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Urban Elevated Small Vehicle Arterials: A Critical Review

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Abstract

This review critically assesses the feasibility and implications of elevated Small Vehicle Arterials as a solution for integrating smaller vehicles into urban environments. It examines the historical context of automobile-centric urban planning and the resulting marginalization of active transportation, positioning SVAs as a potential response to these challenges. The review analyzes SVA design principles, comparing them to existing highway infrastructure and highlighting key adaptations for smaller vehicles. Potential benefits, including reduced congestion, lower vehicle costs, and decreased land usage, are weighed against the challenges of implementation, such as public acceptance, funding, and integration with existing urban infrastructure. Finally, the review identifies key research gaps and future directions for SVA development, emphasizing the need for further investigation to fully understand the potential of this innovative transportation concept.

Keywords: Transportation Planning, Small Vehicle Highways, Urban Mobility, Traffic Congestion, Arterial Design, Infrastructure Cost, Infrastructure Feasibility, Transportation Sustainability, Transportation Economy.

1 Introduction

"The dominance of automobiles in 20th-century urban planning significantly shaped land use” [1]. . Existing roadway infrastructure, primarily designed for cars and trucks, comprises a hierarchy of arterials, collectors, and local roads [2] [3]. Conventional wisdom among transportation planners often prioritizes automobile-centric solutions [4]. This prioritization of automobile infrastructure has often marginalized active forms of transportation [5]. Consequently, smaller individually operated vehicles, such as bicycles, e-bikes, e-motorcycles, e-scooters, velomobiles, and small cargo vehicles, are generally excluded from Limited Access Thoroughfares (LAT), limiting their utility for commuting and longer urban trips [6].

Within this context, the novel concept of elevated Small Vehicle Arterial(s) (SVA) emerges as a potential framing to facilitate discussion for integrating smaller vehicles into the urban landscape more effectively. SVA are most easily conceptualized as scaled down automobile like highway infrastructure exclusively for small vehicles and pedestrians, while prioritizing human powered modes of travel. This review critically examines the feasibility and implications of mirroring the automobile roadway system with smaller scale elevated SVA constructed above existing streets. This conceptualization allows for a direct comparison with urban automobile roadways, examining the potential benefits and drawbacks of a dedicated, high-speed network for small vehicles and pedestrians [7]. However conceptualizing an entirely new roadway class and assuring readers share visualizations is anything but a simple task [8] [9].

The proposed SVA system aims to replicate the core benefits of automobile arterials—speed, efficiency, and high capacity—at a smaller scale, potentially offering a superior level of service for small vehicles in urban areas [10]. SVA highways are to be installed mostly over signalized urban streets. While cars and trucks navigate signalized intersections below, small vehicles on the SVA could bypass these delays, potentially influencing user preferences and alleviating congestion in areas with high traffic generator density [3] [11].

A key challenge in this analysis is the apparent novelty of the elevated urban SVA concept. A comprehensive literature review has revealed no prior research or documentation of SVA networks integrated into existing urban transportation systems. This lack of precedent necessitates a more exploratory approach, drawing upon analogous concepts and principles from related fields to inform the assessment.

To facilitate future analytical work, this review will further explore the potential benefits and challenges of SVA, considering factors such as cost, safety, and accessibility for pedestrians and cyclists [12] [13]. Initial parameters for discussion include a hypothetical lane width of approximately 1.5 meters (4.5 ft) and a hypothetical tare weight limit of 340 kg (750 lbs.) for small vehicles on Class 3 roadway. A philosophical cost analysis comparing select SVA highway construction to traditional automobile highways is undertaken, considering the smaller scale and feasibility of elevated implementation. Finally, the potential trade-offs between replicating the positive attributes of automobile roadways while mitigating their negative impacts at a smaller scale will be addressed.

A hypothesis is that, similar to scaled-down railroads, SVA will be less costly per mile to construct in congested urban areas compared to traditional automobile arterials under similar conditions [14]. This reduced scale is also hypothesized to facilitate the feasibility of elevating the highway above existing city streets.

Given that the small vehicle modes discussed in this review are generally compatible with existing bicycle lanes, research on bicycle infrastructure and usage patterns can inform the analysis of SVA. While numerous studies have examined small vehicles sharing roadway space with automobiles at-grade, there is a notable lack of research specifically addressing the characteristics and design considerations of elevated SVA. However, calls for improved e-bike infrastructure, including elevated arterials, have emerged within the broader discourse on urban transportation [15].

The broadest application for SVA lies in the potential to serve the entire range of vehicles and modes currently excluded from conventional urban arterials. These include everything from motorized small vehicles, such as e-bikes and scooters, to human-powered modes like bicycles and pedestrians. Given the well-established health and livability benefits of active transportation, prioritizing pedestrians and cyclists within this new infrastructure is essential [16]. Designing a state-of-the-art system that accommodates this wide spectrum of users, while prioritizing active forms of travel, presents a unique and complex challenge.

2 Methodology

Any new technology will have positive or negative attributes. The positive attributes can be optimized and the negative attributes can be mitigated. The primary focus at the incipient stage is to illustrate these areas of future optimization or mitigation. Any reader about new technology wants first to understand what the technology is and then an opportunity to discern for themselves whether the positive and negative attributes on balance create an investable opportunity. Therefore the format of the article is organized to describe Benefits and Challenges.

This article introduces the urban elevated SVA concept, an innovative approach to urban transportation design. Originally conceived as Small Vehicle Limited Access Thoroughfare(s) (SVLAT) with supporting feeder roads, the concept has evolved to encompass a broader functional definition of SVA, encompassing small vehicle signalized streets, small vehicle urban highways, and urban SVLAT. This article serves as a foundational framework for future research, providing a preliminary comprehensive exploration of the key aspects of SVA.

This review critically examines the concept of elevated SVA, analyzing basic design principles, potential benefits, costs, and implementation challenges within the context of existing urban transportation systems. The review will assess the feasibility of SVA as a strategy for integrating smaller vehicles into urban environments, considering factors such as cost-effectiveness, safety, environmental impact, and public acceptance.

Given the absence of scaled-down examples, understanding the effects of scaling requires careful engineering analysis through calculations and illustrations. In some cases where no alternatives are viable trial balloons are floated creating hypothetical scenarios. While existing literature provides valuable insights into relevant parameters, a comprehensive review including use of engineer design methods is necessary to establish a shared understanding of the core principles. Therefore, a hybrid approach, integrating design, with a focused literature review is pursued creating a hybrid design and review article.

This initial exploration prioritizes key areas relevant to the nascent stage of SVA development: feasibility, accessibility, equity, environmental impact, and regulatory considerations. The subtopics, identified through brainstorming, form the basis of a utilitarian review designed to illuminate their relationship to scaled-down arterials.

Emerging technologies inherently present both benefits and challenges. At this incipient stage, the primary focus is to highlight potential areas for future optimization and mitigation. The review format avoids drawing conclusions leading readers to draw their own conclusions or use elements of this review in the formation of their own research projects.

Research results are provided mostly 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 using different tools.

3 Background

Existing transportation systems are complex and highly evolved. Integrating a new transportation network, such as the proposed elevated SVA system, presents significant complexities, particularly regarding cost-effectiveness. Successful integration requires a detailed understanding of existing networks, the potential impact of the new network on existing traffic patterns and user behavior, and an accurate assessment of demand for the new infrastructure. Users will inevitably compare the new network with the existing system, creating a daunting challenge to address all current or past issues associated with transportation networks. This review prioritizes discussion of the most critical issues identified by the author and reviewers during the preparation of this article. Given the complexity of the subject, a comprehensive analysis of every potential issue is beyond the scope of this review.

3.1 History and Evolution of the SVA concept

The concept of SVA arose from the need to integrate smaller vehicles more effectively into urban transportation networks. Recognizing the dominance and efficiency of LAT for automobiles, the SVLAT concept proposes a similar infrastructure tailored to the needs of smaller vehicles like electric bicycles, velomobiles, and electric motorcycles. This approach aimed to replicate the benefits of LATs while adapting to the specific characteristics and requirements of these smaller vehicles. Early in the conceptualization phase, the potential for egress routes to be used for normal pedestrian access was recognized. The elevated pedestrian walkway evoked parallels with elevated urban malls which then created a vision of bicycle highways within large pedestrian malls.

3.2 Comparison with Existing Transportation Systems

Existing transportation systems typically classify roadways into four functional types: major arterials, minor arterials, collectors, and local roads [3]. In the United States, the distribution of mileage across these roadway types reveals a minority proportion of lane miles dedicated to higher-capacity arterials, however these arterials carry a disportionately larger share of the traffic [2]. A feature of the US transportation network is the LAT highway system, which comprises 2% of the lane miles while carring 25% of the traffic [17]. While automobiles utilize all four roadway types, smaller vehicles are often restricted to collectors and local roads, limiting their efficient long-distance travel [6]. Some regions, notably the Netherlands, Germany, Denmark and U.K., have implemented bicycle highways, offering a dedicated infrastructure for certain small vehicles [18].

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]

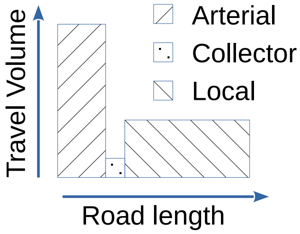
	Principal + Minor Arterial	**Collector**	**Local Road**
Travel Volume (%)	65-80	5–10	10-30
Length (%)	20-25	5-10	65-80
Active Transportation	No Bicycles, no sidewalks	Bicycles lanes on some, sidewalks	Bicycles allowed, sidewalks
Small Vehicle	Few arterials found.	Some collectors.	Widely allowed.

Table 1 shows the relation between roadway miles and volume of traffic for the four functional types of roadway in the USA [2]. Figure 1 is a graphical representation of this data which can aid visualization. The data shows arterials and collectors carry a disproportionate amount of traffic vs the roadway length.

The US Interstate Highway System, comprising 2.6 percent of all roadway lane miles in the United States, carries 26 percent of the nation's vehicle travel [17]. While primarily rural, the Interstate system also serves as a crucial arterial network within major urban areas [19]. This review proposes a system of SVA to provide similar arterial functionality for small vehicles in urban environments. The current lack of such infrastructure may represent a "missing link" in urban transportation networks, which, by design, often prioritize automobiles over smaller, automobile-like transportation modes.

The concept of elevated roadways for bicycles and other small vehicles, as a means of cost reduction and enhanced efficiency, is not new. An 1896 *New York Times* article proposed an elevated bicycle path over a railway line, comparing its cost to that of a subway [20]. However, as was typical of publications from that era, the proposal lacked practical details. Other historical and contemporary examples of elevated bicycle paths include the California Cycleway and the SkyCycle proposal in London [21].

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



Traditional roadway design parameters, often codified in law, demonstrate a clear difference in scale between infrastructure for automobiles and that for smaller vehicles. Table 2 illustrates this disparity, highlighting the larger corridor size and higher design weight for traditional roadways compared to the proposed SVA design. Furthermore, Table 2 shows smaller vehicles typically operate at lower design speeds than automobiles. Recommendations for reducing carbon emissions include strengthening the sustainable transportation system by promoting eco-friendly and energy efficient modes of transportation [22]. Transport sector, and therefore, urban mobility, is a key factor for economic growth and sustainability [23]. This difference in scale, combined with the higher efficiency (see Table 3), lower emissions and less weight of smaller vehicles, underscores the potential benefits of a dedicated SVA network.

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 [2], [21]	1.5 m (4.5 ft)	1.5 m (4.5 ft) [17]	1.5 m(5 ft) to 2.2 m (7 ft) 2 side-by-side [19]	
Maximum Lane Height	16 ft [21]			2.5 m 100” [2]	
Design Weight	39,594 kg (80,000 lbs) [20]	100 kg (220 lbs) – 500 kg (1100 lbs) (estimated)			
Speed	55-75 mph US [24]	Up to 75 kph (45 mph)	50 kph	E-bike 12-18 mph, manual bicycle 4-18 mph. [17]	Walking speed up to 1.0 m/sec, 3.6 kph. [18] i
Preferred lane construction	Slower modes excluded	Faster/Slower modes excluded	Faster/Slower modes excluded	Faster/Slower modes excluded	Faster modes excluded
SVLAT Corridor	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.

[25] [26] [27] [28] [29] [30]

Table 3 Fuel efficiency for select transportation modes.

	Automobile	**Twizzy**	**Bicycle**	**Pedestrian**
Electric Efficiency	30 kwh/100 miles	9.65 kwh/100 miles	1.9 kwh/100 miles	None

[31] [32] [33]

3.3 Types of Small Vehicles for SVA

This review focuses on SVA infrastructure designed exclusively for smaller vehicles, excluding traditional automobiles. While initially conceived for egress, pedestrian and other human powered access has been re-classified to be an integral part of the SVA concept, promoting accessibility and multi-modal integration [15] [34] [35].

The term "automobile" requires careful definition in this context. As smaller vehicles evolve, they may eventually possess similar functionality to automobiles. For the purposes of this review, "small vehicles" are defined as those that can operate in estimated 1.5-meter (4.5-foot) lanes with a minimum tare weight of 340 kg (750 lbs). These parameters are proposed as starting points for discussion and may be subject to further refinement.

4 Potential Benefits of Elevated SVA

Introducing significant transportation capacity for small vehicles above signalized city streets, without substantially impacting traffic flow below, offers several potential advantages. This approach could alleviate congestion, enhance urban mobility, decrease parking costs, lower vehicle expenses, and reduce land use demands and associated costs.

4.1 Increased Transportation Capacity

Elevated Small Vehicle Arterials offer a potential solution to urban traffic congestion by introducing additional capacity above existing roadways without blocking roadways below. This new arterial capacity is achieved by adding dedicated SVA lanes, which can be designed with or without traffic signals. Some versions are similar to existing Limited Access Transportation systems for automobiles.

Estimating per-lane capacity for uninterrupted-flow SVA highways presents challenges. While Highway Capacity Manual speed-flow curves offer guidance, their applicability to SVA is limited. The HCM primarily focuses on speeds between 90 km/hr and 120 km/hr, exceeding the anticipated operating speeds of SVA [36]. Furthermore, existing mathematical models may have limitations [37] , and real-world data for calibration and validation are non-existent for SVA [38].

However, fundamental models based on driver reaction time offer a valuable starting point [39]. These models posit that consistent driver experience, in terms of vehicle controls and perceived highway design, leads to similar reaction times. This consistency in reaction time translates to a relatively uniform time gap between vehicles, which is a key determinant of lane capacity.

This concept of a time gap, often referred to as the "two-second rule," is a cornerstone of USA driver education [39] [40] [41]. While the traditional practice of maintaining a safe following distance by counting car lengths (one car length per 10 mph) is applicable, consistent adherence to the two-second rule renders lane capacity largely independent of speed.

> The two-second rule, when considered from a capacity perspective, offers a simplified illustration of highway lane capacity. A stationary observer on a highway where drivers adhere to the two-second rule will observe a vehicle passing every two seconds, resulting in a flow rate of 30 vehicles per minute. Because the two-second rule is, in principle, independent of speed, this flow rate remains constant, assuming consistent adherence to the rule.

Therefore, assuming throttle-controlled vehicle operation, the capacity of a conventional limited-access highway lane can serve as a reasonable first approximation for the capacity of a small-vehicle limited-access lane on SVA.

4.2 Reduced Traffic Congestion

Traffic congestion has been a persistent issue since the advent of roadways [42] [43]. Traditionally, congestion has been addressed by increasing transportation capacity. However, the limitations of expanding urban automobile infrastructure have been recognized, prompting a reassessment of congestion relief strategies [44]. The ongoing transition from gasoline to electric vehicles is projected to exacerbate congestion, and various models have explored methods to alleviate this on existing highways [45] [46] [47]. A critical unanswered question is whether constructing scaled-down highways above existing city streets for smaller vehicles offers a cost-effective temporal solution to congestion.

This article discusses a novel paradigm: building elevated arterials for small vehicles above existing transportation networks in congested urban areas. This approach offers a substantial capacity increase with minimal impact on surface land use, potentially alleviating stress on overburdened transportation systems.

Urban automobile streets are often characterized by high congestion and numerous impediments to smooth traffic flow [48]. In contrast, elevated SVA can facilitate uninterrupted traffic flow through congested urban areas. Strategically locating SVA in areas with the highest congestion, which are often concentrated trip generation zones [11], could significantly improve traffic conditions.

4.3 Improved Urban Mobility **C**ompared State

The trend towards larger automobiles in US transportation has been likened to an "arms race," where individuals opt for increasingly larger vehicles, escalating system costs, emissions, and consequently, health-related expenses [49]. Congestion pricing has demonstrated its effectiveness in mitigating major automobile externalities by reducing both vehicle sizes and congestion [50]. The implementation of SVA systems, by expanding the usability of inherently lower-cost small vehicles, could potentially yield similar benefits to congestion pricing, while simultaneously enhancing, rather than restricting, urban mobility.

4.4 Reduced Parking Costs

While self-reported out-of-pocket parking costs for automobiles may be negligible among low-income individuals [51] , this does not reflect the true cost, which is often obscured from the consumer. Smaller vehicles inherently incur lower parking costs due to their reduced size and weight [52]. This cost reduction can also benefit providers of "free" parking. Moreover, the smaller size requirements allow for more conveniently located parking for small vehicles, with some cases, such as folding bicycles, potentially eliminating the need for formal parking spaces altogether.

Compared to automobiles, bicycles require significantly less parking space, potentially as little as one-sixth the area [52]. This translates to lower parking costs for both bicycles and small electric vehicles. Folding electric bicycles and automated parking structures further minimize land use per vehicle. Promoting the use of vehicles with reduced parking costs, along with their broader societal cost benefits, provides an economic rationale for increased investment in SVA highways.

4.5 Reduced vehicle costs

Smaller electric vehicles offer significant cost advantages compared to traditional automobiles. Studies indicate that societal costs for small electric vehicles operating on existing roadways can be as low as one-sixth of those associated with conventional cars [53]. The high-volume production of electric bicycles contributes to their lower purchase price compared to automobiles [54]. Furthermore, economies of scale suggest that increased production of scaled-down, car-like electric vehicles could lead to even lower costs due to reduced material and energy requirements [55] [56]. Consumers opting for smaller vehicles designed for dedicated SVA would likely experience lower overall costs compared to purchasing and operating a standard automobile on conventional roads.

Smaller vehicles designed for exclusive use on SVA offer significant cost advantages compared to traditional automobiles. These cost reductions stem from several factors, including lower material usage, simpler manufacturing processes, and reduced battery requirements.

The smaller size and simpler designs of SVA-compatible vehicles translate to lower material costs. This is particularly evident in the reduced need for structural materials such as steel and aluminum. Furthermore, the simpler designs often involve fewer components, simplifying the manufacturing process and reducing associated labor costs. For example, the average cost of a kei car in Japan, a category of small vehicles with engine displacement and dimension restrictions, is significantly lower than that of a standard passenger car [57]. While kei cars are not specifically designed for SVAs, their cost structure provides a useful analogy for the potential cost savings associated with smaller, purpose-built SVA vehicles.

Electric vehicles designed for SVAs also benefit from reduced battery requirements. The lower weight and expected operating speeds of these vehicles allow for smaller battery packs, which represent a substantial portion of the overall vehicle cost. This cost advantage is further amplified by the potential for SVA infrastructure to incorporate charging capabilities, reducing the need for extensive individual charging infrastructure [58].

4.6 Reduced Land Use

Land consumption for roadways represents a significant economic and environmental consideration. A 2016 study estimated the value of land used for USA roadways at $4.1 trillion, further noting that the average cost of roadway expansion often significantly outweighs the benefits when land value is considered [59]. The proposed elevated SVA system offers a potential solution to this challenge. By utilizing the airspace above existing city streets and employing narrower lane widths, SVAs can achieve increased transportation capacity with a substantially smaller land footprint compared to traditional roadway expansion.

The SVA design minimizes disruption to existing street-level activity. Columns supporting the elevated structure can be strategically placed to leverage existing infrastructure, such as traffic signals, electrical poles, and light poles, relocating these functions to the SVA structure itself. While the design of SVA supports presents a complex engineering challenge, requiring careful consideration of structural needs, existing street uses, and potential underground interference, it offers a significant land-use advantage.

Optimizing SVA alignment is crucial for cost mitigation and minimizing disruption. Designers can prioritize alignments that minimize interference with existing infrastructure and street-level activities. While the design process is inherently complex, it is reasonable to anticipate minimal disruption to existing urban functions along the SVA corridor. In essence, SVAs can provide additional transportation capacity without consuming valuable urban land. Furthermore, SVA implementation can lead to a significant reduction in traffic on existing streets, opportunities for repurposing land currently dedicated to roadways may emerge.

4.7 Auxiliary Uses for Structure

Integrating urban utilities within the SVA structure offers significant value. Potential applications include accommodating electrical cables, fiber-optic cables, pipes, package conveyors, solar collectors, and exercise corridors. While incorporating some of these auxiliary uses during initial construction is feasible, designing the structure with adaptable space and load capacity for future utility upgrades is likely cost-effective. Furthermore, rack-mounted utilities, compared to underground systems, offer easier access for maintenance and repair. Therefore, routing essential utilities above ground on the SVA structure enhances resilience against flood and wind damage, presenting at times a superior alternative to traditional overhead or underground placement.

4.8 Improved Accessibility

Active transportation modes, such as walking and cycling, play a crucial role in promoting accessibility [60]. Electric bicycles and scooters can also enhance accessibility [61]. These active modes, powered by human effort or pedal assistance, contribute to improved public health outcomes [15] [34] [35]. Accommodating manual modes within the SVA system serves multiple purposes, including transportation, accessibility, and emergency egress. Integrating accessibility considerations into the fundamental design philosophy of SVA will ensure enhanced accessibility along the entire highway corridor. Wide sidewalks, for example, can encourage walking and running while also providing access for emergency responders and egress routes for the population.

Studies have shown that public transportation offers greater economic benefits in terms of accessibility compared to private automobiles [62]. Similarly, designing streets and roads that prioritize bicycle usage has demonstrated positive economic impacts [63]. These advantages may stem from the costs and complexities associated with automobile parking. In contrast, individuals using public transit can immediately transition to pedestrian mode upon exiting the system. By accommodating smaller, more easily parked vehicles, SVA are expected to function more akin to mass transit than to private automobiles in terms of accessibility. However, since SVA also share operational similarities with automobile infrastructure, certain deficiencies associated with automobile-centric design may persist. Further research is needed to fully understand these potential drawbacks and develop strategies for their mitigation.

4.9 Increased Average Modal Speed

Average modal speed considers the entirety of a trip, from inception to completion, encompassing various interactions and potential modal shifts [64]. For automobile travel, the distance from origin to parking, including navigation of local roads before accessing arterials, can significantly impact overall trip time [65] . Public transit introduces additional complexities, such as wait times and transfers. Conversely, small vehicle commuting offers advantages like convenient parking or even parking elimination with options like folding bicycles or walking. Providing parking for small vehicles in congested urban areas can also be more cost-effective [52] . Modeling mode choice, however, remains a complex undertaking [66] [67].

Predicting average trip speed is highly dependent on the specific trip and urban environment characteristics. While various models attempt to predict passenger behavior following the introduction of new transportation systems, many have proven inadequate [68]. Given the absence of existing SVA infrastructure, mathematical trip generation models [69] remain untested, raising concerns about their accuracy. Surveys, while potentially useful, are limited by participants' inability to accurately visualize and assess unfamiliar systems. Therefore, this analysis focuses on arterial speed to evaluate the potential utility of elevated SVA compared to other modes. However, a truly predictive analysis for a novel mode of transportation like SVA may only be feasible after real-world implementation.

The US Federal Highway Administration recommends a 50 kph (30 mph) speed limit for local urban streets [70]. Vehicles on these streets encounter impediments such as traffic signals, roundabouts, and stop signs. An uninterrupted elevated highway operating at the maximum speed of surface street traffic would inherently achieve a higher average modal speed. Similarly, pedestrians or cyclists on an uninterrupted sidewalk experience higher average modal speeds compared to those navigating signalized intersections. This improved traffic flow for SVA can contribute to reduced average modal speed.

5 Costs for SVA Infrastructure

Costs for SVA infrastructure are a combination of land and construction costs. To do a cost estimation we first need a design, however not only do we not know what to build where but we do not have agreement what to build. Therefore a cost estimation at this stage is impractical. A preliminary assessment, however, can be conducted by comparing cost precursors for traditional automobile urban arterials with novel SVA.

5.1 Land Acquisition Costs

SVA systems, as entirely new infrastructure within existing urban environments, will necessitate some land acquisition. However, the projected alignment of the infrastructure primarily within existing public right-of-way suggests that land acquisition costs will be lower than those associated with new automobile arterials. Furthermore, increased traffic flow generated by SVA systems could benefit adjacent private facilities. This potential for mutual benefit may facilitate voluntary interconnections between SVAs and private facilities, potentially obviating some need for land acquisition through eminent domain.

5.2 Cost Comparison: SVA vs. Automobile Arterials

As indicated in Table 1, the projected volumetric footprint of SVA corridors is substantially smaller than traditional automobile highway corridors, approximately half the height and one-third the width. This allows for a six-fold increase in lane capacity within the same volume. Furthermore, lower operating speeds of small vehicles translate to reduced static and dynamic design loads per lane compared to limited access transportation systems [71] [72]. This combination of reduced loads and smaller volumetric footprint can significantly decrease bridge construction costs for equivalent traffic volumes. Microcars, with their lightweight design, represent a vehicle class potentially compatible with both LAT and SVA systems [73] [74].

The smaller scale and lower design loads of SVA corridors favor above-ground construction using steel structures. While SVA structures must adhere to bridge design methodologies for dynamic loads, the reduced weight and speed of small vehicles result in lower design loads compared to automobile bridges [71]. Consequently, less material is required per lane compared to elevated automobile highways. Steel structures also offer faster erection times compared to traditional at-grade urban highways, potentially minimizing construction costs and disruptions to existing transportation networks.

Although estimating infrastructure costs for a novel structural category is complex, SVA cost prediction could be relatively straightforward. The design and construction methods are well-established, drawing parallels from existing low-rise commercial structures with similar occupancy and height parameters. As public roadways designed by professional engineers using modern tools, SVA structures should exhibit superior resilience to extreme weather events compared to typical residential structures [75]. Their covered or potentially enclosed nature may also offer advantages for emergency access in extreme situations, unlike conventional roadways which are susceptible to debris blockage.

SVA building design must integrate both commercial building codes and bridge design codes. While the structures will experience cyclic loading from traffic similar to bridges, the magnitude of these loads will be reduced due to lower vehicle speeds and weights [28]. Pedestrian walkway design loads will closely resemble that of commercial buildings, therefore the resultant structure should be similar. Incorporating design margins for future capacity expansion or vehicle evolution may prove cost-effective. A detailed study of requirements may necessitate the development of new standards to address the unique combination of factors associated with SVA.

Accurate cost estimation is currently hampered by factors such as routing studies, underground utility assessments, and various technical challenges identified in this study. Mitigating interference with underground utilities can influence routing and above-ground design details, requiring site-specific considerations for each locality [76]. The design process, including cost-benefit reconciliation, will require significant time and resources.

5.3 Spacing Considerations for Elevated SVA

A critical factor influencing the economic feasibility of SVA systems is the required spacing between arterials and ramps. Wider spacing reduces overall system costs by minimizing the number of required components. Commuting patterns are a key consideration in transportation system design, with studies indicating a willingness to bicycle up to 4.36 km (2.7 miles) from mass transit to work locations [77] [78]. This distance may be greater with electric-assist vehicles. Given that most SVA users will be using vehicles, SVA have the potential to address last-mile challenges associated with mass transit systems for commuters.

The 4.36 km (2.7 miles) travel distance provides insight into potential arterial spacing. Hypothetically, arterials spaced every 8.72 km (5.4 miles) could achieve full coverage for work commuting. However, analogous to automobile arterial spacing, such wide spacing may be impractical in many urban contexts. Similar to automobile arterials, SVA spacing may range from 0.2 km (1/8 mile) to 4.8 km (3 miles) [79]. These could include SVLAT or elevated secondary arterials with marked lanes for pedestrian traffic.

The potential for wider spacing offers flexibility in SVLAT alignment, potentially reducing costs or enhancing accessibility compared to systems with stricter spacing requirements. This flexibility can be leveraged during the design phase to optimize system performance and integration within the urban fabric.

Therefore, numerous feasible alignments and ramp locations exist for SVA systems, offering greater spacing flexibility compared to other transportation infrastructure alternatives due to the use of personal vehicles by most users.

6 Challenges for SVA Implementation

Implementing SVA infrastructure presents significant challenges. While the potential benefits of reduced congestion, lower vehicle costs, and decreased land usage are substantial, several obstacles must be addressed. Existing preferences for larger automobiles may pose a barrier to SVA adoption [80]. SVA design must anticipate user preferences to create a route large number of users will prefer. A cultural shift is required towards funding transportation improvements, particularly in areas with the greatest transportation needs, such as underserved communities, will likely be difficult [81]. However, the global scale of transportation challenges and the potential for SVA to address these challenges warrant further investigation.

6.1 Economic Justification and Potential Applications of Elevated SVA Networks

New SVA projects must compete with existing transportation marginal improvement projects that aim to optimize existing infrastructure. Therefore, identifying locations where the benefits of SVA implementation are exceptionally high is crucial for justifying initial development.

Several potential applications warrant consideration:

6.1.1 Waterway Crossings in Congested Urban Areas

Many cities are situated near waterways, requiring bridges and tunnels that are often subject to congestion pricing [50]. The lower construction costs of scaled down SVA bridges, compared to traditional automobile highway bridges for equivalent traffic volumes, further enhances their suitability in such contexts.

6.1.2 Transportation Upgrades for Major Events

Cities hosting events like the Olympics or World Fairs often require significant transportation upgrades [82] [83]. SVA potentially offer a faster and more cost-effective solution. The advantages include above-ground steel construction, reduced parking requirements, lower design loads, elevated traffic corridors, wide coverage, non-stop service potential and high capacity.

6.1.3 Flood Mitigation and Adaptation in Coastal Cities

Rising sea levels and increased storm intensity due to climate change and land subsidence pose significant challenges for coastal cities [84]. Elevated, enclosed SVA networks, designed to modern codes and climate resilience standards, can provide a crucial transportation alternative in flood-prone areas.

6.1.4 Congested Urban Areas with Predominantly Small Vehicle Usage

In regions with high traffic congestion and a prevalence of small vehicles, the economic benefits of improved mobility alone may justify the investment in elevated SVA systems.

6.1.5 Underserved Urban Areas with Limited Highway Access

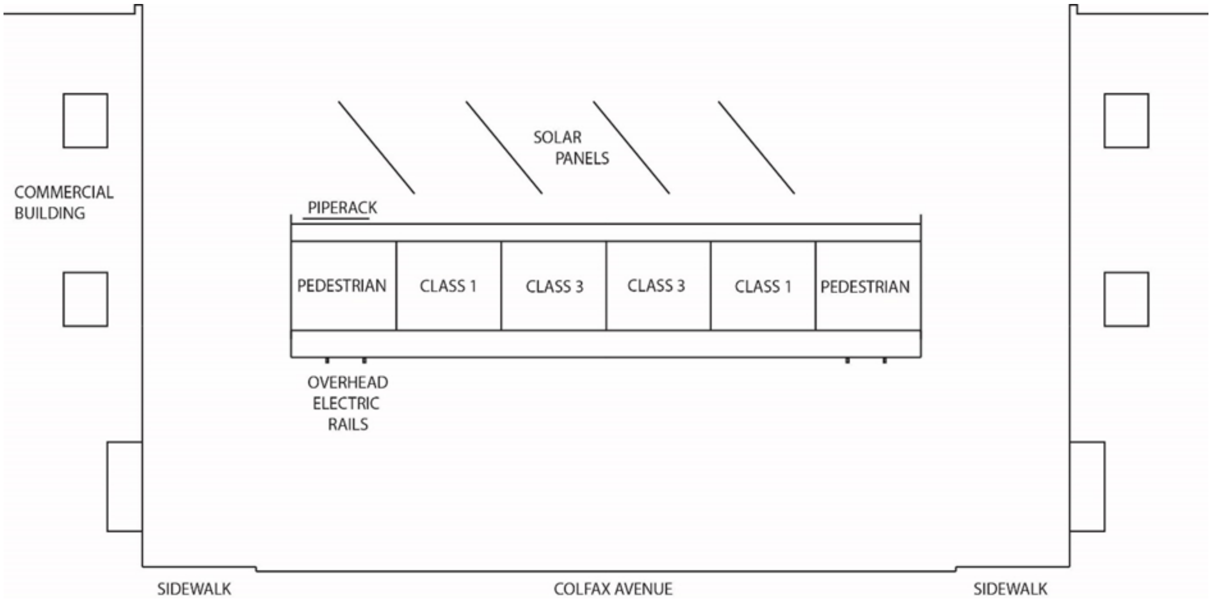
A strong positive correlation exists between city size and household travel costs, driven by increased spatial distances and traffic congestion [85]. In urban areas lacking adequate highway access, such as Manhattan Island where limited-access highways terminate at the island's boundaries, elevated SVA can provide a viable solution for expanding transportation capacity where underground or surface network expansion is impractical.

6.2 Integrating SVA within Existing Urban Infrastructure: A Feasibility Study

The successful integration of SVA within the existing urban fabric requires careful consideration of potential physical interferences with existing infrastructure. To assess feasibility under constrained conditions, a sketch study was conducted, demonstrating a hypothetical SVA installation over a relatively narrow street. This study assumed the accommodation of three traffic classes: pedestrians, Class 1 vehicles (e.g., bicycles), and Class 3 vehicles (e.g., small electric vehicles), with the understanding that existing utilities (electric lines, traffic signals) could be relocated and building interferences would be avoided.

Figure 2 presents the results of this study for a single-level SVA configuration over an 80-foot (24.38 m) wide street. The design incorporates 12-foot (3.66 m) square traffic corridors mounted 24 feet (7.32 m) above street level. The findings indicate that this configuration can accommodate all three traffic classes within the available space, adhering to current regulatory structures.

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



Another critical aspect of SVA integration is the intersection of non-stop highways above existing roadways. Figure 3 illustrates a stacked configuration of two SVA and traffic circles, positioned 24 feet (7.32 m) above an intersection, maintaining a total height of less than 100 feet (30.5 m). The Class 3 electric vehicle traffic circle is placed above the Class 1 circle, based on the assumption that electric vehicles can manage elevation changes more effectively than manually powered bicycles. For simplicity Figure 3 only shows the primary space allocation, in this configuration only left turning traffic is required to enter the roundabout space.

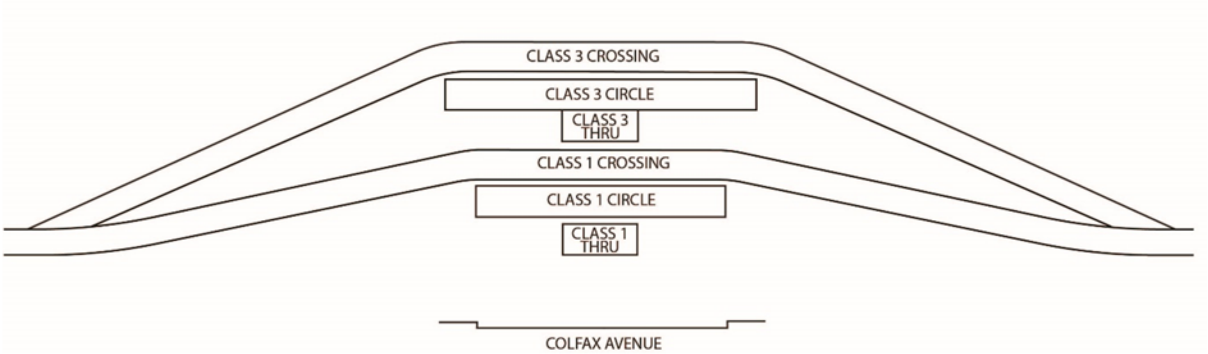


Figure 3: Two vehicle traffic circles over 80' (24.38 m) wide street.

6.3 Vehicle Design and Regulatory Considerations for SVA

The increasing popularity of small electric vehicles, as evidenced by the higher sales of electric bicycles compared to electric automobiles in the US from 2018-2022 [86], suggests a readily available initial user base for SVA. Various operational models are possible, with vehicles provided by the system operator, third-party operators, or even individual users. In any scenario, the smaller, lighter, and lower-speed vehicles used in SVA are expected to have lower costs than conventional automobiles [87]. However, critical safety considerations, such as fire risk, enclosed-environment air quality, and the potential for full automation, necessitate the development of comprehensive regulations to ensure uniform safety standards.

The potential of fully autonomous vehicles to enhance highway capacity and reduce accidents is well-recognized [88]. While retrofitting existing highways for autonomous driving may be impractical [89], designing new infrastructure like SVA with integrated features like centralized monitoring/control, dedicated communication systems, and fixed highway sensors offers a unique opportunity to optimize for autonomous driving safety. Targeted studies could explore limiting new Class 3 SVA or specific lanes to fully autonomous operation.

The ongoing evolution of vehicle designs, from velomobiles [90] to specialized delivery vans [91], further underscores the dynamic nature of this field. The introduction of SVA may even stimulate the development of novel vehicle concepts tailored to this new infrastructure. Accommodating such future innovations may require adaptable lane designs and system flexibility.

In conclusion, the foundational elements for SVA vehicle fleets already exist, and the potential for further design evolution is significant. A proactive approach to safety regulations and a forward-looking design philosophy will be crucial for maximizing the benefits of SVA.

6.4 Technical Challenges in SVA Infrastructure Development

Designing and constructing extensive low-rise steel structures for elevated SVA, while technically feasible, presents distinct challenges beyond mere structural considerations. A primary concern lies in anticipating and accommodating diverse human behaviors for this novel transportation system. While insight can be gleaned from current transportation industry experience, attributes unique to SVA will need to be discovered and explored. The design must address a full spectrum of operating conditions, including routine maintenance, emergency response scenarios, and normal daily operations.

Despite these challenges, the unique characteristics of SVA also present opportunities for operational improvements compared to conventional automobile highways. The lower vehicle loads and narrower roadways, for instance, enable the use of prefabricated drop-in panels for rapid roadway surface renewal. Furthermore, optimizing the internal design of enclosed SVA corridors can minimize the effects of internal air friction on vehicle performance.

While design recommendations for bicycle pathways are comprehensive for local and some highway applications, the emergence of SVA necessitates the development of new standards. For instance, the *Manual on Uniform Traffic Control Devices* [92] allocates considerably more attention to automobile signage on highways than to signage for SVA. This disparity highlights the need for further research and standardization in SVA signage and other design parameters to ensure safe and efficient operation.

The dominance of the automobile has led to varying degrees of automobile dependency in urban areas [93], ranging from complete reliance to mixed transit/automobile dependence. Integrating a new transportation system like SVA into existing urban environments, particularly those heavily adapted to automobile-centric infrastructure, presents complex and often unforeseen challenges [94]. Understanding the interplay between existing urban form and the introduction of SVA is crucial for most successful implementation.

6.5 Potential Detrimental Effects of Elevated SVA and Mitigation Strategies

Elevated SVA networks, while offering numerous potential benefits, may also present certain visual and environmental challenges. In areas with existing low-rise buildings or street-level art installations, elevated structures could obstruct sightlines and diminish aesthetic appeal. However, in areas dominated by modern high-rise buildings, the visual impact is likely to be less pronounced. Given that SVA corridors are generally envisioned as low-rise structures, not exceeding the height of a five-story building, their integration into existing urban landscapes requires careful consideration.

The elevated corridors will inevitably cast shadows on nearby buildings and streets below. While the relative sparsity of the highways may minimize this impact, mitigation strategies such as strategic lighting, route selection, and corridor design should be explored. Furthermore, incorporating windows into elevated structures may create sun glare, potentially contributing to accidents on the streets below. This issue can be addressed during the design phase by incorporating external louvers or angling the windows to minimize glare.

Social isolation has been shown to be reduced by increasing mobility through public transportation [95]. SVA by incorporating active forms of travel can have a positive effect on health outcomes for older population [96]. Social spaces such as rooftop entertainment venues or parks could transform transportation infrastructure into destinations, fostering social interaction. Similarly, encouraging nearby buildings to provide elevated access and incorporating commercial spaces within or adjacent to SVA corridors can create vibrant hubs of activity. Routing SVA traffic partially or fully through building interiors, particularly in designated destination areas, could further enhance social interaction. Prioritizing accessibility and connectivity within SVA design can help mitigate the potential for social isolation.

6.6 Regulatory Frameworks and Design Considerations for SVA Networks

Existing transportation regulations are often optimized for the current infrastructure and vehicle types. The widespread adoption of urban elevated SVA networks will necessitate the development of new regulations tailored to this novel transportation mode. Commute time preferences, typically capped at 30 minutes, and alternative proposals considering 15-minute increments, should inform these regulations [35]. The reduced speeds of some small vehicles compared to automobiles will inherently limit the effective range of SVA vehicles, influencing network design, city design and user adoption.

Electric bicycles have demonstrated the potential to overcome certain limitations associated with traditional cycling, including range, grade, and speed [97]. Designing SVA infrastructure to accommodate diverse classes of electric bicycles is crucial for maximizing average modal speed for small vehicle commuting.

The lower speeds envisioned for SVA networks align with sustainability goals [98]. Higher speeds offer the advantage of increased range for a given travel time, however some research questions the value of increased speed [99]. Determining appropriate speed limits for SVA will likely involve ongoing discussion and analysis. Currently, small motorcycles, including some electric models, possess the size and weight characteristics suitable for SVA usage and can navigate existing LAT systems. The practice of lane splitting, permitted in certain jurisdictions, highlights the maneuverability of motorcycles in narrower lanes [100]. Similarly, microcars can navigate narrower lanes than automobiles [73] [74]. Continued development may enable smaller, LAT-capable automobiles to utilize SVA infrastructure.

Small, throttle-controlled vehicles, such as electric bicycles, motorcycles, and some electric cars, can be designed for a wide range of speeds. However, existing vehicle classifications, such as Class 3 vehicles with a maximum speed of 47 kph (28 mph) [101], provide a useful reference point. While the optimal maximum speed for SVA remains an open question, focusing on the Class 3 designation simplifies the discussion within this paper.

6.7 User Preference

A critical question for any proposed transportation system is its likely adoption rate. Will potential users embrace the new infrastructure? This question highlights the crucial role of user preferences in transportation system design. User preferences are a key feasibility factor, shaped by perceptions of safety, convenience, cost, and cultural norms. These perceptions can vary significantly across cities, countries, and individuals. Transportation designers must therefore strive to find optimal compromises for each design detail to encourage positive user perceptions [102]. Human perceptions can be surprisingly resistant to change [103]. Therefore, early investments in creating a positive user experience for initial SVA installations are likely to yield long-term benefits.

Meeting user needs is essential for the success of any transportation system. If perceived needs are unmet, users will likely opt for alternative modes [104]. Given that SVA are a novel concept, virtual highway environments could prove valuable in testing and correlating user perceptions with design variables.

User preference for the private automobile has profoundly shaped urban environments [105]. The core of the SVA proposal is to create urban highways that offer a level of service comparable to automobiles, particularly in congested areas [106]. The implementation of SVA could also incentivize vehicle manufacturers to design smaller vehicles that align with current automobile user perceptions.

Studies of Dutch-style bicycle highways have demonstrated that certain features, such as reduced interaction with motorized traffic, perceived safety, and increased speeds, attract users [107]. However, this preference for bicycle highways tends to diminish with increasing distance from the corridor. Research in Munich has also shown that investments in infrastructure can increase the share of walking and cycling [108]. These findings underscore the importance of studying human factors in the initial implementations of SVA, with the goal of replicating successful features in subsequent designs to maximize positive user perceptions.

The Level of Traffic Stress, based on Dutch design criteria, has been used as a metric to evaluate cycle paths [109]. SVA ramps, roundabouts, and elevated structures, especially if enclosed, present novel environmental experiences for users. Design details that contribute to perceived stress must be carefully considered. For example, the perceived stress of traversing a long, enclosed corridor without windows could potentially be mitigated through the strategic placement of windows.

Studies indicate that user route preference is often based on perceived route quality, with some cultural variations observed. For instance, cyclists in Greece are more likely to choose slower routes compared to their counterparts in Germany. However, the implementation of dedicated bike infrastructure along main streets appears to be a consistently preferred strategy across different user groups and locations, likely due to the increased order and predictability it provides [110] [111]. These findings suggest that users might favor elevated, non-stop, physically separated SVA lanes located near or above existing commercial streets.

Transportation amenities can be a significant factor in attracting visitors to urban areas [112]. While the novelty of the first SVA may initially draw users, the long-term appeal will likely depend on the availability of a transportation highway utilizing low-cost vehicles and facilitating easy access to urban amenities. The ability to park conveniently and transition seamlessly to pedestrian mode could transform congested urban centers into more desirable destinations.

6.8 Integration with Existing Transportation Networks

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

SVA pedestrian to street level

SVA Pedestrian to building on elevated walkway

SVA Class I to street

SVA Class I to SVA pedestrian

SVA Class 3 to street

SVA Class 3 to SVA pedestrian

Automobile Arterial to SVA Class 3

SVA or pedestrian

SVA 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 SVA Class 3 Interface

It is possible to design vehicles that meet both the criteria to travel along the traditional arterials and the SVA system, electric motorcycle is one such vehicle [113]. Micro cars could be developed which also meet both criteria for weight, size and speed [73]. Good speed control along SVA for these faster vehicles would be required to achieve acceptable perceived safety for SVA riders.

SVA to Mass Transit Interface

Rather than supplanting existing mass transit networks, SVA offer the potential for synergistic integration with long-distance, rapid transit systems [114]. In automobile-centric urban environments, where private vehicles often utilize LAT infrastructure for portions of their journeys, SVA can serve as a complementary mode to mass transit for shorter distances [115]. Considering that Class 3 vehicle speeds are approximately half those of LAT systems, the effective range of Class 3 vehicles is likely half that of automobiles using LAT infrastructure. This reduced range presents an opportunity for bus and rail networks to provide intermediate-range transportation, bridging the gap between small vehicle and automobile travel. Such integration could enhance the capacity and continued relevance of mass transit systems [116].

SVA Integration with Pedestrian Infrastructure and Building Access

Effective integration of SVA with existing pedestrian infrastructure and building access is crucial for seamless transitions between roadway and pedestrian modes. Various parking solutions can facilitate this transition, including valet services provided by existing vendors, automated parking systems [117], conventional surface lots, and designated parking areas within the SVA structure itself [118]. Specialized options, such as in-building valet services for bicycles and lockers for both standard and folding bicycles and microcars, can further enhance convenience. Parking locations can be strategically positioned near primary SVA corridors or along secondary arterials and collector roads.

Beyond parking, convenient pedestrian access to city amenities is essential. Stair and elevator towers can provide vertical connections between the SVA structure and street level, while bridge connections can facilitate direct access between buildings and the SVA, accommodating both pedestrians and small vehicles. Small vehicle ramps integrated with parking structures or lots can enable smooth transitions into commercial buildings.

Furthermore, incorporating slow-speed electric or manual transportation corridors within large new buildings, such as shopping malls or the lower levels of high-rise structures, can optimize mode switching convenience. These corridors can be designed as separate entities or fully integrated into the building's functionality, particularly in the case of pedestrian corridors. However, implementing such systems within existing buildings requires detailed feasibility studies to assess their practicality and impact.

6.9 Social Equity Considerations

Transportation social equity is a critical concern in urban planning, particularly for disadvantaged groups who may experience limitations due to socioeconomic status, education level, or physical disabilities. Early integration of equity considerations into the SVA development cycle is essential [119].

Several studies have explored how transportation planning can address economic disparities [120]. If SVA systems adopt similar financing models to existing LAT systems, user would directly pay only vehicle costs these vehicle purchase and operational costs will be lower [121].

Alignment choices also play a significant role in transportation equity. Routing studies should prioritize urban mobility for working-class communities, drawing on existing methodologies used in bicycle route planning to optimize accessibility and avoid potential pitfalls [122] [123]. Leveraging big data analysis in conjunction with an understanding of current transportation system shortcomings offers a valuable opportunity to design SVA alignments that enhance economic equity.

Furthermore, the novelty of SVA infrastructure allows for the integration of cutting-edge automated transportation technologies, such as fully autonomous vehicles. Such features could be particularly beneficial for users with physical limitations, increasing their independence and access to transportation [124]. Existing services and vehicles designed for disadvantaged riders on LAT systems can be adapted for SVA, potentially offering a high degree of personalized service.

The potential benefits of SVA for disadvantaged users include increased speed, lower costs, automation options, and enhanced service, especially for those who must use public transit options. These factors suggest that SVA implementation may not only avoid exacerbating existing transportation inequities but could also positively contribute to improved accessibility and mobility for diverse populations.

6.10 Climate and Health Impacts

Cycling offers numerous health benefits, including increased cognitive function [125], physical activity and exposure to the outdoors, but also carries risks related to route sensitive pollution exposure [126] and infrastructure precursors for accidents [127]. While both traditional and electric-assist (pedelec) bicycles offer positive health outcomes, the enclosed nature of some proposed SVA systems may limit the benefits associated with outdoor exposure [34] [125].

Traffic-related air pollution significantly contributes to poor urban air quality, and proximity to major roadways has been linked to an increased incidence of ischemic stroke [128]. Promoting alternative transportation options, such as public transit, ridesharing, walking, and cycling, is crucial for mitigating traffic emissions and improving public health . The implementation of SVA could encourage the use of zero-emission vehicles including active forms of travel, potentially contributing to positive health outcomes [129].

However, enclosed SVA systems raise concerns about indoor air quality, similar to those observed in subway systems [130]. Whether SVA are enclosed or open-air, careful analysis of potential pollutants is necessary. Given that many European cities have established low-emission zones [131], SVA, designed exclusively for zero-emission vehicles, could play a vital role in serving these zones and facilitating access to them.

The design of SVA enclosures will directly impact both indoor and outdoor pollution levels. Open-air systems expose users to ambient pollution, precipitation, and wind, while fully enclosed systems require strategically placed air intakes (e.g., on the roof of the SVA or adjacent buildings) to minimize pollution exposure within the corridor [132]. The implementation of nuanced policies, such as those adopted in Paris to reduce or eliminate automobiles from the city core, could be complemented by SVA systems, providing efficient small vehicle transportation to and from car-free zones [133].

Cycling safety concerns have increased in the USA [134]. While SVA offer the potential to improve perceived safety through physical separation of different vehicle classes and modes of travel [135], the increased use of small vehicles on local streets connecting to SVA could potentially lead to a rise in accident rates or severity for small children [136] [137]. This potential trade-off requires further investigation. Furthermore, while counter-intuitive, studies suggest that cities with higher bicycle usage may have lower bicycle-automobile accident rates but higher pedestrian fatality rates [138]. The underlying causes of these complex relationships warrant further research.

6.11 Technological Risk

Wind can significantly affect small vehicle operation, particularly in areas where wind is channeled by buildings or the SVA structure itself [139]. In enclosed designs, internal air movement generated by other vehicles can also influence vehicle operation [140]. Therefore, aerodynamic studies are essential to quantify these effects under various scenarios. Such studies are not technologically challenging if conducted properly and recommendations are implemented effectively.

Pedestrian accessibility, often referred to as "walkability," can be compromised by urban design, particularly in residential areas where pedestrian movement is often restricted to designated walkways [141]. In larger urban areas, street-level pedestrian activity can be exposed to safety concerns and inconveniences such as long wait times at crosswalks. Elevated SVA, incorporating continuously grade-separated walkways, offer the potential to enhance urban walkability by providing well-lit and camera-surveilled pedestrian corridors.

Designing camera surveillance systems for SVA with multiple access points presents a complex challenge. Such systems resemble city-wide surveillance networks rather than localized building surveillance. While these large-scale systems are feasible, security can be enhanced by integrating various technologies. For example, pedestrian access control points with tap-to-enter technology can identify individuals prior to entry and potentially serve as payment centers if fees are implemented.

The primary technological risk in SVA construction lies in the design and implementation of underground foundations, especially in congested urban environments. Underground investigations can necessitate the relocation of existing infrastructure, potentially leading to non-uniform span lengths for the elevated structure.

Fire and emergency response protocols for SVA will require specialized consideration due to the unique dimensions and loading characteristics of these structures. The evolving nature of battery fire risks, driven by increased scrutiny and ongoing research [142], necessitates the development of specific regulations and best practices. Battery safety is a complex issue [143], with fire risks varying depending on battery chemistry, which is a subject of continuous development and assessment [144]. Comprehensive regulations encompassing vehicle and battery design, fire suppression systems, egress design, building materials, ventilation, and emergency access will likely be required.

6.12 Integrating Emerging Technologies

The potential of emerging technologies within a novel highway network warrants careful consideration. Advancements such as fully autonomous driving, automated lane control systems, centralized vehicle control, enhanced security measures, wireless charging capabilities, and wireless communication networks [145] [146] [147].

Automating highway infrastructure for freight delivery and automated mass transit is a particularly promising area of development [148] [149]. Such automation could involve lane control mechanisms that physically restrict access to lanes designated for autonomous vehicles. These access controls could be implemented based on time of day or day of the week, granting autonomous vehicles exclusive use of specific lanes or even the entire roadway during designated periods. These dedicated zones could be unidirectional or limited to specific sections of the highway.

For instance, during off-peak hours (e.g., 10:00-11:00, 13:30-14:30, and 21:00-05:00), certain lanes could be reserved exclusively for autonomous vehicles, restricting access for human drivers. Road users would adapt to the dynamic allocation of lane capacity based on time of day.

When introducing new systems into existing urban environments, fully anticipating the outcomes can be challenging. However, a proactive approach that analyzes the potential impacts of new technologies is generally preferred over a reactive, laissez-faire approach [150]. While discussing the physical impacts of SVA and predicting user behavior based on economic needs is relatively straightforward, actual changes in travel behavior can be complex and sometimes counterintuitive [94].

Framing sustainability considerations in terms of outcomes such as induced demand, risky behavior, and efficiency improvements can help planners anticipate and manage both desirable and undesirable effects of new transportation paradigms [151].

Current literature lacks specific analysis of elevated SVA as a distinct transportation option. For instance, while some studies extensively discuss the rationale for implementing bicycle highways in urban areas, they often overlook the potential impacts of elevated designs [152]. This omission highlights a gap in the current transportation discourse, potentially limiting the consideration of all available possibilities.

Traditional traffic planning tools rely on comparisons with real-world conditions before and after infrastructure changes [153]. However, given that elevated SVA represent a novel technology without existing real-world implementations, the accuracy of these analytical tools remains uncertain until such systems are constructed and the tools are validated against empirical data.

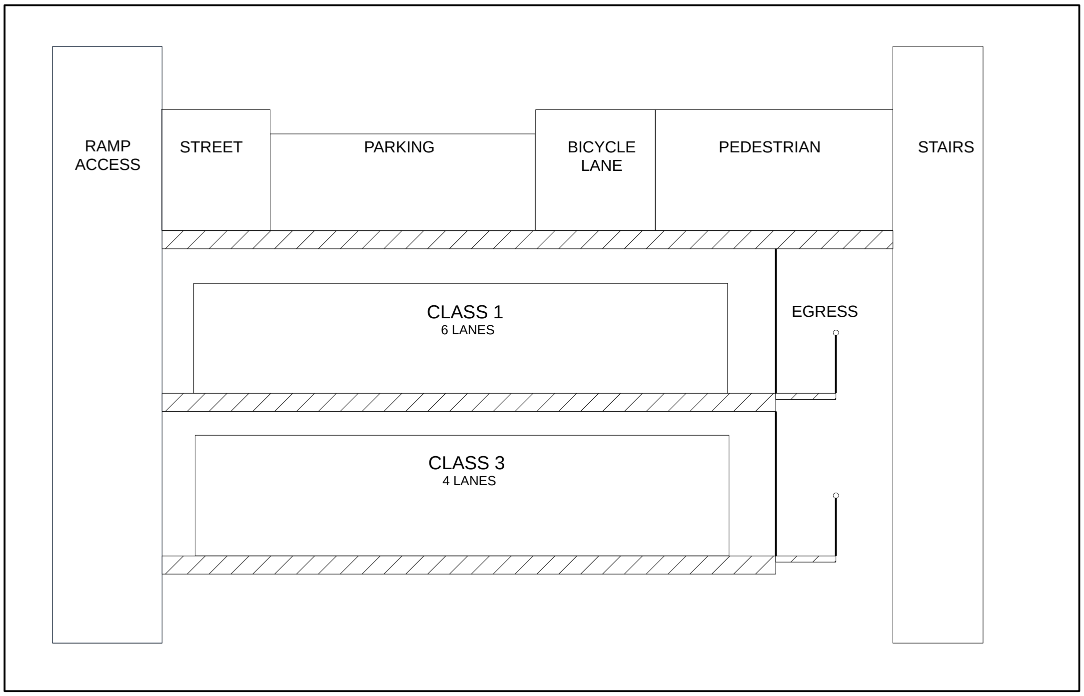
6.13 Awareness of Existing or Proposed SVA Designs

Dedicated elevated bicycle pathways are an increasingly prevalent solution for addressing specific urban transportation challenges [154] [155] [156] [157]. Notable examples of such infrastructure exist in Denmark, Germany, China, the Netherlands, and the USA. Dubai has proposed a large network of air conditioned walking paths [158].

Figure 4 depicts a proposed one-way SVA design using methodologies discussed in this article, integrating established urban roadway methodologies within a three-tiered elevated structure. The lower two levels accommodate continuous-flow traffic lanes for small vehicles, while the upper level prioritizes accessibility, featuring pedestrian walkways, bicycle lanes, and designated small vehicle parking to facilitate mode shifting. This configuration effectively separates four distinct travel modes: pedestrians, cyclists, and small vehicles operating on Class 1 and Class 3 roadways, while allowing intermingling of the modes along the local street. The design also incorporates a roof structure suitable for parking, recreational spaces, or urban parks [159]. Access between levels is provided via stairs, elevators, and ramps, integrated within dedicated chases. The design accommodates the integration of crossing highways above, below, or between the SVA levels. The uppermost level functions as a local street exclusively for small two, three, and four-wheeled vehicles. Designers can change the composition of each level as desired.

The modular design of the SVA corridors illustrated in Figure 4 allows for full or partial enclosure, mitigating the impact of atmospheric precipitation and potentially extreme climates. Restricting wind flow within enclosed corridors further enhances climate control. Seasonal enclosure offers flexibility in adapting to varying climatic conditions.

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



6 Lemmas Discussed in This Article

One way to understand the breadth of issues discussed in this article is to evaluate the lemmas discussed. Below is a table of lemmas in each section. This format resembles a topical outline for the article. No lemmas are included for the methodology section as this document is not intended to analyze itself.

Section	Lemmas

1	Introduction	Automobile dominance
		Roadway functional classes
		Active transportation marginalization
		SVA(s) SVA proposal
		Infrastructure comparison
		Cost-benefit analysis
		Safety and accessibility
		Scale and feasibility
		Trade-offs and mitigation
		Cost-Effectiveness of Elevated SVA
		Scalability and Urban Integration of SVA
		Multimodal Accessibility of SVA
		Balancing Benefits and Drawbacks of SVA
		Context-Specific Design Considerations for SVA
		Relevance of Bicycle Infrastructure Research to SVA Design
		Research Gap in Elevated SVA Roadways
		Demand for Improved E-bike Infrastructure
		Transferability of Findings from At-Grade Small Vehicle Studies
		Integrating SVA into Existing Bicycle Networks
		Addressing the Needs of Underserved Transportation Modes
		Prioritizing Active Transportation within SVA Design
		Multimodal Integration and Accessibility in SVA
		Balancing the Needs of Diverse User Groups
		Health and Livability Benefits of Active Transportation
3	Background	Integration Challenges of New Transportation Networks within Existing Urban Environments
		Cost-Effectiveness Analysis of Elevated SVA Systems
		Impact of Elevated SVA on Traffic Patterns and User Behavior
		Demand Forecasting for Novel Transportation Infrastructure
3.1	History and Evolution of the SVA concept	Origins and Development of the SVA Concept
		Adapting Limited Access Thoroughfare Principles for Small Vehicles
		Integrating SVA with Pedestrian Infrastructure
		The Role of Electric Vehicles in Shaping the SVA Concept

3.2 Comparison with Existing Transportation Systems	A Comparative Analysis of Roadway Functional Classifications and Their Relevance to SVA The Role of Limited Access Thoroughfares in Urban Transportation Networks and Their Implications for Small Vehicle Mobility Historical and Contemporary Examples of Elevated Bicycle and Small Vehicle Infrastructure Scaling Roadway Design Parameters for Small Vehicles: A Comparative Analysis of Automobile and Small Vehicle Infrastructure The Potential of SVA to Enhance Urban Mobility and Reduce Carbon Emissions Roadway Functional Classifications Roadway Mileage Distribution Traffic Distribution Limited Access Thoroughfares (LAT) Small Vehicle Road Usage Restrictions Bicycle Highways Roadway Design Parameters Roadway Scale Disparity Small Vehicle Efficiency and Emissions SVA Pedestrian Integration Small Vehicle Definition
3.3 Types of Small Vehicles for SVA	Defining the Scope of "Small Vehicles" in the Context of SVA Integrating Pedestrians and Human-Powered Transport into SVA Networks The Evolving Functionality of Small Vehicles and Its Implications for SVA Design Case Studies of Small Vehicle Types Suitable for SVA

3	Background	Feasibility of Urban Elevated SVA Accessibility and Equity Impacts of SVA Environmental Implications of SVA Regulatory Challenges for SVA Implementation Benefits and Challenges of Urban Elevated SVA Urban Arterials Small Vehicle Limited Access Thoroughfares Feeder Roads Signalized Streets Urban Highways Urban Limited Access Thoroughfares (LAT) Small Vehicle Prioritization Integrating New Transportation Networks with Existing Infrastructure Cost-Effectiveness of SVA Implementation Impact of SVA on User Behavior and Traffic Patterns Assessing Demand for SVA Infrastructure Public Perception and Acceptance of SVA
3.1	History and Evolution of the SVA concept	Urban Transportation Integration Limited Access Thoroughfares (LAT) Small Vehicle LAT(s) (SVLAT) Micromobility Egress and Pedestrian Access Elevated Urban Malls Bicycle Highways within Malls Feasibility and Implications Transportation System Comparison Multi-Modal Transportation
3.2	Comparison with Existing Transportation Systems	A Comparative Analysis of Roadway Functional Classifications and Their Relevance to SVA The Role of LAT in Urban Transportation Networks and Their Implications for SVA Historical and Contemporary Examples of Elevated Bicycle and Small Vehicle Infrastructure Scaling Roadway Design Parameters for Small Vehicles: A Comparative Analysis of Automobile and Small Vehicle Infrastructure The Potential of SVA to Enhance Urban Mobility and Reduce Carbon Emissions

3.3	Types of Small Vehicles for SVA	Defining the Scope of "Small Vehicles" in the Context of SVA Integrating Pedestrians and Human-Powered Transport into SVA Networks The Evolving Functionality of Small Vehicles and Its Implications for SVA Design Case Studies of Small Vehicle Types Suitable for SVA
4	Benefits of SVA	The Impact of Elevated SVA on Urban Traffic Congestion The Effects of SVA on Urban Mobility and Accessibility The Economic Benefits of SVA: A Cost-Benefit Analysis The Land Use Implications of SVA: Minimizing Surface Impacts A Critical Evaluation of the Potential Benefits and Challenges of SVA Implementation
4.1	Increased Transportation Capacity	Consistent driver experience in terms of vehicle controls and perceived highway design results in similar driver reaction times. Fundamental model with uniform time gaps between vehicles, dictated by consistent driver reaction times, determine lane capacity. Adherence to the "two-second rule" makes lane capacity largely independent of vehicle speed.
4.2	Reduced Traffic Congestion	The Potential of Elevated SVA for Congestion Relief A Comparative Analysis of Traditional and Innovative Congestion Mitigation Strategies The Impact of Electric Automobiles on Urban Traffic Congestion Optimizing the Location of SVA for Maximum Congestion Relief The Role of Land Use in Urban Traffic Congestion and Mitigation Strategies
4.3	Improved Urban Mobility	The Potential of SVA Systems to Improve Urban Mobility and Accessibility A Comparative Analysis of Congestion Pricing and SVA Systems The Economics of Scale in the Production of Small Vehicles The Impact of Vehicle Size on Transportation Costs and Emissions The Role of SVA Systems in Promoting Sustainable Transportation
4.4	Reduced parking costs	The Economic Benefits of Reduced Parking Costs for Small Vehicles The Impact of Parking Costs on Mode Choice and Transportation Policy The Relationship Between Vehicle Size and Parking Requirements Innovative Parking Solutions for Small Vehicles in Urban Environments The Role of Parking Costs in the Economic Justification for SVA

4.5	Reduced vehicle costs	Cost Savings Economies of Scale Societal Costs Vehicle Purchase Price Dedicated Infrastructure Material and Manufacturing Cost Savings in SVA Vehicles Reduced Battery Requirements and Associated Cost Savings in SVA Electric Vehicles Lower Overall Ownership Costs for SVA Vehicles Comparison of Kei Car Costs in Japan as an Analogy for SVA Vehicle Costs
4.6	Reduced land use	Land Use Efficiency of Elevated SVA Minimizing Disruption to Existing Urban Functions Cost Mitigation through Optimized SVA Alignment Repurposing Urban Land Following SVA Implementation Integrating SVA Supports with Existing Infrastructure
4.7	Auxiliary Uses for Structure	SVA Multi-Functionality Urban Utility Integration Auxiliary Uses Cost-Effectiveness of Adaptability Utility Maintenance and Repair Resilience to Environmental Hazards Alternative Utility Routing
4.8	Improved Accessiblity	Accessibility Benefits of Active Transportation Integrating Accessibility into SVA Design Economic Benefits of Prioritizing Active and Public Transportation Operational Similarities and Differences between SVA, Public Transit, and Automobile Infrastructure Potential Deficiencies of SVA and Mitigation Strategies
4.9	Increased Average Modal Speed	The Impact of Modal Shifts and Urban Environment on Average Trip Speed Challenges in Modeling Passenger Behavior and Trip Generation for Novel Transportation Systems Evaluating the Potential of Elevated SVA Arterials to Improve Urban Mobility The Influence of Traffic Impediments on Average Modal Speed in Urban Environments Comparing Average Modal Speeds for Different Modes of Transportation in Urban Areas

5	Costs for SVA Infrastructure	Land Acquisition Costs for SVA Construction Costs for SVA Comparison of Cost Precursors for Traditional Urban Arterials and SVA Challenges in Estimating SVA Infrastructure Costs
5.1	Land Acquisition Costs	Minimizing Land Acquisition Costs in SVA Implementation Economic Benefits of Integrating Small Electric Vehicles into Urban Transportation Networks The "Arms Race" in Automobile Size and Its Impact on Transportation Costs and Emissions Congestion Pricing and SVA Systems: A Comparative Analysis of Their Effects on Urban Mobility The Societal Costs of Traditional Automobiles vs. Small Electric Vehicles
5.2	SVA vs. Automobile Arterial Costs	Cost Optimization Strategies for Elevated SVA Construction Structural Design Considerations for Elevated SVA Integration of Building Codes and Bridge Design Standards for SVA Structures Impact of Microcar Adoption on the Feasibility and Design of SVA Systems Underground Utility Interference Mitigation in SVA Routing and Design
5.3	SVA Spacing	Optimization of SVA Arterial Spacing for Cost-Effectiveness and Coverage The Role of SVA in Addressing Last-Mile Challenges in Urban Transportation Impact of SVA Alignment Flexibility on System Costs and Accessibility Comparison of SVA Spacing Requirements with Other Urban Transportation Infrastructure Influence of Commuting Patterns on SVA System Design and Planning
6	Challenges for SVA Implementation	Public Acceptance of SVA Funding Mechanisms for SVA Development Addressing Transportation Needs in Underserved Communities Balancing the Benefits and Challenges of SVA Overcoming Barriers to SVA Adoption
6.1	Economic Justification and Potential Applications of Elevated SVA Networks	Cost-Benefit Analysis of Elevated SVA Systems Compared to Traditional Highway Infrastructure The Role of Elevated SVA in Enhancing Urban Mobility and Accessibility SVA as a Climate-Resilient Transportation Solution for Coastal Cities Impact of SVA on Traffic Congestion and Travel Times Environmental Impacts of SVA Construction and Operation Public Acceptance and Perceptions of SVA Regulatory and Policy Considerations for SVA Implementation Comparison of SVA with Other Urban Transportation Solutions

6.2 Integrating SVA within Existing Urban Infrastructure: A Feasibility Study	Spatial Requirements for SVA Integration in Urban Environments Design Considerations for SVA Intersections and Vertical Alignment
	Case Study: Feasibility Analysis of SVA Integration in a Dense Urban Setting
6.3 Vehicle Design and Regulatory Considerations for SVA	Vehicle Fleet Composition and Operational Models for SVA
	Safety Regulations and Standards for SVA Vehicles
	The Impact of SVA on Vehicle Design Innovation
6.4 Technical Challenges in SVA Infrastructure Development	Human Factors Considerations in SVA Design
	Operational Advantages and Opportunities of SVA Infrastructure
	Integration of SVA Networks into Existing Urban Environments
	The Need for Standardized Signage on SVA
	Comparing Signage Requirements for Automobiles and Small Vehicles on Highways
	Adapting Existing Traffic Control Devices for SVA
6.5 Potential Detrimental Effects of Elevated SVA and Mitigation Strategies	Visual Impact of Elevated SVA Networks on Urban Landscapes
	Mitigation Strategies for Environmental Impacts of SVA
	Social Implications of SVA systems and Strategies for Promoting Social Interaction
6.6 Regulatory Frameworks and Design Considerations for SVA Networks	Regulatory Adaptation for SVA networks
	Impact of SVA speed on Range and User Adoption
	Optimizing SVA Design for Electric Bicycle Integration
	Safety and Operational Considerations for Mixed Vehicle Usage on SVA
6.7 User Preference	Influence of User Preferences on Transportation System Design
	Utilizing Virtual Environments for User Preference Testing
	Impact of SVA on Vehicle Design and User Perceptions
	Level of Traffic Stress and its Implications for SVA Design
	Cultural Factors Influencing Route Preference
	The Role of Transportation Amenities in Urban Attractiveness
6.8 Integration with Existing Transportation Networks	Dual-Mode Vehicle Design for SVA Integration
	Safety Considerations for Dual-Mode Vehicles on SVA
	Impact of Dual-Mode Vehicles on SVA Capacity and Efficiency
	SVA-Mass Transit Integration
	Range Limitations of Small Vehicles
	Mass Transit as a Bridge for SVA Range Gaps
	SVA-Pedestrian Interface Design
	Parking Solutions for SVA
	Building Integration with SVA
	Feasibility of Retrofitting Existing Buildings for SVA Access

6.9	Social Equity Considerations	Transportation Equity and SVA
		SVA Alignment and Accessibility
		Automation and Accessibility in SVA
		Cost-Effectiveness of SVA for Disadvantaged Riders
		Adapting Existing Services for SVA
6.10	Climate and Health Impacts	SVA and Air Quality
		SVA and Cycling Safety
		SVA and Pedestrian Safety
		Enclosed vs. Open-Air SVA
		SVA Integration with Low-Emission Zones
		Health Benefits of Cycling in the Context of SVA
		Accident Severity in Small Vehicles
6.11	Technological Risk	Aerodynamic Considerations for SVA Design
		Enhancing Urban Walkability through Elevated SVA
		Security and Access Control Systems for SVA
		Technological and Logistical Challenges in SVA Construction
		Fire and Emergency Response Strategies for SVA
		Predicting the Impacts of SVA on Urban Environments
		Analyzing User Behavior and Travel Patterns on SVA
		Sustainability Assessment of Elevated SVA
		Methodological Challenges in Evaluating Novel Transportation Systems
6.12	Integrating Emerging Technologies	Evaluating the Effectiveness of Traffic Planning Tools for Novel Transportation Systems
		The Need for Empirical Validation of Traffic Models for Elevated SVA
		Predictive Capabilities of Traffic Planning Tools in the Absence of Real-World Data
6.13	Awareness of Existing or Proposed SVA Designs	Elevated Bicycle Pathways
		Urban Transportation Challenges
		Infrastructure Solutions
		International Examples
		Multi-Modal Integration in SVA Design
		Climate Control in Elevated SVA Corridors
		Accessibility and Mode Shifting in SVA
		Integrating SVA Structures with Existing Urban Environments
		Optimizing SVA Design for Traffic Flow and Safety

References

[1].…K. Boussauw, E. Papa, and K. Fransen, “Car Dependency and Urban Form,” *UP*, vol. 8, no. 3, pp. 1–5, Jul. 2023, doi: 10.17645/up.v8i3.7260.
[2].…..American Association of State Highway and Transportation Officials, Ed., *A policy on geometric design of highways and streets*, 4. ed., 2. print. Washington, DC: AASHTO, 2001.
[3]...........“Highway Functional Classification: Concepts, Criteria and Procedures,” U.S. Department of Transportation. Federal Highway Administration., 2023. [Online]. Available: https://www.fhwa.dot.gov/planning/processes/statewide/related/hwy-functional-classification-2023.pdf
[4]....S. Gössling, “Why cities need to take road space from cars - and how this could be done,” *Journal of Urban Design*, vol. 25, no. 4, pp. 443–448, Jul. 2020, doi: 10.1080/13574809.2020.1727318.
[5]. E. Sadeghvaziri, R. Javid, and M. Jeihani, “Active Transportation for Underrepresented Populations in the United States: A Systematic Review of Literature,” *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2678, no. 6, pp. 403–414, Jun. 2024, doi: 10.1177/03611981231197659.
[6]…Zoabe Hafeez, “Driving Progress: Health and Economic Effects of Arterial Thoroughfare Design,” Rice University’s Baker Institute for Public Policy, Issue Brief, Jan. 2024. [Online]. Available: https://www.bakerinstitute.org/research/driving-progress-health-and-economic-effects-arterial-thoroughfare-design
[7]........W. Schade, “Comparison of Innovation Systems of Different Transport Modes and the Need for Public Intervention,” *Transportation Research Procedia*, vol. 14, pp. 4105–4112, 2016, doi: 10.1016/j.trpro.2016.05.508.
[8]…E. Cascetta and I. Henke, “The seventh transport revolution and the new challenges for sustainable mobility,” *Journal of Urban Mobility*, vol. 4, p. 100059, Dec. 2023, doi: 10.1016/j.urbmob.2023.100059.
[9].............“Rebound: unintended consequences of transport policy and technology,” The Institution of Engineering and Technology, 2010. [Online]. Available: https://www.theiet.org/media/3436/rebound.pdf
[10]..A. Weiss, S. Pollock, and L. Kattan, “Scooting into place: How comfort on different infrastructure types influences shared e-scooter trip making,” *Journal of Cycling and Micromobility Research*, vol. 2, p. 100047, Dec. 2024, doi: 10.1016/j.jcmr.2024.100047.
[11].........S. Çolak, A. Lima, and M. C. González, “Understanding congested travel in urban areas,” *Nat Commun*, vol. 7, no. 1, p. 10793, Mar. 2016, doi: 10.1038/ncomms10793.
[12].….G. De Rus, M. P. Socorro, J. Valido, and J. Campos, “Cost-benefit analysis of transport projects: Theoretical framework and practical rules,” *Transport Policy*, vol. 123, pp. 25–39, Jul. 2022, doi: 10.1016/j.tranpol.2022.04.008.
[13]..........D. V. Achillopoulou, S. A. Mitoulis, S. A. Argyroudis, and Y. Wang, “Monitoring of transport infrastructure exposed to multiple hazards: a roadmap for building resilience,” *Science of The Total Environment*, vol. 746, p. 141001, Dec. 2020, doi: 10.1016/j.scitotenv.2020.141001.
[14]…H. S. Pereira and B. J. Navarro, “The implementation and development of narrow-gauge railways in Portugal as a case of knowledge transfer (*c.* 1850– *c.* 1910),” *The Journal of Transport History*, vol. 39, no. 3, pp. 355–380, Dec. 2018, doi: 10.1177/0022526618791726.
[15]..........E. Carlson, “E-Bikes and the Bike Infrastructure of the Future,” Los Angeles, CA 90010, Jan. 2023. [Online]. Available: https://www.planetizen.com/features/120766-e-bikes-and-bike-infrastructure-future

[16]……D. Capasso Da Silva, D. A. King, and S. Lemar, “Accessibility in Practice: 20-Minute City as a Sustainability Planning Goal,” *Sustainability*, vol. 12, no. 1, p. 129, Dec. 2019, doi: 10.3390/su12010129.
[17]. “AMERICA’S INTERSTATE HIGHWAY SYSTEM AT 65,” TRIP, Washington, D.C., Jun. 2021. [Online]. Available: https://tripnet.org/wp-content/uploads/2021/06/TRIP_Interstate_Report_June_2021.pdf
[18]G. J. Cabral Dias and P. J. Gomes Ribeiro, “Cycle Highways: a new concept of infrastructure,” *European Planning Studies*, vol. 29, no. 6, pp. 1003–1020, Jun. 2021, doi: 10.1080/09654313.2020.1752154.
[19]..........R. F. Weingroff, “The Genie in The Bottle: The Interstate System and Urban Problems, 1939-1957,” Turner-Fairbank Highway Research Center, McLean, VA 22101, Vol. 64 No. 2, Oct. 2000. [Online]. Available: https://highways.dot.gov/public-roads/septoct-2000/genie-bottle-interstate-system-and-urban-problems-1939-1957
[20]..........Burton, T J, “ELEVATED CYCLE PATH: A Suggestion for One Through Eighth Avenue and Hudson Street.,” *ProQuest Historical Newspapers: The New York Times with Index*, New York, Jan. 11, 1896. [Online]. Available: https://www.nytimes.com/1896/01/11/archives/elevated-cycle-path-a-suggestion-for-one-through-eighth-avenue-and.html
[21]........O. Wainwright, “Norman Foster unveils plans for elevated ‘SkyCycle’ bike routes in London,” Article, Jan. 2014. [Online]. Available: https://www.theguardian.com/artanddesign/architecture-design-blog/2014/jan/02/norman-foster-skycycle-elevated-bike-routes-london
[22]……Emmanuel Augustine Etukudoh, Adedayo Adefemi, Valentine Ikenna Ilojianya, Aniekan Akpan Umoh, Kenneth Ifeanyi Ibekwe, and Zamathula Queen Sikhakhane Nwokediegwu, “A Review of sustainable transportation solutions: Innovations, challenges, and future directions,” *World J. Adv. Res. Rev.*, vol. 21, no. 1, pp. 1440–1452, Jan. 2024, doi: 10.30574/wjarr.2024.21.1.0173.
[23]............A. Amin, B. Altinoz, and E. Dogan, “Analyzing the determinants of carbon emissions from transportation in European countries: the role of renewable energy and urbanization,” *Clean Techn Environ Policy*, vol. 22, no. 8, pp. 1725–1734, Oct. 2020, doi: 10.1007/s10098-020-01910-2.
[24]……“FHWA Home / Safety / Speed Management / USLIMITS2,” Federal Highway Administration, Sep. 2020. [Online]. Available: https://safety.fhwa.dot.gov/uslimits/more_info.cfm?p=rtetyp_info
[25]…..National Association of City Transportation Officials, Ed., *Urban bikeway design guide*, 2nd ed. New York: National Association of City Transportation Officials, 2012.
[26]M. Giannoulaki and Z. Christoforou, “Pedestrian Walking Speed Analysis: A Systematic Review,” *Sustainability*, vol. 16, no. 11, p. 4813, Jun. 2024, doi: 10.3390/su16114813.
[27]...........C. Adriazola-Steil, D. Pérez-Barbosa, B. Batista, N. Luke, W. Li, and A. Bray Sharpin, “Safe Bicycle Lane Design Principles: Responding to Cycling Needs in Cities during COVID and Beyond,” *WRIPUB*, 2021, doi: 10.46830/wrigb.20.00063.
[28]...............................*Bridge Formula Weights*, FHWA-HOP-19-028, Aug. 2019. [Online]. Available: https://ops.fhwa.dot.gov/freight/publications/brdg_frm_wghts/fhwahop19028.pdf
[29]. .*A Policy on Design Standards—Interstate System*, 6th ed. American Association of State Highway and Transportation Officials, 2016.
[30]…K. H. Alexander Grausam, T. M. Benedikt Kloss, and Darius Scurtu, “Minimobility: The next big thing in urban mobility?,” McKinsey Center for Future Mobility, Sep. 2022. [Online]. Available: https://www.mckinsey.com/features/mckinsey-center-for-future-mobility/mckinsey-on-urban-mobility/minimobility-the-next-big-thing-in-urban-mobility
[31]...............D. Alcázar-García and L. R. Martínez, “Micromobility and smart cities: efficiency, energy consumption and range analysis for electric vehicles,” *Renew. Energy Environ. Sustain.*, vol. 7, p. 14, 2022, doi: 10.1051/rees/2021052.
[32].........Tom McCarran, Nicole Carpenter, “Electric Bikes: Survey and Energy Efficiency Analysis,” EFFICIENCY VERMONT, DSS TECH DEMO REPORT 000–053, Mar. 2018. [Online]. Available:

https://www.efficiencyvermont.com/Media/Default/docs/white-papers/efficiency-vermont-electric-bike-white-paper.pdf

[33].......David Gohlke, Yan Zhou, Xinyi Wu, and Calista Courtney, “Assessment of Light-Duty Plug-in Electric Vehicles in the United States, 2010 – 2021,” Argonne National Laboratory, U.S. DOE, ANL-22/71, Nov. 2022. [Online]. Available: https://publications.anl.gov/anlpubs/2022/11/178584.pdf

[34].......H. B. Sundfør and A. Fyhri, “A push for public health: the effect of e-bikes on physical activity levels,” *BMC Public Health*, vol. 17, no. 1, p. 809, Dec. 2017, doi: 10.1186/s12889-017-4817-3.

[35]........F. Gaglione, C. Gargiulo, F. Zucaro, and C. Cottrill, “Urban accessibility in a 15-minute city: a measure in the city of Naples, Italy,” *Transportation Research Procedia*, vol. 60, pp. 378–385, 2022, doi: 10.1016/j.trpro.2021.12.049.

[36]Transportation Research Board and National Academies of Sciences, Engineering, and Medicine, *Highway Capacity Manual 7th Edition: A Guide for Multimodal Mobility Analysis*. Washington, D.C.: National Academies Press, 2022, p. 26432. doi: 10.17226/26432.

[37].S. Darbha, K. R. Rajagopal, and V. Tyagi, “A review of mathematical models for the flow of traffic and some recent results,” *Nonlinear Analysis: Theory, Methods & Applications*, vol. 69, no. 3, pp. 950–970, Aug. 2008, doi: 10.1016/j.na.2008.02.123.

[38].............Barton-Aschman Associates, Inc. and Cambridge Systematics, Inc., “Model Validation and Reasonableness Checking Manual,” Travel Model Improvement Program Federal Highway Administration, Manual FHWA-EP-01-023, Jun. 2001. [Online]. Available: https://rosap.ntl.bts.gov/view/dot/66008

[39]....L. A. Pipes, “An Operational Analysis of Traffic Dynamics,” *Journal of Applied Physics*, vol. 24, no. 3, pp. 274–281, Mar. 1953, doi: 10.1063/1.1721265.

[40] C. J. Colbourn, I. D. Brown, and A. K. Copeman, “Drivers’ Judgments of Safe Distances in Vehicle Following,” *Hum Factors*, vol. 20, no. 1, pp. 1–11, Feb. 1978, doi: 10.1177/001872087802000101.

[41]R. Jurecki and M. Poliak, “The Impact of the Safe following Distance onto the Traffic Safety,” *Komunikácie*, vol. 26, no. 1, pp. A37–A49, Jan. 2024, doi: 10.26552/com.C.2024.014.

[42]..................J. E. Vance, *Capturing the horizon: the historical geography of transportation since the transportation revolution of the sixteenth century*. New York, NY: Harper & Row, 1986.

[43]......G. Duranton and M. A. Turner, “The Fundamental Law of Road Congestion: Evidence from US Cities,” *American Economic Review*, vol. 101, no. 6, pp. 2616–2652, Oct. 2011, doi: 10.1257/aer.101.6.2616.

[44].....“TRAFFIC CONGESTION AND RELIABILITY: TRENDS AND ADVANCED STRATEGIES FOR CONGESTION MITIGATION,” Federal Highway Administration’s (FHWA) Office of Operations, 7091.720, Sep. 2005. [Online]. Available: https://ops.fhwa.dot.gov/congestion_report/

[45].....T. Wang, T.-Q. Tang, H.-J. Huang, and X. Qu, “The adverse impact of electric vehicles on traffic congestion in the morning commute,” *Transportation Research Part C: Emerging Technologies*, vol. 125, p. 103073, Apr. 2021, doi: 10.1016/j.trc.2021.103073.

[46]……A. Grigorev, T. Mao, A. Berry, J. Tan, L. Purushothaman, and A.-S. Mihaita, “How will electric vehicles affect traffic congestion and energy consumption: an integrated modelling approach,” 2021, *arXiv*. doi: 10.48550/ARXIV.2110.14064.

[47]….N. Brinkel, T. AlSkaif, and W. Van Sark, “Grid congestion mitigation in the era of shared electric vehicles,” *Journal of Energy Storage*, vol. 48, p. 103806, Apr. 2022, doi: 10.1016/j.est.2021.103806.

[48]. D. N. D. Jayaratne and H. R. Pasindu, “Empirical study on capacity evaluation of urban multi-lane roads under heterogeneous traffic conditions,” *Transportation Research Procedia*, vol. 48, pp. 3595–3606, 2020, doi: 10.1016/j.trpro.2020.08.092.

[49]C. Winston and J. Yan, “Vehicle size choice and automobile externalities: A dynamic analysis,” *Journal of Econometrics*, vol. 222, no. 1, pp. 196–218, May 2021, doi: 10.1016/j.jeconom.2020.07.032.

[50]..........Wikipedia contributors, “Congestion pricing, 1259631338,” *Wikipedia*. Wikipedia, The Free Encyclopedia., Nov. 26, 2024. Accessed: Dec. 08, 2024. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Congestion_pricing&oldid=1259631338
[51]........Matt Sussman, “The Impact of Transportation on Affordability: An Analysis of Parking Cost,” Manhattan Strategy Group, 2013, HUD Contract C-DEN-02518: HTA Index. [Online]. Available: https://files.hudexchange.info/resources/documents/Analysis-of-Parking-Cost.pdf
[52]….A. Lee and A. March, “Recognising the economic role of bikes: sharing parking in Lygon Street, Carlton,” *Australian Planner*, vol. 47, no. 2, pp. 85–93, Jun. 2010, doi: 10.1080/07293681003767785.
[53]. .S. Gössling and A. S. Choi, “Transport transitions in Copenhagen: Comparing the cost of cars and bicycles,” *Ecological Economics*, vol. 113, pp. 106–113, May 2015, doi: 10.1016/j.ecolecon.2015.03.006.
[54].........Derek Markham, “E-Bikes Are Radically More Efficient Than Electric Cars,” CleanTechnica, 2023. [Online]. Available: https://cleantechnica.com/2023/12/11/e-bikes-are-radically-more-efficient-than-electric-cars/
[55]. .M. C. Rodríguez-Villalobos and J. G. García-Martínez, “Economies of Scale and Minimization of the Cost: Evidence from a Manufacturing Company,” *JEERBE*, vol. 2018, pp. 1–16, Jan. 2018, doi: 10.5171/2018.128823.
[56]I. Graessler and X. Yang, “Product life cycle cost approach for modular lightweight design,” *Procedia CIRP*, vol. 84, pp. 1048–1053, 2019, doi: 10.1016/j.procir.2019.03.199.
[57]……M. Tanishita, B. V. Wee, and （Corresponding Author）, “Car ownership and usage in Japan: a comparison of Kei-cars and other cars,” 2018, doi: 10.13140/RG.2.2.28340.71047.
[58]. D. M. Nguyen, M. A. Kishk, and M.-S. Alouini, “Dynamic charging as a complementary approach in modern EV charging infrastructure,” *Sci Rep*, vol. 14, no. 1, p. 5785, Mar. 2024, doi: 10.1038/s41598-024-55863-3.
[59]...........E. Guerra, G. Duranton, and X. Ma, “Urban Roadway in America: The Amount, Extent, and Value,” *Journal of the American Planning Association*, pp. 1–15, Aug. 2024, doi: 10.1080/01944363.2024.2368260.
[60].........K. J. Hansmann, M. Grabow, and C. McAndrews, “Health equity and active transportation: A scoping review of active transportation interventions and their impacts on health equity,” *Journal of Transport & Health*, vol. 25, p. 101346, Jun. 2022, doi: 10.1016/j.jth.2022.101346.
[61]….K. Lee and I. N. Sener, “E-bikes Toward Inclusive Mobility: A Literature Review of Perceptions, Concerns, and Barriers,” *Transportation Research Interdisciplinary Perspectives*, vol. 22, p. 100940, Nov. 2023, doi: 10.1016/j.trip.2023.100940.
[62]...........J. Eliasson, F. Kopsch, S. Mandell, and M. Wilhelmsson, “Transport Mode and the Value of Accessibility–A Potential Input for Sustainable Investment Analysis,” *Sustainability*, vol. 12, no. 5, p. 2143, Mar. 2020, doi: 10.3390/su12052143.
[63]...........Dana Yanocha and Sarah Mawdsley, “Making the Economic Case for Cycling,” Institute for Transportation and Development Policy. [Online]. Available: https://itdp.org/wp-content/uploads/2022/06/Making-the-Economic-Case-for-Cycling_6-13-22.pdf
[64]............U. Lachapelle and G. Boisjoly, “Breaking down public transit travel time for more accurate transport equity policies: A trip component approach,” *Transportation Research Part A: Policy and Practice*, vol. 175, p. 103756, Sep. 2023, doi: 10.1016/j.tra.2023.103756.
[65]…M. Salonen and T. Toivonen, “Modelling travel time in urban networks: comparable measures for private car and public transport,” *Journal of Transport Geography*, vol. 31, pp. 143–153, Jul. 2013, doi: 10.1016/j.jtrangeo.2013.06.011.
[66].........L. Pearson *et al.*, “Effectiveness of interventions for modal shift to walking and bike riding: a systematic review with meta-analysis,” Jul. 31, 2024, *Public and Global Health*. doi: 10.1101/2024.07.29.24311197.

[67]……L. Frank, M. Bradley, S. Kavage, J. Chapman, and T. K. Lawton, “Urban form, travel time, and cost relationships with tour complexity and mode choice,” *Transportation*, vol. 35, no. 1, pp. 37–54, Nov. 2007, doi: 10.1007/s11116-007-9136-6.
[68]...........S. Tsafarakis, P. Gkorezis, D. Nalmpantis, E. Genitsaris, A. Andronikidis, and E. Altsitsiadis, “Investigating the preferences of individuals on public transport innovations using the Maximum Difference Scaling method,” *Eur. Transp. Res. Rev.*, vol. 11, no. 1, p. 3, Dec. 2019, doi: 10.1186/s12544-018-0340-6.
[69]......R. Ewing and R. Cervero, “Travel and the Built Environment: A Meta-Analysis,” *Journal of the American Planning Association*, vol. 76, no. 3, pp. 265–294, Jun. 2010, doi: 10.1080/01944361003766766.
[70].................“Methods and Practices for Setting Speed Limits: An Informational Report,” Institute of Transportation Engineers, Washington, DC, Handbook FHWA-SA-12-004, Apr. 2012. [Online]. Available: https://safety.fhwa.dot.gov/speedmgt/ref_mats/fhwasa12004/fhwasa12004.pdf
[71].........*AASHTO guide specifications for LRFD seismic bridge design*, 3rd edition. Washington, DC: American Association of State Highway and Transportation Officials, 2023.
[72]. Michael A. Grubb, P.E., Kenneth E. Wilson, P.E., S.E., Christopher D. White, and P.E., William N. Nickas, P.E., *LRFD for Highway Bridge Superstructures*, REFERENCE MANUAL FHWA-NHI-15-047, Apr. 2007. [Online]. Available: https://rosap.ntl.bts.gov/view/dot/43721/dot_43721_DS1.pdf
[73]........H. E. Masry, M. E. Esawey, K. El-Araby, and A. Osama, “Operational Impact of Microcars on Urban and Suburban Road Corridors,” *Transportation Research Record: Journal of the Transportation Research Board*, vol. 2676, no. 6, pp. 488–502, Jun. 2022, doi: 10.1177/03611981221075022.
[74]........I. Loustric and M. Matyas, “Exploring city propensity for the market success of micro-electric vehicles,” *Eur. Transp. Res. Rev.*, vol. 12, no. 1, p. 42, Dec. 2020, doi: 10.1186/s12544-020-00416-8.
[75]…J. He, F. Pan, and C. S. Cai, “A review of wood-frame low-rise building performance study under hurricane winds,” *Engineering Structures*, vol. 141, pp. 512–529, Jun. 2017, doi: 10.1016/j.engstruct.2017.03.036.
[76].A. J. Al-Bayati and L. Panzer, “Reducing Damage to Underground Utilities: Lessons Learned from Damage Data and Excavators in North Carolina,” *J. Constr. Eng. Manage.*, vol. 145, no. 12, p. 04019078, Dec. 2019, doi: 10.1061/(ASCE)CO.1943-7862.0001724.
[77]......T. Zuo, H. Wei, N. Chen, and C. Zhang, “First-and-last mile solution via bicycling to improving transit accessibility and advancing transportation equity,” *Cities*, vol. 99, p. 102614, Apr. 2020, doi: 10.1016/j.cities.2020.102614.
[78].................American Association of State Highway and Transportation Officials, Ed., *Guide for the development of bicycle facilities*, Fourth edition. Washington, DC: American Association of State Highway and Transportation Officials, 2012.
[79]…HERBERT S. LEVINSON, “Street Spacing and Scale,” Transportation Research Board, E-C019, Dec. 2000. [Online]. Available: https://onlinepubs.trb.org/onlinepubs/circulars/ec019/Ec019_b7.pdf
[80].......J. Shin, C. R. Bhat, D. You, V. M. Garikapati, and R. M. Pendyala, “Consumer preferences and willingness to pay for advanced vehicle technology options and fuel types,” *Transportation Research Part C: Emerging Technologies*, vol. 60, pp. 511–524, Nov. 2015, doi: 10.1016/j.trc.2015.10.003.
[81]......Emmanuel Augustine Etukudoh, Adedayo Adefemi, Valentine Ikenna Ilojianya, Aniekan Akpan Umoh, Kenneth Ifeanyi Ibekwe, and Zamathula Queen Sikhakhane Nwokediegwu, “A Review of sustainable transportation solutions: Innovations, challenges, and future directions,” *World J. Adv. Res. Rev.*, vol. 21, no. 1, pp. 1440–1452, Jan. 2024, doi: 10.30574/wjarr.2024.21.1.0173.
[82]................C. Gratton and H. Preuss, “Maximizing Olympic Impacts by Building Up Legacies,” *The International Journal of the History of Sport*, vol. 25, no. 14, pp. 1922–1938, Dec. 2008, doi: 10.1080/09523360802439023.

[83].........G. Lopes Dos Santos, R. Macário, M. Delaplace, and S. Di Vita, “The Long-Standing Issue of Mobility at the Olympics: From Host Cities to Host Regions in the Ongoing Case Study of Milan–Cortina 2026,” *Sustainability*, vol. 14, no. 2, p. 910, Jan. 2022, doi: 10.3390/su14020910.

[84]…M. Mitchell, J. Hendricks, and D. Schatt, “Road network analyses elucidate hidden road flooding impacts under accelerating sea level rise,” *Front. Environ. Sci.*, vol. 11, p. 1083282, Mar. 2023, doi: 10.3389/fenvs.2023.1083282.

[85].........Z. Li and T. Li, “How Does City Size Affect the Cost of Household Travel? Evidence from an Urban Household Survey in China,” *IJERPH*, vol. 19, no. 11, p. 6890, Jun. 2022, doi: 10.3390/ijerph19116890.

[86]..........Levin, Tim, “The Incredible Earth Saving Electric Bicycle is Having a Moment.,” May 2023. [Online]. Available: https://www.businessinsider.com/electric-bikes-popularity-sustainability-evs-2023-4#:~:text=Last%20year%2C%20Americans%20bought%20just,-bike-industry%20trade%20group

[87]...........A. D. Brooker, J. Ward, and L. Wang, “Lightweighting Impacts on Fuel Economy, Cost, and Component Losses,” presented at the SAE 2013 World Congress & Exhibition, Apr. 2013, pp. 2013-01–0381. doi: 10.4271/2013-01-0381.

[88]........M. Abdel-Aty and S. Ding, “A matched case-control analysis of autonomous vs human-driven vehicle accidents,” *Nat Commun*, vol. 15, no. 1, p. 4931, Jun. 2024, doi: 10.1038/s41467-024-48526-4.

[89]. .O. Tengilimoglu, O. Carsten, and Z. Wadud, “Infrastructure requirements for the safe operation of automated vehicles: Opinions from experts and stakeholders,” *Transport Policy*, vol. 133, pp. 209–222, Mar. 2023, doi: 10.1016/j.tranpol.2023.02.001.

[90] M. Ferrari *et al.*, “Development of a hybrid human-electric propulsion system for a velomobile,” in *2013 Eighth International Conference and Exhibition on Ecological Vehicles and Renewable Energies (EVER)*, Monte Carlo: IEEE, Mar. 2013, pp. 1–8. doi: 10.1109/EVER.2013.6521591.

[91].............DaSilva, S, “UPS is testing pedal-powered delivery bike-van-thingies in NYC,” Jun. 2022. [Online]. Available: https://jalopnik.com/ups-is-testing-pedal-powered-delivery-bike-van-thingies-1849064350

[92]..........“Manual on Uniform Traffic Control Devices for Streets and Highways,” U.S. Department of Transportation., National Standard 11th Edition, Dec. 2023. [Online]. Available: https://mutcd.fhwa.dot.gov/pdfs/11th_Edition/mutcd11thedition.pdf

[93]........P. Saeidizand and K. Boussauw, “Patterns of car dependency of metropolitan areas worldwide: Learning from the outliers,” *International Journal of Sustainable Transportation*, vol. 18, no. 3, pp. 221–235, Mar. 2024, doi: 10.1080/15568318.2023.2283462.

[94] A. Abdulhafedh, “Addressing Traffic Congestion by Using of the Counter-Intuitive Phenomenon of Braess’ Paradox in Transportation Networks,” *OALib*, vol. 09, no. 09, pp. 1–12, 2022, doi: 10.4236/oalib.1109229.

[95].......Y. Du, G. Sun, E. Y. Choe, and M.-P. Kwan, “Mediation effects of social isolation on pathways connecting public transport use with subjective wellbeing among older people,” *Journal of Transport & Health*, vol. 25, p. 101378, Jun. 2022, doi: 10.1016/j.jth.2022.101378.

[96] P. Voorheis, S. M. Hasnain, I. Tiznado-Aitken, M. J. Widener, and M. P. Silver, “Understanding and supporting active travel in older adults using behavioural science: Systematic scoping review and strategic behavioural analysis,” *Journal of Transport & Health*, vol. 30, p. 101602, May 2023, doi: 10.1016/j.jth.2023.101602.

[97]. P. Rérat, “The rise of the e-bike: Towards an extension of the practice of cycling?,” *Mobilities*, vol. 16, no. 3, pp. 423–439, May 2021, doi: 10.1080/17450101.2021.1897236.

[98]....................J. Mulrow and S. Derrible, “Is slower more sustainable? The role of speed in achieving environmental goals,” *Sustainable Cities and Society*, vol. 57, p. 102030, Jun. 2020, doi: 10.1016/j.scs.2020.102030.

[99].....D. Banister, “The trilogy of distance, speed and time,” *Journal of Transport Geography*, vol. 19, no. 4, pp. 950–959, Jul. 2011, doi: 10.1016/j.jtrangeo.2010.12.004.

[100]...........“Motorcycle Lane-Sharing (Lane-Splitting and Lane-Filtering),” Washington Traffic Safety Commission, Research Summary, Dec. 2017. [Online]. Available: https://wtsc.wa.gov/wp-content/uploads/dlm_uploads/2019/05/Motorcycle-Lane-Sharing_Dec2017.pdf

[101]............................“People for bikes, model electric bicycle law with classes.” [Online]. Available: http://www.peopleforbikes.org/electric-bikes/policies-and-laws

[102]…S. Sinha, H. M. Shivanand Swamy, and K. Modi, “User Perceptions of Public Transport Service Quality,” *Transportation Research Procedia*, vol. 48, pp. 3310–3323, 2020, doi: 10.1016/j.trpro.2020.08.121.

[103]..K. Gao, Y. Yang, L. Sun, and X. Qu, “Revealing psychological inertia in mode shift behavior and its quantitative influences on commuting trips,” *Transportation Research Part F: Traffic Psychology and Behaviour*, vol. 71, pp. 272–287, May 2020, doi: 10.1016/j.trf.2020.04.006.

[104]........Department of Computing and Information Systems, School of Engineering and Technology, Sunway University, Malaysia *et al.*, “User Mode Choice Behavior in Public Transportation: A Systematic Literature Review,” *jkukm*, vol. 34, no. 1, pp. 11–28, Jan. 2022, doi: 10.17576/jkukm-2022-34(1)-02.

[105].............N. Low and B. Gleeson, Eds., *Making urban transport sustainable*. Basingstoke: Palgrave Macmillan, 2003.

[106]. .R. Prieto Curiel, H. González Ramírez, M. Quiñones Domínguez, and J. P. Orjuela Mendoza, “A paradox of traffic and extra cars in a city as a collective behaviour,” *R. Soc. open sci.*, vol. 8, no. 6, p. 201808, Jun. 2021, doi: 10.1098/rsos.201808.

[107].......H. S. Rayaprolu, C. Llorca, and R. Moeckel, “Impact of bicycle highways on commuter mode choice: A scenario analysis,” *Environment and Planning B: Urban Analytics and City Science*, vol. 47, no. 4, pp. 662–677, May 2020, doi: 10.1177/2399808318797334.

[108]...........D. Schröder and F. Gotzler, “Comprehensive spatial and cost assessment of urban transport options in Munich,” *Journal of Urban Mobility*, vol. 1, p. 100007, Dec. 2021, doi: 10.1016/j.urbmob.2021.100007.

[109]…..L. Cabral and A. M. Kim, “An empirical reappraisal of the level of traffic stress framework for segments,” *Travel Behaviour and Society*, vol. 26, pp. 143–158, Jan. 2022, doi: 10.1016/j.tbs.2021.09.007.

[110]........M. Hardinghaus and P. Papantoniou, “Evaluating Cyclists’ Route Preferences with Respect to Infrastructure,” *Sustainability*, vol. 12, no. 8, p. 3375, Apr. 2020, doi: 10.3390/su12083375.

[111].............M. G. Bellizzi, L. Eboli, and C. Forciniti, “Segregation vs interaction in the walkways: An analysis of pedestrians’ perceptions,” *Research in Transportation Business & Management*, vol. 33, p. 100410, Dec. 2019, doi: 10.1016/j.rtbm.2019.100410.

[112]. .L. Ford, “The City as a Ride,” *Focus on Geography*, vol. 52, no. 3–4, pp. 39–47, Dec. 2009, doi: 10.1111/j.1949-8535.2009.tb00253.x.

[113].......D. Zhao, H. Chen, and W. Jia, “Examining user satisfaction and vehicle development for Mini EVs and Non-mini EVs,” *Transportation Research Part A: Policy and Practice*, vol. 180, p. 103952, Feb. 2024, doi: 10.1016/j.tra.2023.103952.

[114]…..G. Oeschger, P. Carroll, and B. Caulfield, “Micromobility and public transport integration: The current state of knowledge,” *Transportation Research Part D: Transport and Environment*, vol. 89, p. 102628, Dec. 2020, doi: 10.1016/j.trd.2020.102628.

[115]............I. Kosmidis and D. Müller-Eie, “The synergy of bicycles and public transport: a systematic literature review,” *Transport Reviews*, vol. 44, no. 1, pp. 34–68, Jan. 2024, doi: 10.1080/01441647.2023.2222911.

[116]….W. Cai, Z. Wu, and Y. Lu, “The Impact of High-Speed Rails on Urban Consumption—From the Perspective of ‘Local-Adjacent’ Effect,” *Front. Environ. Sci.*, vol. 10, p. 884965, Jun. 2022, doi: 10.3389/fenvs.2022.884965.

[117]..............R. Labudzki, A. Patalas, R. Talar, D. Szadkowska, N. Wierzbicka, and P. Zawadzki, “The construction of an automated bicycle parking,” *J. Phys.: Conf. Ser.*, vol. 1426, no. 1, p. 012028, Jan. 2020, doi: 10.1088/1742-6596/1426/1/012028.

[118]…R. Egan, C. Mark Dowling, and B. Caulfield, “Planning for Diverse Cycling Practices: A Cycle-Parking Type Preference Typology,” *Case Studies on Transport Policy*, vol. 10, no. 3, pp. 1930–1944, Sep. 2022, doi: 10.1016/j.cstp.2022.08.007.

[119]...................A. Faghri, P. Boyle, and D. Lee, “Review of Social Equity and Environment in Urban Transportation,” *CUS*, vol. 10, no. 04, pp. 556–574, 2022, doi: 10.4236/cus.2022.104033.

[120]E. Suel, C. Lynch, M. Wood, T. Murat, G. Casey, and A. Dennett, “Measuring transport-associated urban inequalities: Where are we and where do we go from here?,” *Transport Reviews*, vol. 44, no. 6, pp. 1235–1257, Nov. 2024, doi: 10.1080/01441647.2024.2389800.

[121]….L. Del Rosario *et al.*, “Assessing the monetary value of active transport and e-micromobility: A systematic review,” *Transportation Research Interdisciplinary Perspectives*, vol. 27, p. 101243, Sep. 2024, doi: 10.1016/j.trip.2024.101243.

[122]......B. Ladd, “‘You can’t build your way out of congestion.’ – Or can you?: *A Century of Highway Plans and Induced Traffic*,” *disP - The Planning Review*, vol. 48, no. 3, pp. 16–23, Sep. 2012, doi: 10.1080/02513625.2012.759342.

[123]........HERMANN KNOFLACHER, “Success and failures in urban transport planning in Europe—understanding the transport system,” 2007. [Online]. Available: http://www.reconnectingamerica.org/assets/Uploads/knoflachertransportsuccessfailure.pdf

[124]K. Emory, F. Douma, and J. Cao, “Autonomous vehicle policies with equity implications: Patterns and gaps,” *Transportation Research Interdisciplinary Perspectives*, vol. 13, p. 100521, Mar. 2022, doi: 10.1016/j.trip.2021.100521.

[125]. .L.-A. Leyland, B. Spencer, N. Beale, T. Jones, and C. M. Van Reekum, “The effect of cycling on cognitive function and well-being in older adults,” *PLoS ONE*, vol. 14, no. 2, p. e0211779, Feb. 2019, doi: 10.1371/journal.pone.0211779.

[126].....E. Willberg, A. Poom, J. Helle, and T. Toivonen, “Cyclists’ exposure to air pollution, noise, and greenery: a population-level spatial analysis approach,” *Int J Health Geogr*, vol. 22, no. 1, p. 5, Feb. 2023, doi: 10.1186/s12942-023-00326-7.

[127]..............C. C. Reynolds, M. A. Harris, K. Teschke, P. A. Cripton, and M. Winters, “The impact of transportation infrastructure on bicycling injuries and crashes: a review of the literature,” *Environ Health*, vol. 8, no. 1, p. 47, Dec. 2009, doi: 10.1186/1476-069X-8-47.

[128]............E. R. Kulick, G. A. Wellenius, A. K. Boehme, R. L. Sacco, and M. S. Elkind, “Residential Proximity to Major Roadways and Risk of Incident Ischemic Stroke in NOMAS (The Northern Manhattan Study),” *Stroke*, vol. 49, no. 4, pp. 835–841, Apr. 2018, doi: 10.1161/STROKEAHA.117.019580.

[129]..............Tegan K. Boehmer, PhD1, Stephanie L. Foster, MPH2, Jeffrey R. Henry, BA2, Efomo L. Woghiren-Akinnifesi2, and Fuyuen Y. Yip, PhD, “Residential Proximity to Major Highways — United States, 201,” Supplement 62(03);46–50, Nov. 2013. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/24264489/

[130]...........D. Roy, E. S. Lyou, J. Kim, T. K. Lee, and J. Park, “Commuters health risk associated with particulate matter exposures in subway system – Globally,” *Building and Environment*, vol. 216, p. 109036, May 2022, doi: 10.1016/j.buildenv.2022.109036.

[131].........Y. L. P. Jens Müller, “Low-Emission Zones are a success - but they must now move to zero-emission mobility,” briefing, Sep. 2019. [Online]. Available: https://www.transportenvironment.org/articles/low-emission-zones-are-success-they-must-now-move-zero-emission-mobility

[132]....M. Li and J. M. Gernand, "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*, vol. 12, no. 11, pp. 1387–1398, Nov. 2019, doi: 10.1007/s11869-019-00753-1.
[133].......Zaheer AllamMark NieuwenhuijsenZarrin Allam, "Paris's parking policy for healthier cities," Urban Transformations Research Centre (UTRC), Western Sydney University, Comment, Jun. 2024. [Online]. Available: https://www.thelancet.com/pdfs/journals/lanplh/PIIS2542-5196(24)00089-5.pdf
[134]. S. Jaffe, "Cycling safety concerns grow in US cities," *The Lancet*, vol. 394, no. 10211, pp. 1791–1792, Nov. 2019, doi: 10.1016/S0140-6736(19)32757-6.
[135].....R. Aldred, B. Elliott, J. Woodcock, and A. Goodman, "Cycling provision separated from motor traffic: a systematic review exploring whether stated preferences vary by gender and age," *Transport Reviews*, vol. 37, no. 1, pp. 29–55, Jan. 2017, doi: 10.1080/01441647.2016.1200156.
[136]….I. N. Botton, D. Takagi, A. Shlez, H. Yechiam, and E. Rosenbloom, "Road accidents in children involving light electric vehicles cause more severe injuries than other similar vehicles," *Eur J Pediatr*, vol. 180, no. 11, pp. 3255–3263, Nov. 2021, doi: 10.1007/s00431-021-04089-w.
[137]......L. F. Goodman *et al.*, "Electric bicycles (e-bikes) are an increasingly common pediatric public health problem," *Surgery Open Science*, vol. 14, pp. 46–51, Aug. 2023, doi: 10.1016/j.sopen.2023.06.004.
[138].N. N. Ferenchak and W. E. Marshall, "Traffic safety for all road users: A paired comparison study of small & mid-sized U.S. cities with high/low bicycling rates," *Journal of Cycling and Micromobility Research*, vol. 2, p. 100010, Dec. 2024, doi: 10.1016/j.jcmr.2024.100010.
[139] P. A. Irwin, "Overview of ASCE Report On Outdoor Comfort Around Buildings: Assessment And Methods Of Control," in *Structures 2004*, Nashville, Tennessee, United States: American Society of Civil Engineers, May 2004, pp. 1–12. doi: 10.1061/40700(2004)49.
[140]….F. Alam, P. Silva, and G. Zimmer, "Aerodynamic study of Human Powered Vehicles," *Procedia Engineering*, vol. 34, pp. 9–14, 2012, doi: 10.1016/j.proeng.2012.04.003.
[141]….M. Southworth, "Designing the Walkable City," *J. Urban Plann. Dev.*, vol. 131, no. 4, pp. 246–257, Dec. 2005, doi: 10.1061/(ASCE)0733-9488(2005)131:4(246).
[142]…J. Zhao *et al.*, "Battery engineering safety technologies (BEST): M5 framework of mechanisms, modes, metrics, modeling, and mitigation," *eTransportation*, vol. 22, p. 100364, Dec. 2024, doi: 10.1016/j.etran.2024.100364.
[143] K. Liu, Y. Liu, D. Lin, A. Pei, and Y. Cui, "Materials for lithium-ion battery safety," *Sci. Adv.*, vol. 4, no. 6, p. eaas9820, Jun. 2018, doi: 10.1126/sciadv.aas9820.
[144].......C. Aichberger and G. Jungmeier, "Environmental Life Cycle Impacts of Automotive Batteries Based on a Literature Review," *Energies*, vol. 13, no. 23, p. 6345, Dec. 2020, doi: 10.3390/en13236345.
[145].A. Pompigna and R. Mauro, "Smart roads: A state of the art of highways innovations in the Smart Age," *Engineering Science and Technology, an International Journal*, vol. 25, p. 100986, Jan. 2022, doi: 10.1016/j.jestch.2021.04.005.
[146]..........PreScouter Editorial Team, "4 smart road technologies shaping the future of transportation," Prescouter, Chicago Illinois, Jun. 2021. [Online]. Available: https://www.prescouter.com/2021/06/4-smart-road-technologies-shaping-the-future-of-transportation/
[147]...F. Caleffi, L. D. S. Rodrigues, J. D. S. Stamboroski, and B. M. Pereira, "Small-scale self-driving cars: A systematic literature review," *Journal of Traffic and Transportation Engineering (English Edition)*, vol. 11, no. 2, pp. 271–292, Apr. 2024, doi: 10.1016/j.jtte.2023.09.005.
[148] D. Paddeu and G. Parkhurst, "The potential for automation to transform urban deliveries: Drivers, barriers and policy priorities," in *Advances in Transport Policy and Planning*, vol. 5, Elsevier, 2020, pp. 291–314. doi: 10.1016/bs.atpp.2020.01.003.

[149]…M. Jaller, C. Otero-Palencia, and A. Pahwa, "Automation, electrification, and shared mobility in urban freight: opportunities and challenges," *Transportation Research Procedia*, vol. 46, pp. 13–20, 2020, doi: 10.1016/j.trpro.2020.03.158.

[150].....T. Cohen and C. Cavoli, "Automated vehicles: exploring possible consequences of government (non)intervention for congestion and accessibility," *Transport Reviews*, vol. 39, no. 1, pp. 129–151, Jan. 2019, doi: 10.1080/01441647.2018.1524401.

[151]T. Goldman and R. Gorham, "Sustainable urban transport: Four innovative directions," *Technology in Society*, vol. 28, no. 1–2, pp. 261–273, Jan. 2006, doi: 10.1016/j.techsoc.2005.10.007.

[152]G. Grigoropoulos *et al.*, "Traffic Simulation Analysis of Bicycle Highways in Urban Areas," *Sustainability*, vol. 13, no. 3, p. 1016, Jan. 2021, doi: 10.3390/su13031016.

[153].....P. Næss and A. Strand, "Traffic Forecasting at 'Strategic', 'Tactical' and 'Operational' Level: A Differentiated Methodology Is Necessary," *disP - The Planning Review*, vol. 51, no. 2, pp. 41–48, Apr. 2015, doi: 10.1080/02513625.2015.1064646.

[154]..................LUKAS ARBÉN, "Elevated Bicycle Lane," KTH Industriell teknik och management, Stockholm, Sweden, Stockholm, Sweden. [Online]. Available: https://www.diva-portal.org/smash/get/diva2:1152853/FULLTEXT01.pdf

[155]...........Rob Stumpf, "Forget Bike Lanes: Elevated Cycleways Were a Great Idea That Left Us Too Soon," The Drive, Sep. 2021. [Online]. Available: https://www.thedrive.com/news/42070/forget-bike-lanes-elevated-cycleways-were-a-great-idea-that-left-us-too-soon

[156]..........Enrico Punsalang, "Swiss Startup URB-X Is Developing Elevated Bike Paths For European Cities," inside evs, New York, NY 10022, Jan. 2023. [Online]. Available: https://insideevs.com/news/628898/urbx-elevated-bike-paths-europe/

[157]. .Ron Johnson, "Here are the Most Stunning Elevated Bike Paths in the World," Momentum Mag, Aug. 2024. [Online]. Available: https://momentummag.com/here-are-the-most-stunning-elevated-bike-paths-in-the-world/

[158]......Adam Williams, "Dubai transforms into walkable city with air-conditioned paths," New Atlas, Dec. 2024. [Online]. Available: https://newatlas.com/architecture/dubai-walk-master-plan/

[159]Y. Harada and T. H. Whitlow, "Urban Rooftop Agriculture: Challenges to Science and Practice," *Front. Sustain. Food Syst.*, vol. 4, p. 76, Jun. 2020, doi: 10.3389/fsufs.2020.00076.