermore, estimates must be made of technologies that do not yet exist to demonstrate the practicality of SVLATs. The parameters or performance of a new technology can be estimated using “rules of thumb,” which were applied in this study to develop a rudimentary and seemingly conservative capacity estimate. Indeed, capacity constitutes a critical economic consideration, understanding how congestion can be relieved, and overall costs shared among a large number users.

This conceptual study was consistent with the modern scoping level project management process and it involved brainstorming a list of various potential options, risks, and benefits of the proposed SVLAT based on experience and conjectured innovations. Identifying such factors as early as possible can help facilitate work planning and criticism. This recommended project management process also reduces the possibility of thoughts being overlooked or not being considered in a timely manner. Most items on this list are not discussed in the existing literature because of the novelty of the proposal. This brainstorming process is ongoing and will expand as the development team grows, and therefore, there likely remain risks or opportunities that are yet to be recognized.

Finally, a section titled “Potential High Value Applications” discusses transportation problems that can be alleviated by characteristics inherent to the new infrastructure. These problems include elevating highways over flood prone areas, providing high-capacity transit to entertainment venues, and relieving congestion when urban areas are separated by significant bodies of water. These problem-solving applications can lead to a wider adoption if the system is extended from a problem solution area.

#  DISCUSSIONS

This section discusses the reviewed literature, provides sketches for demonstrating the practicality of the SVLAT, suggests a highway capacity estimate, presents a brainstorming list detailing potential risks/opportunities, and finally presents potential high-value applications

##  Literature review

A literature review of research on e-bikes, bicycle highways, accessibility, and associated topics was conducted to uncover known perspectives on this emerging transportation sector. The search results were used to develop topics for discussion, addressed in turn below; many of these topics are related to issues of accessibility addressed in subsequent discussions.

*Current climate of transportation morphology*

Changes in transportation systems have been likened to a morphological process by which important geneses of change (i.e., individual decisions) are obscured by history (Vance 1990). Owing to the present focus on climate impacts and technological advances, transportation systems appear to be undergoing a major change from fossil fuel powered vehicles to BEVs (Crabtree 2019); however, some have reasonably questioned the sustainability of this BEV trend (Machedon-Pisu and Borza 2020d). Many predictions of when automobile manufacturers will no longer sell fossil fuel powered automobiles have been presented (Domoneske 2021). This likely imminent shift to electric vehicles creates a unique set of circumstances that can allow our transportation networks to change in unexpected ways. Indeed, the current shift to BEVs is likely to change economic relationships that can be re-balanced by new infrastructure design. Lowering costs has been a key driver of transportation changes in the past; for example, horse and carriage maintenance was more expensive than a Ford Model T maintenance, which helped spur automobile adoption (Vance 1990). Societal costs for e-bikes are as little as one sixth of those for electric cars (Gössling and Choi 2015), which is sufficiently significant to propose a re-design of our transportation infrastructure to better accommodate this lower-cost vehicular mode.

*Potential applicability of SVLAT networks*

Although the proposed SVLAT system is likely to provide utility for sprawling, congested automobile-centric cities such as those found in the USA and Australia, there is likely significant application potential in many other parts of the world as well, especially where motor scooters presently dominate the transportation mode. Furthermore, the high-level service provided by the proposed SVLAT is likely to draw users from other transportation modes (Rayaprolu et al. 2020, Hallberg et al. 2021). Overall, the proposed SVLAT represents a mobility option that offers enhanced accessibility in areas of the urban core where accessibility has historically been a significant challenge.

*Accessibility encouraged by design for active transportation modes*

In line with the modern transportation design philosophy of maximizing accessibility for active forms of travel, the preliminary design of the proposed SVLAT should provide physical accessibility by incorporating features that encourage pedestrian and traditional bicycle traffic. Providing economic accessibility for the user can be as simple as ensuring vehicle affordability or as complex as choosing where bicycle paths are located (Parker et al. 2021). Furthermore, increasing accessibility by increasing the speed of various active modes of transportation can contribute to sustainability (Capasso Da Silva et al. 2020). Promoting active modes of cycling or walking in cities designed for automobiles continues to remain challenging; however, this challenge can be met by cycling in 30-min cities (Both et al. 2020). In addition, electric bicycles have been identified as an emerging transportation mode that provides the potential to improve sustainability (Rérat 2021). Innovation and development of pedelecs is ongoing, and the UPS shipping company has even tested a small, enclosed pedelec cargo delivery van in New York City designed to utilize existing bicycle lanes and thus improve freight accessibility in congested areas (DaSilva 2022).

*Significant new transportation capacity can help relieve congestion*

Traffic congestion has been a problem since the 1920s in the USA (Vance 1990), and it is currently a major growing economic problem throughout the world (Busari et al. 2021). This issue is likely to aggravate with the emerging automated vehicle technology (Cohen and Cavoli 2019). Travel times can be reduced and accessibility can be improved if significant transportation capacity can be made available in the most congested areas. A traditional approach to resolving system congestion has been to increase capacity (Vance 1990); thus, significantly increasing transportation capacity *above* city streets can dramatically help relieve congestion in local areas.

*Similarities to European bicycle highways*

The literature contains a great deal of discussion detailing newer dedicated transportation systems that can accommodate the small BEV trend; bicycle highways are one such example (Cabral Dias and Gomes Ribeiro 2021, Rich et al. 2021). Modeling indicates that the usage of highways carrying combined conventional and electric bicycle traffic would be better than those of conventional bicycle-only highways (Hallberg et al. 2021). However, Dutch-style bicycle highways can only be installed in areas where adequate land is available to accommodate additional lanes into existing transportation corridors; installing elevated SVLATs over city streets eliminates this constraint.

*Improvements in transportation speed for targeted modes*

Transportation mode speed is a major factor affecting transportation system sustainability (Mulrow and Derrible 2020) and user choice. In cities designed around the automobile, there is an inherent assumption of a high associated automobile modal speed (Vance 1990). In such cities, installing an SVLAT network for small BEVs can enable a higher mode speed for these emergent vehicle types; thus, small BEVs can offer the best possible competition for the automobile. Indeed, this new infrastructure will likely increase utilization partly at the expense of other transit modes by increasing the average mode speed (Hallberg et al. 2021). Pedestrians will be able to walk without navigating crosswalks or contending with adverse weather conditions, which will encourage walking (Southworth 2005). Further, the proposed infrastructure will improve the opportunity for users of bicycles and small BEVs to move across a broad area on and off the SVLAT without changing modes; this increase in accessibility can be expected to increase cycling (Saghapour et al. 2019) and promote walking, which will help fulfill the accessibility design goal of more trips being completed using bicycles or by pedestrians.

*New SVLATs can be a tool for traffic calming*

Traffic calming (Rayaprolu et al. 2020, Zalewski et al. 2021) is often used to improve accessibility for pedestrians and bicycles rather than automobiles. However, this traffic will likely also need to be calmed in some areas if the volume of small BEVs, traditional bicycles, and pedestrians increase. The innovation of small BEV SVLATs can be used as a tool to facilitate calming in urban environments by encouraging traffic to bypass the calmed areas.

*Health effects*

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 benefit health and well-being (Sundfør and Fyhri 2017, Leyland et al. 2019). Recent accident data suggest that the occurrence of cycling accidents have increased in US cities (Jaffe 2019). One Israeli study indicated that road accident injuries for children in small BEVs are more severe than those in other similar vehicles, which necessitates adjustments in accident and injury prevention strategies (Botton et al. 2021). Another study indicated that the increased usage of Copenhagen cycle highways resulted in lower cost–benefit ratios because of the increased accident rates (Rich et al. 2021). Thus, more research is required for understanding and mitigating accident precursors.

Furthermore, enclosed SVLATs can be potentially designed to have fewer negative health effects than conventional roadways because appropriate building air intake design has been shown to mitigate urban pollutant intake (Li and Gernand 2019). Research into particulate generation caused by tire wear and the minimization of exposure through ventilation design and regulation can significantly ameliorate the associated threat to user health because the generation of particulates within an enclosed roadway can result in pollutant exposure (Roy et al. 2022).

*Transportation challenges are ubiquitous*

Transportation challenges are an international problem that afflict developed and developing countries alike (Busari et al. 2021). Previous studies have determined that traffic is increasing faster than economic activity (Goldman and Gorham 2006). Furthermore, many developing countries rely heavily on two-wheeled vehicle transportation; for example, Ghana exhibits a 78% usage of motorcycles (Konkor 2021). It is further concluded that separate lanes should be provided for bicyclists to reduce accidents and improve safety.

*Velomobiles may be suitable for use on SVLATs*

Although the use of bicycles, which exposes riders to the weather, may be untenable for some, efficient aerodynamically shaped three-to-four wheeled Class 1 pedal assisted vehicles—i.e., velomobiles (Ferrari et al. 2013)—could be equipped with excellent accident protection, climate control, passenger seating, and/or package storage to facilitate the adoption of small vehicle transportation modes by more users.

*Last mile issues*

The “last mile” challenge for urban mass transit is an ongoing topic of discussion and research (Kåresdotter et al. 2022) connected to social equity (Zuo et al. 2020). In one USA study, traditional bicycles are found to enable 4.36 km (2.7 miles) of travel distance from a transit stop to the destination compared to the 1.3 km (0.80 miles) achieved by walking (Zuo et al. 2020). The higher speed of pedelecs can extend this distance further. Extrapolating these results to the proposed SVLAT indicates that elevated Class 1 SVLAT lanes could be networked a minimum of 8.7 km (5.4 miles) apart to achieve full coverage for work commuting. A wider SVLAT spacing can result in lower costs to provide coverage in some areas because of the fixed infrastructure costs per kilometer. For example, Midtown Manhattan, New York USA is only 3.2 km (2.0 miles) from the Hudson River to the East River according to Google Maps, which would allow full coverage of the Midtown Manhattan area if only one elevated SVLAT system was centrally located parallel to the two rivers in Midtown Manhattan.

##  Example illustrations

The potential of an innovation can be highlighted by demonstrating how it solves a problem in less-than-ideal circumstances. Therefore, one of the narrowest corridors above the longest commercial street in the USA—Colfax Avenue between Pennsylvania and Pearl streets in Denver, Colorado—is employed for the discussion below to illustrate the feasibility of installing non-stop SVLATs over existing transportation corridors. This corridor was selected because of its proximity to the author and its historical significance in the area.

Figure 1 shows a sketch of a non-stop SVLAT for Class 1 and Class 3 vehicles over Colfax Avenue along the existing buildings between Pennsylvania and Pearl streets. A 7.32 m (24 ft) vehicle headroom clearance is shown for the street below, which is 24.38 m (80 ft) wide. The depicted SVLAT is 21.95 m (72 ft) wide and accommodates six separate 3.66 m (12 ft) wide unidirectional corridors for Class 1, Class 3, and pedestrian usage; therefore, each corridor should be able to accommodate up to two lanes. Further, the sketch depicts placement options for solar panels, utility chases, and overhead electric rails. The proposed layout demonstrates that there is indeed sufficient space to install a two-class single level SVLAT over a relatively narrow section of a busy commercial street.



Furthermore, lanes can shift to the left or right, splitting the SVLAT to allow ramps, emergency access, or elevators. In addition, the elevation of the SVLAT can be moved up or down to accommodate intersections or geography. The longitudinal spacing of the ramps will be dictated by safety considerations; however, they can likely be closer than that of typical automobile highway ramps or subway stops, which can improve accessibility along the roadway compared to traditional automobiles or subway systems.

A flat roof over the SVLAT allows space for pipe and cable trays, which enables the distribution of various utilities and solar panels, or for the construction of entertainment venues. Running paths and small package freight conveyors can be incorporated into the structure. The economic potential of these services is unknown but likely to be significant. The potential for overhead electric rails underneath the structure should be noted because these can be used to power trolleys or trucks or to provide battery recharging.

Figure 2 depicts an elevation sketch that shows the feasibility of installing two stacked roundabouts above a 24.38 m (80 ft) wide street; the same street width is shown in Figure 1. The intersection shows one highway in line with the sketch and one crossing at a right angle; this configuration requires lanes to traverse above and below the roundabouts. The connecting ramps are not shown; in this configuration, only left turns need to enter the circle. A Class 1 traffic circle with a diameter of 24.38 m (80 ft) is shown at the lower level with a gently sloped ramp configured to accommodate vehicles such as traditional bicycles that cannot easily navigate more aggressive ramps. A larger diameter Class 3 roundabout is located atop to accommodate more powerful motors that can easily navigate steeper ramps. The envisioned intersection is approximately 30.48 m (100 ft) high to provide a consistent 7.32 m (24 ft) clearance underneath. Therefore, this sketch demonstrates the ability to install a nonstop SVLAT intersection above a city street.



##  Estimating SVLAT capacity

To estimate the maximum capacity of the proposed SVLAT, the “two second rule” (Colbourn et al. 1978) is used to teach drivers appropriate roadway spacing, and it provides a seemingly conservative insight because this recommended spacing is directly proportional to the vehicle speed.

For Class 1 vehicles (25 km/h; 2 s spacing)

For Class 3 vehicles (45 km/h, 2 s spacing)

A single level of the SVLAT shown in Figure 1 with one Class 1 and one Class 3 vehicle lane in each direction (four total lanes) can be anticipated to provide a capacity of 4 × 1800 = 7200 vehicles per hour in both directions. Two additional transportation levels can be added to the SVLAT with pre-planning; this results in 3 levels, with a total capacity of 3 × 7200 = 21,600 vehicles per hour. The peak subway station usage of 1000–5000 passengers per hour has been reported in New York City (Chen et al. 2009), which is one of the busiest subway systems in the world. Thus, each station handles up to 25% of the estimated example SVLAT capacity (21,600 passengers per hour). This simple calculation and comparison demonstrate that an SVLAT over a congested city street can significantly add to the urban transportation capacity.

This calculation method illustrates an important point. For the first approximation, limited access thoroughfare (LAT) capacity is independent of the vehicle speed. Therefore, the slower SVLAT highway lanes will have similar capacities of automobile LAT highway lanes.

Moreover, the SVLAT systems will have significantly lower design loads and narrower lane requirements than equivalent automobile LAT systems. The lower design load will result in lower costs per unit area; with narrower lanes resulting in less area, the required costs will be lower than the traditional LAT systems for an equivalent routing.

##  Risk and opportunity brainstorm list

Traditional LAT systems are designed to routinely accommodate large trucks with design loads more than 30,000 kg (66,000 lbs). The SVLAT systems are to be designed for two oversized people per vehicle plus vehicle weight approximately 300 kg (660 lbs). This 100-fold reduction in design weight will reduce construction costs compared to those of equivalent LAT systems.

Nonstop SVLATs can be considered a viable alternative to subways, either as new, replacement, or auxiliary infrastructure.

Accessibility to second and third floor adjacent real estate can be enhanced potentially by providing elevated pedestrian walkways spanning from the pedestrian corridor to adjacent buildings. This improved accessibility to underutilized commercial spaces can promote walking along the walkways.

Separating Class 1 travel lanes from pedestrian lanes with bollards can facilitate mode changes from the bicycle to the pedestrian, and vice versa, by allowing cyclists to walk bicycles to racks or parking spots when near a destination. This convenient and ubiquitous intermodal switching can promote accessibility to those areas best or only accessible by walking.

Drop-in screw-down panels for SVLAT surfaces can allow for rapid surface renewal.

Research into reduced parking costs for smaller vehicles can help justify SVLAT infrastructure in some locations.

Designing the SVLAT infrastructure to allow additional traffic level(s) to be added above the initial corridor can allow for the expansion or re-balancing capacity without interrupting the SVLAT below.

A potential optimization of the SVLAT concept may be to laterally space Class 3 highways such that they are wider than Class 1 highways, it is possible to locate Class 3 lanes with every other Class 1 lane.

A possible development strategy could be to develop Class 1 SVLATs first because Class 3 vehicles are currently routed through existing roadways; if future conditions warrant, Class 3 SVLATs could then be installed above.

Central heating and cooling district expansion can be accommodated by including piping chases into the SVLAT structure. The cost of updating local fiber optic networks can be lowered by

providing a convenient location for fiber optic cables in the SVLAT structure.

The SVLAT structure roof can provide space for entertainment venues atop. Further,

indoor running paths can be incorporated into the structure.

Enclosing SVLATs can enable climate control and help ameliorate the effects of adverse weather.

The elevated SVLATs can help alleviate the effects of flooding on infrastructure by routing traffic above the flood level.

Engineered structures can be designed to withstand known environmental hazards, and they facilitate highly reliable transportation in emergencies.

 The cost to provide full city coverage should be a significant subject of multiple optimization efforts.

The elevated noise emissions from small, low speed BEVs should be minimal but studied in the future.

Lanes can be routed into buildings or entertainment venues to provide access as well as a steady stream of potential customers.

Routing lanes alongside or inside urban malls creates potential development opportunities.

Small package delivery services can be collocated along the SVLAT, which creates convenient access to the lanes for the delivery of packages or food.

Small BEV taxis can enhance mobility for handicapped users or others with special transportation needs.

Further, vehicle designs presently unimaginable are likely to emerge once the proposed SVLATs are constructed.

The appearance of SVLAT structures can range from utilitarian designs to sophisticated architectural designs based on the needs and objectives of the area.

 Service to transportation hubs such as regional bus stations, regional train stations, and airports will create multi-modal transportation opportunities.

Research into the design and accommodation of freight vehicles capable of moving standard pallets is likely to be beneficial. The automated vehicles can easily move along the SVLAT, and a convoy of such vehicles could move large quantities of freight during periods of low usage.

The design of buses, taxis, or automated vehicles to best accommodate handicapped users on the SVLAT is likely to be encouraged.

Further, the use of a folding pedelec will allow complete transportation from a residential closet to an office cubical. Although

the design load for a pedestrian thoroughfare is like the load applied by a single automobile, the design of new emergency vehicles to optimally navigate these and similar SVLATs is likely.

Select lanes can be designed to accommodate heavier freight-laden vehicles

, and the space above city streets is government owned and often minimally utilized for overhead utilities.

If the construction of an SVLAT improves the accessibility of the urban region, the tax base can increase, which can contribute significantly to local government economics.

The SVLAT has novel occupancy, egress, fuel hazards, and structure, and therefore, significant effort will be required to develop fire safety plans and regulations if the envisioned SVLAT is enclosed. A combination of vehicle regulations, active fire suppression, emergency egress/access, isolation doors, alarms, structural protection, special vehicles, and monitoring can be expected to result in the most cost-effective solution.

##  Potential High Value Applications

Installing SVLAT highways elevated over existing transportation networks can be used as a tool to solve specific transit problems. The most likely near-term applications will utilize the unique characteristics of the SVLAT proposal to create exceptional value. Some unique circumstances that can create additional value by helping solve local problems are presented below.

*Relieving congestion crossing New York City rivers*

Bridges or tunnels can be operated easily at or above capacity for an extended length of time because of the cost of spanning wide navigable rivers (Deka 2021). Reducing the cost of bridges over these waterways can allow the addition of lower cost transportation capacities. However, simply constructing a bridge without highways to feed traffic can result in sub-optimal traffic flows over the bridge. Therefore, SVLAT can be used to feed traffic to bridges while serving local area traffic needs and facilitating economical nonstop high-capacity traffic flows over the waterway.

Conceptually, some New York City traffic congestion can be relieved by a Class 1 pedelec bridge over the Hudson River, and two crossing SVLATs for traffic distribution. The westernmost SVLAT can run within 4.35 km (2.7 miles) of the Hudson River west bank in New Jersey. The second SLVAT would run along the middle of the Manhattan Island. These crossing SVLATs would likely feed sufficient traffic if they are approximately 8.3 km (5 miles) long each for an approximate total SVLAT length of 25 km (15 miles). At 25 km/h (15 mph), it would take 30 min to traverse to the farthest distance of 12.5 km (7.5 miles) from Manhattan Island to New Jersey on the described SVLAT.

*Providing storm-resilient transportation in a vacation-oriented beach community while enhancing active transportation modes*

Some coastal or river delta areas suffer a combination of subsidence and increased water levels. Constructing elevated SVLAT can allow traffic to flow unimpeded by high water levels. New structures can be designed for worst case storm events, and therefore, it can potentially survive adverse weather events such as hurricanes providing transportation capacity immediately after the storm passes.

An SLVAT over the top of a main street along a beach community can enhance ocean views for cyclists. The active forms of transportation can be a preferred mode of transportation growth for these space congested communities by reducing overall land use requirements and promoting recreational exercise.

*Improving ambiance in congested mountain towns*

Some mountain communities suffer from congestion, high pollution from internal combustion engines, problems with parking, street noise, snow, and lack of mass transit options. Elevated enclosed SVLATs can achieve high-capacity transportation while minimizing the effects of weather and noise emissions to the surrounding community.

Elevated SLVAT in mountain communities can be designed to maximize views while providing easy access to entertainment venues such as ski lifts or restaurants. Because of the small size of many mountain communities and the need to carry ski gear, the SLVAT needs to be optimized for pedestrians and buses. The buses could be self-driving and they could carry skiers directly from their hotel to their destinations.

*Providing transportation access for “one off” entertainment events such as the Olympics or the World Fair*

Some entertainment venues such as Olympic events require significant new additions to transportation infrastructure. The installation of SVLAT can provide high-capacity transportation from a wide area while not interrupting existing networks. In one case study, one car parking spot is replaced by six bicycle parking spots (Lee 2021). A reduction in parking land use can significantly improve economics in some highly congested areas. Elevated pedestrian access along the SVLAT can allow the convenient routing of pedestrians over existing transportation features. Although the initial installation can be designed to best serve the event, later additions can help facilitate integration with the surrounding urban area transportation requirements.

#  CONCLUSIONS AND RECOMMENDATIONS

This study demonstrated the feasibility of constructing SVLATs in modern cities by routing them over city streets and other transportation corridors. The intersecting traffic can be accommodated with stacked traffic circles to facilitate the left turns. Nonstop urban transportation corridors for BEVs, bicycles, and pedestrians create a level of service that is currently only available to the automobile user. Accessibility options that enable the creation of elevated indoor malls next to SVLATs can result in an excellent, if not bespoke, level of service that exceeds the automobile. Such facilities can provide a nearby travel destination and result in significant economic development, which increases the local property values. Moreover, the economic value of the auxiliary services can be enabled by an SVLAT structure, which includes overhead electric rails, thermal piping, electrical and fiber optic cables, small package conveyors, and entertainment venues, can significantly improve the economic case for adoption. Further, covering the SVLAT system creates an opportunity to control the atmosphere within, which helps potentially reduces the users’ exposure to pollution. Finally, while the last mile issues limit the economic impact of traditional mass transit systems, the proposed SVLAT has the potential to provide access beyond the last mile. Limited guidance already exists in the literature for traditional bicycle transit network configuration, which indicates that manual bicycle SVLAT spacing every approximately 8 km (4.7 miles) can result in full coverage for work commuting. This distance likely represents the minimum required SVLAT spacing to provide work commuting because small BEVs can perform longer distance travel over the same amount of time.

Studies investigating the currently increasing accident rate for small BEVs will likely require mitigation, without mitigation could be a future stumbling block. Such efforts should include vehicle design, education, laws, law enforcement, SVLAT infrastructure design, and existing infrastructure improvements. Emphasis is also required on children's safety. The emerging class of vehicles known as velomobiles represents a notable potential technology that can help improve safety. In addition, research into SVLAT infrastructure costs and associated benefits will likely help guide investment decisions because the cost–benefit calculations employ past costs and factored benefits. Indeed, considering the low cost of small BEV's reported in the literature’s future work will likely justify some, if not all costs of SVLATs. A compelling investment case can be made by coupling cost offsets with a high level of service afforded by SVLATs; this can result in rapid adoption upon physical demonstration. Moreover, future research should focus on risk and reward evaluations of SVLAT networks: risks identified in this study include rising BEV accident rates, indoor pollution caused by BEV tires, SVLAT infrastructure costs, need to determine effects on local real estate prices, preferred SVLAT routing, preliminary structural design, underground interference, and projected ridership; further, the rewards include improved accessibility, value of auxiliary services, reduced congestion, potential cost savings for users, creation of large scale elevated indoor malls, and densification of the urban core.

This conceptual study showed that an appropriately designed relatively sparse SVLAT network can be expected to provide significant additional transportation capacity that rivals high-capacity subway systems, facilitates bespoke accessibility to commercial areas, and realizes zero second wait times on the SVLAT network. Additionally it is found societal costs for small BEV's and parking land use requirements are 1/6th that of traditional automobiles. Given this unique combination of characteristics, SVLATs are likely to be economically compelling in some urban areas.

**References**

Both, A., L. Gunn, C. Higgs, M. Davern, A. Jafari, C. Boulange, and B. Giles-Corti. 2020. “Achieving ‘active’ 30 minute cities: How feasible is it to reach work within 30 minutes using active transport modes?” *ISPRS* *Int. J. Geo-Inf.,* 11 (1). https://doi.org/10.3390/ijgi11010058*.*

Botton, I. N., D. Takagi, A. Shlez, H. Yechiam, and E. Rosenbloom*.* 2021. “Road accidents in children involving light electric vehicles cause more severe injuries than other similar vehicles.” *Eur. J. Pediatr.*, 180 (11), 3255–3263. https://doi.org/10.1007/s00431-021-04089-w.

Busari, A. A., R. T. Loto, S. O. Ajayi, O. Odunlami, A. Folake, O. Kehinde, and O. Olawuyi. 2021. “Ameliorating urban traffic congestion for sustainable transportation.” *IOP Conf. Ser.: Mater. Sci. Eng.*, 1107 (1), 012102. https://doi.org/10.1088/1757-899X/1107/1/012102.

Cabral Dias, G. J., and P. J. Gomes Ribeiro*.* 2021. “Cycle highways: A new concept of infrastructure.” *Eur. Plan. Stud.*, 29 (6), 1003–1020. https://doi.org/10.1080/09654313.2020.1752154.

Capasso Da Silva, D. C., D. A. King, and S. Lemar*.* 2020. “Accessibility in practice: 20-minute city as a sustainability planning goal.” *Sustainability*, 12 (1), 129. https://doi.org/10.3390/su12010129.

Chen, C., J. Chen, and J. Barry. 2009. “Diurnal pattern of transit ridership: A case study of the New York City subway system.” *J. Transp. Geogr.*, 17 (3), 176–186. https://doi.org/10.1016/j.jtrangeo.2008.09.002.

Cohen, T., and C. Cavoli*.* 2019. “Automated Vehicles: Exploring possible consequences of government (non)intervention for congestion and accessibility.” *Transp. Rev.*, 39 (1), 129–151. https://doi.org/10.1080/01441647.2018.1524401.

Colbourn, C. J., I. D. Brown, and A. K. Copeman. 1978. “Drivers’ judgments of safe distances in vehicle following.” *Hum. Factors,* 20 (1), 1–11. https://doi.org/10.1177/001872087802000101.

Crabtree, G.2019. “The coming electric vehicle transformation.” *Science*, 366 (6464), 422–424. https://doi.org/10.1126/science.aax0704.

DaSilva, S. 2022. “UPS is testing pedal-powered delivery bike-van-thingies in NYC.” *Jalopnik*, 12:30 pm.

Deka, D. and J. Carnegie. 2021. “Predicting transit mode choice of New Jersey workers commuting to New York City from a stated preference survey.” *J. Transp. Geogr.*, 91, 102965.

Domoneske, C. 2021. http://www.npr.org. “Giving up gas-powered cars was a fringe idea. It’s now on its way to reality.” *Nat. Public Radio*.

Ferrari, M., N. Biachi, A. Doria, and E. Giolo. 2013. “Development of a hybrid human-electric propulsion system for a velomobile” *Eighth Int. Conf. Exhibit. Ecol. Veh. Renew. Energies (EVER)* 978-1-4673-5271-0/13/$31,00.

Goldman, T., and R. Gorham. 2006. “Sustainable urban transport: Four innovative directions.” *Technol. Soc.*, 28 (1–2), 261–273. https://doi.org/10.1016/j.techsoc.2005.10.007.

Gössling, S., and A. S. Choi. 2015. “Transport transitions in Copenhagen: Comparing the cost of cars and bicycles.” *Ecol. Econ.*, 113, 106–113. https://doi.org/10.1016/j.ecolecon.2015.03.006.

Hallberg, M., T. K. Rasmussen, and J. Rich*.* 2021. “Modelling the impact of cycle superhighways and electric bicycles.” *Transp. Res. Part A,* 149, 397–418. https://doi.org/10.1016/j.tra.2021.04.015.

Jaffe, S. November 16, 2019*.* “Cycling safety concerns grow in US cities.” http://www.thelancet.com. *Lancet,* 394 (10211), 1791–1792. https://doi.org/10.1016/S0140-6736(19)32757-6.

Kåresdotter, E., J. Page, U. Mörtberg, H. Näsström, and Z. Kalantari. 2022. “First mile/last mile problems in smart and sustainable cities: A case study in Stockholm County.” *J. Urban Technol.,* 29 (2), 115–137. https://doi.org/10.1080/10630732.2022.2033949.

Konkor, I. “Examining the relationship between transportation mode and the experience of road traffic accident in the upper west region of Ghana.” *Case Stud. Transp. Policy*, 9 (2), 715–722.https://doi.org/10.1016/j.cstp.2021.03.009.

Lee, A. and A. March. 2010. “Recognising the economic role of bikes: sharing parking in Lygon Street, Carlton.” *Aus. Plan.*, *47*(2), 85–93.DOI: 10.1080/07293681003767785

Leyland, L. A., B. Spencer, N. Beale, T. Jones, and C. M. van Reekum. 2019. “The effect of cycling on cognitive function and well-being in older adults.” *PLOS One,* 14 (2), e0211779. https://doi.org/10.1371/journal.pone.0211779.

Li, M., and J. M. Gernand. 2019. “Identifying shelter locations and building air intake risk from release of particulate matter in a three-dimensional street canyon via wind tunnel and CFD simulation.” *Air Qual. Atmos. Health*, 12 (11), 1387–1398. https://doi.org/10.1007/s11869-019-00753-1.

Machedon-Pisu, M., and P. N. Borza*.* 2020. “Are personal electric vehicles sustainable? A hybrid E-bike case study.” *Sustainability*, 12 (1), 10.339/su12010032. https://doi.org/10.3390/su12010032.

Mulrow, J., and S. Derrible. 2020. “Is slower more sustainable? The role of speed in achieving environmental goals.” *Sustain. Cities Soc.,* 57. https://doi.org/10.1016/j.scs.2020.102030.

Parker, S. K., H. M. Hinson, and R. Porter. 2021. “Spatial accessibility of bicycle routes in the Quad Cities: Impacts for environmental justice.” *Leisure/Loisir*, 45 (3), 371–396. https://doi.org/10.1080/14927713.2021.1880338.

“People for bikes, model electric bicycle law with classes.” August 2022. http://www.peopleforbikes.org/electric-bikes/policies-and-laws.

Rayaprolu, H. S., C. Llorca, and R. Moeckel*.* 2020. “Impact of bicycle highways on commuter mode choice: A scenario analysis.” *Environ. Plan. Part B*, 47 (4), 662–677. https://doi.org/10.1177/2399808318797334.

Rérat, P. 2021. “The rise of the e-bike: Towards an extension of the practice of cycling?” *Mobilities,* 16 (3), 423–439. https://doi.org/10.1080/17450101.2021.1897236.

Rich, J., A. F. Jensen, N. Pilegaard, and M. Hallberg. 2021. “Cost-benefit of bicycle infrastructure with e-bikes and cycle superhighways.” *Case Stud. Transp. Policy,* 9 (2), 608–615. https://doi.org/10.1016/j.cstp.2021.02.015.

Roy, D., E. S. Lyou, J. Kim, T. K. Lee, and J. Park. 2022. “Commuters health risk associated with particulate matter exposures in subway system – Globally.” *Build. Environ.*, 216, 10936. https://doi.org/10.1016/j.buildenv.2022.109036.

Saghapour, T., S. Moridpour, and R. Thompson. 2019. “Sustainable transport in neighbourhoods: Effect of accessibility on walking and bicycling.” *Transportmetrica A*, 15 (2), 849–871. https://doi.org/10.1080/23249935.2018.1540502.

Southworth, M. 2005. “Designing the walkable city.” *J. Urban Plann. Dev.,* 131, 246–257. https://doi.org/10.1061/(ASCE)0733-9488(2005)131:4(246).

Sundfør, H. B., and A. Fyhri*.* 2017. “A push for public health:The effect of e-bikes on physical activity levels.” *BMC Public Health*, 17 (1), 809. https://doi.org/10.1186/s12889-017-4817-3.

Vance, J. E. 1990, *Capturing the Horizon: The historical geography of transportation since the 16th century*. London: John Hopkins University Press.

Zalewski, A., J. Chmielewski, J. Kempa, B. Santos, and J. Gonçalves*.* 2021. “Traffic calming in historic city centres – A case study.” *IOP Conf. Ser.: Mater. Sci. Eng.,* 1203 (2)*,* 022106*.* https://doi.org/10.1088/1757-899X/1203/2/022106.

Zuo, T., H. Wei, N. Chen, and C. Zhang. 2020. “First-and-last mile solution via bicycling to improving transit accessibility and advancing transportation equity.” *Cities*, 99, 102614. https://doi.org/10.1016/j.cities.2020.102614.

Figure 1. Cutaway view above Colfax Street, Denver Colorado.
Figure 2. Intersection arrangement above Colfax Street, Denver Colorado.

 d revising this section heading to better reflect its contents.

Since this statement is very general, it makes for an ideal introduction to this section, then you can get into the details of the specific shift and why the shift is ocurring.

A citation to Machedon-Pisu 2020 was changed to match the reference list. Please check this change is correct.

I have relocated this information from the end of the section to improve the flow of the paragraph from the discussion of general mode shifts to the discussion of the specific mode shift in question.

I have removed the detailed discussion of the incorporation of pedestrians and bicycles from this section as the other sections tend to focus solely on the literature and how it applied to the LAT, rather on the configuration of the LAT itself. I have relocated this information to the beginning of the methods section.

If Capasso Da Silva et al. 2020 is a citation, no matching reference was found. Please delete the citation or add the missing reference if necessary. WorldCat Search

I recommend clarifying that this is a shipping company for readers who may not be immediately familiar with this abbreviation as a company.

Please clarify. Do you mean a pedal-assist electric (pedelec) cargo delivery van, as implied by the pedelec previous in this sentence, or a BEV delivery van? The mode of power seems to be an important aspect.

The difference between superhighways and highways in this sentence is not clear. I have assumed the difference is predicated on the carrying of mixed traffic in my revisions. Please confirm that this edit has retained the intended meaning of the text.

You dont need to state in the form of automobiles as you have already stated that these cities are automobile centric

Note that less is used when referring to an uncountable quantity, whereas fewer is used when referring to a countable quantity. In this case, the negative health effects can be counted or enumerated, so "fewer" is more appropriate.

Added to explain why velomobiles would be advantageous. Please confirm that this edit has retained the intended meaning of the text.

Note that the new target journal states that the usage of SI units is mandatory, and that other units of measurement may be given in parentheses after the SI units if desired.

Revised to provide SI units as per target journal requirements.

Please clarify: is this factually the longest commercial street or is it more generally one of the longest commercial streets?

You have already stated why this site was chosen in the previous sentence, so you dont need to do so again here.

Note that the figure shows four lanes, all for Class 3 vehicles. I assumed it should show Class 1 vehicle lanes on the outside of the Class 3 lanes. Please confirm.

 I have provided SI units here and placed the Imperial units in parentheses following.

I suggest calling them overhead electric rails as you propose their use for more than just trolleys.

Please confirm this more detailed description.

Based on your math above, and considering the two lanes in each direction shown in Figure 1, this should be 3600 vehicles per hour in *each* direction (each direction comprises two lanes at 1800 v/l/h), or a total of 7200 v/h in *both* directions. Please confirm.

4 lanes X 3 levels X 1800 v/l/h = 21600 v/h. Its not clear where 43,000 comes from here; looks like you d have to have three levels of eight lanes to get 43,000, which is not what the text indicates. Please check and provide additional explanation as necessary.

I have revised this sentence to clarify the comparison being made here. Please confirm that this edit has retained your intended meaning.

Revised to avoid using cost twice in the same sentence, which can be confusing.

Please confirm that this edit has retained the intended meaning of the text.

Revised to provide more formal terminology.

Please provide these units in SI; you could also simply state standard pallet and avoid the problem of units altogether.

Revised to provide a more widely used and formal term.

Please confirm that this edit has retained the intended meaning of the text. I have differentiated between the *design load* for a pedestrian throughfare, which is typically 80 90 psf, and the *load applied by a single automobile,* as the *design* *load* for automobile traffic is typically the HL-93 truck, which is substantially heavier than the pedestrian load.

This paragraph discusses advantages of the proposed LAT.

Please confirm that this edit has retained the intended meaning of the text.

Please note that include already implies that the list is not exhaustive, so the phrase but are not limited to is unecessary.

This paragraph enumerates recommendations for future research.

I have relocated this paragraph to the end of the conclusions as it provides a good summary of the contribution of the study to close with.

In the reference Busari, A. A., R. T. Loto, S. O. Ajayi, O. Odunlami, A. Folake, O. Kehinde, and O. Olawuyi. 2021, the journal title IOP Conf. S.: Mater. Sci. Eng. differs from Crossref. **Suggestion:** *IOP Conf. Ser.: Mater. Sci. Eng.*

No citation to the reference Capasso Da Silva, D. C., D. A. King, and S. Lemar*.* 2020. Accessibility in Practice: 20-Minute City as a Sustainability Planning Goal. *Sustainability*, 12 (1), 129. <https://doi.org/10.3390/su12010129>. was found. Please delete the reference or add a citation to it in the text.

In the reference Capasso Da Silva, D. C., D. A. King, and S. Lemar*.* 2020, the title was updated from Crossref. Please check and amend if necessary.

In the reference Colbourn, C. J., I. D. Brown, and A. K. Copeman. 1978, the title Drivers judgements of safe distances in vehicle following differs from PubMed. **Suggestion:** Drivers judgments of safe distances in vehicle following

In the reference Jaffe, S. November 16, 2019, the punctuation of the title Cycling safety concerns grow in U.S cities differs from PubMed. **Suggestion:** Cycling safety concerns grow in US cities

In the reference Parker, S. K., H. M. Hinson, and R. Porter. 2021, the journal title Leis./Loisir differs from Crossref. **Suggestion:** *Leisure/Loisir*

No citation to the reference People for bikes, model electric bicycle law with classes. August 2022. <http://www.peopleforbikes.org/electric-bikes/policies-and-laws>. was found. Please delete the reference or add a citation to it in the text.

In the reference Southworth, M. 2005, the journal title J. Urban Plan. Dev. differs from Crossref. **Suggestion:** *J. Urban Plann. Dev.*

In the reference Zalewski, A., J. Chmielewski, J. Kempa, B. Santos, and J. Gonçalves*.* 2021, the journal title IOP Conf. S.: Mater. Sci. Eng. differs from Crossref. **Suggestion:** *IOP Conf. Ser.: Mater. Sci. Eng.*

Line break deleted.