Transportation Forestry as an Interdisciplinary Field for Urban Sustainability

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Abstract

Existing and expanding evidence indicates that trees in communities offer substantial social and ecological benefits. Discussions around trees in transportation systems have centered on roads and streets, with efforts to address human safety, reducing tree-related hazards and maintenance challenges. Expertise in fields such as urban forestry and public health is rarely integrated. We propose a new sub-field, "Transportation Forestry," to optimize the effectiveness and promote the holistic co-benefits of transportation-related green infrastructure. Transportation Forestry bridges urban and community forestry, landscape architecture, transportation and urban planning, civil and automotive engineering, and environmental and public health. The field takes a transdisciplinary approach to enable the appropriate siting, selection, planting, and maintenance implementation of green infrastructure to most effectively and holistically address concurrent urban challenges. Focusing on roads and streets, we highlight the value of this sub-field and call for action to build a Transportation Forestry workforce. Transportation Forestry offers a pathway to sustainably advance transportation development, enhance human health, and build climate change resilience in cities worldwide.

1. Introduction

Transportation systems enable the mass movement of people and commodities around cities, countries and the globe. Among the many forms of transportation – from air and rail to vehicular and active mobility – roads and streets have particularly shaped contemporary cities. All mobility corridors and lands can generate positive and negative outcomes for human health, ecosystems, climate change adaptation/mitigation and environmental challenges[1].

As humanity grapples with the rapidly escalating effects of pollution, biodiversity loss and climate change, nature-based solutions addressing these interlinked crises are increasingly important, particularly in cities. Urban and community forests and other forms of green infrastructure offer numerous empirically supported benefits, from sequestering carbon and reducing heat, noise and air pollution to promoting health through stress reduction, social cohesion and physical activity[2,3]. However, trees also have trade-offs and disservices, such as maintenance and conflicts with grey infrastructure[4], warranting improved communication and collaboration between multiple fields and disciplines.

One field dedicated to tree and green infrastructure management is urban and community forestry (U&CF). U&CF emerged in the 1960s to address urban forestry management and the demand by residents for dedicated city foresters and programs concerning tree loss caused by development and disease[5]. U&CF is now widely recognized as a profession and a major driver of urban green infrastructure. Its science and practice are not limited in scope to specific areas of cities (such as parks or reserves) but also encompass the management of tree stands and supporting green infrastructure, spanning most public and private areas of cities, suburbs and rural communities[6]. The expression of green infrastructure we reference will likely vary across the rural-urban transect[7]. In suburban and rural areas, green infrastructure may primarily refer to trees, shrubs, and ground vegetation. In contrast, in more densely built urban settings, it may refer to other elements such as green roofs, bio-retention cells, rainwater harvest gardens and barrels, and permeable paving, which may not include trees. Depending on built environment densities, green infrastructure may focus on trees and associated vegetation or be expressed as green walls and roofs, vegetation-based stormwater management technologies or heat reduction plantings.

Implementing U&CF requires broad and advanced knowledge of the ecological health and functions of greenspaces[8]. Trees near healthcare facilities may necessitate a deep understanding of therapeutic landscapes and the socioeconomic and psychological benefits of green spaces. Trees around schools may be optimized to provide educational opportunities while fostering stewardship and enhanced learning. Trees in commercial districts may warrant prioritizing shade and aesthetics to increase walkability and patronage behavior. Ultimately, any given place and landscape represents a unique context to consider when best realizing and designing for the multimodal benefits and risks of trees[9]. U&CF also requires detailed knowledge of species-based plant needs, siting requirements, and sustained management to secure long-term benefits.

Practicing U&CF along roads and streets is a unique and complex challenge. Specialized expertise is needed in traffic management and safety, considering root structures to avoid pavement and utility damage[10], species that thrive in harsh conditions[11], the complex interaction between air quality benefits and ozone production[12], visibility of sight lines and injuries/fatalities from vehicular crashes[13]. Though urban tree plantings are often concentrated along streets[14], research on the benefits and selection of species has historically not been integrated within transportation engineering and planning[15]. Many tree management decisions along roads and streets, at least in the U.S., are made by engineers without adequate U&CF training or consultation with the public or other fields and disciplines[16]. Beyond benefits specific to the transportation sector, trees and green infrastructure can protect nearby communities from the large public health externalities of transportation, such as urban heat, air and noise pollution, neighborhood disconnect, visual blight, and driver aggression. Additional co-benefits of transportation-adjacent U&CF extend well beyond the mitigation of burdens. Many cities now seek to improve access to trees and greenspace. A notable example is increasing policy adoption of the "3-30-300 rule," which advocates for all residents to have at least three trees visible from their dwelling, for neighborhoods having at least 30% canopy cover, and that every resident have access to greenspace within 300 meters of their dwelling[17]. Considering these cumulative benefits and city initiatives, financial investments for plantings are increasingly being allocated through federal transportation departments and state-level urban transportation-related projects[18–20].

This perspective highlights the need for Transportation Forestry as a transdisciplinary sub-field in U&CF, focused on planning and managing trees and other green infrastructure associated with transportation and transit systems. We describe the value of establishing this sub-field and provide calls for action that promote its implementation. We also propose research, collaborations, and development of a trained workforce needed to ensure its success. Because of their extreme environmental and landcover needs, this perspective focuses on roadway systems and integrated active transportation. Roads and parking areas occupy one-third to half of any U.S. city's footprint[21], accounting for roughly 80% of the urban public realm. While the guiding principles outlined here primarily address roadway systems, they broadly apply to other transportation sectors. Future work must explore the role of trees and green infrastructure in other impactful contexts, including airports, rail yards, ports and rail lines, where research and U&CF practice are less established.

2. Defining Transportation Systems and Transportation Forestry

Broadly defined, a transportation system is a spatial network of connected physical infrastructures at multiple scales that permit the flow of people and commodities[1]. These include roads spanning different service scales from highways across regions to intracity arterials, neighborhood-level collectors and local streets but also transit (e.g., bus, light/elevated/subterranean rail), sidewalks, bicycle infrastructure, greenways, rail yards, and airports. Transportation facilities can create barriers to community connectivity, including obstacles to mobility, access, or economic development, due to high speeds or vehicle volumes and grade separations acting as physical barriers and other design factors[22].

Roads and streets are particularly relevant to Transportation Forestry given that these systems comprise an outsized portion of urban land cover and contribute to environmental health burdens[21]. Roadway traffic is a primary source of air pollution in many cities and communities[23]. Air and road traffic emit noise levels and frequencies that harm health and wellbeing[24]. Roadways constitute the largest impervious surface area in many cities and neighborhoods, a leading cause of urban heat island effects and flooding[25]. The burdens of other transportation systems, broadly speaking, may also be extensive.

Despite potential public burdens, the functions of transportation facilities are essential in contemporary societies. Still, they can come at a high cost to the environment and health of many communities, particularly those that are most vulnerable or socioeconomically disadvantaged[1]. Transportation-related politics and policies are a root cause of disadvantages across many communities, ranging from the externalities of road placement (such as economic and community decline) to direct environmental harms, often reinforcing longstanding social and ecological divides[26]. Transportation Forestry can promote processes linking transportation with human and environmental health in cities across diverse contexts[1].

We envision Transportation Forestry as an integration of the multiple disciplines, fields and approaches needed to successfully design and implement transportation-adjacent forestry that maximizes sustainability and cumulative benefits. It consolidates considerations related to siting, selection, maintenance, and anticipated effects of trees while supporting all green infrastructure proximal to transportation infrastructure. Importantly, it emphasizes collaboration with communities to integrate local knowledge and to prevent and in-part overcome environmental injustices (**Figure 1**). The integration of U&CF, landscape architecture, natural sciences, urban planning and environmental psychology offer important insights, including: which species are best suited within varied contexts, such as specific climates and environments; effects on local ecosystems and communities; how to encourage ownership and stewardship on behalf of residents; how to promote proper alignment and support of city tree ordinances and policies; and how to endorse management for long-term survivability and sustainability of trees, people and cities.

Successful implementation requires including best practices across a host of professional disciplines. Utility arboriculture provides expertise on the pruning, regulation, compliance, and monitoring related to overhead utility lines and rights-of-way safety. Transportation and urban planning offer frameworks for incorporating green spaces into existing and future roadways and transit, walking and bicycling corridors. Civil and transportation engineers generate road geometries that promote safe travel speeds, reduce roadside crash risk and minimize safety concerns of trees and green infrastructure, including sight lines, clear zones and vegetative material management. Landscape architects collaborate, using planting plans to mitigate stormwater flow, air pollution dispersal and excessive noise, as well as designing to meet place-making goals.

Beyond the expertise needed to establish and implement physical aspects of Transportation Forestry, human and social responses to space and place must be considered. Rapidly expanding research and expertise in environmental and public health clarifies how trees and supporting green infrastructure generate extensive, cumulative co-benefits for human health. Community development experts can promote authentic dialog and design participation opportunities for residents living near transportation corridors to incorporate their values, needs and interests. Environmental sociology, justice and inclusion scholarship offer perspectives on links between differing effects of green infrastructure and the legacies of concentrated disadvantage, wherein underserved groups suffer from intersecting and compounding socioeconomic disparities and environmental stressors and may be subject to displacement due to gentrification due to facilities improvements. These factors may influence the effectiveness and local acceptance of urban forestry and green infrastructure projects.

A transdisciplinary approach is important to ensure appropriate local context-dependent design and implementation. For example, highways generating high burdens of air pollution, noise, heat, and runoff may optimally benefit from large dense plantings yet still allow for sightlines and airflow. In contrast, local access roads that typically generate lower burdens may incorporate interspersed canopy trees and shrubs for shade, aesthetic quality, and public green spaces that optimally benefit mental health and promote physical activity. Across these and other situations, a wide variety of expertise must be integrated, utilizing transdisciplinary synthesis to weigh tradeoffs and combine field and discipline-specific knowledge for context-sensitive design and implementation.

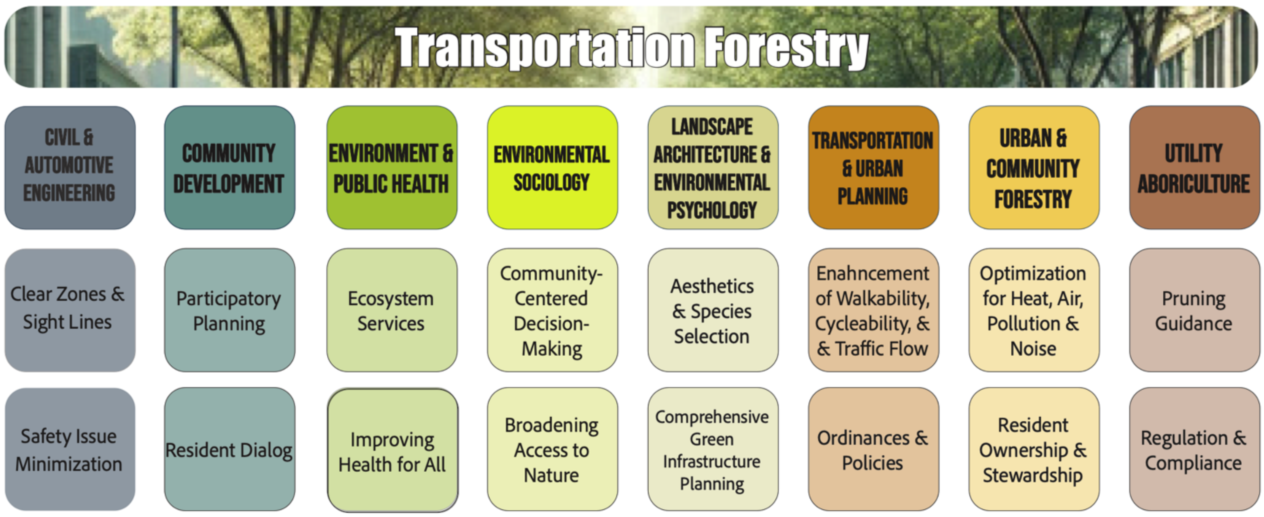

Figure 1. Representation of disciplines, fields and approaches that contribute to the sub-field of Transportation Forestry, recognizing that areas of expertise will overlap in practice.

3. Benefits of Transportation Forestry

Safety is of the utmost importance in mobility and transportation design, and is essential also in practices of Transportation Forestry. More than 1.3 million people are killed each year on roads around the world, and millions are seriously injured[27]. Crashes on roadways are among the top ten causes of death globally, with car crashes being the leading cause of death in the U.S. for people ages 5 to 29[27]. Vision Zero policies are supported by a global movement to end traffic-related fatalities and serious injuries by taking a systemic approach to road safety. Improving safety across the complexity of transportation systems involves a review of current best practices and exploring innovation opportunities. In the U.S., the widely referenced Green Book (A Policy on Geometric Design of Highways and Streets) contains highway and street design guidance, such as traffic lane width, intersections and curve radii at different speeds[28]. However, it has historically emphasized the importance of clear zones in high-speed roads and highways, resulting in roadsides free of fixed objects, including trees. "Fixed objects," including utility poles, trees, and signage, are of particular concern as they are inflexible on impact, heightening the risk of severe injury and death. Research suggests clear zone policies should reflect specific road situations, including rural versus urban risk levels, rather than universal application[35]. While transportation leaders may understand the benefits of trees and supporting green infrastructure, this understanding may not be sufficient to counteract perceived safety issues[29].

There are opportunities to utilize trees and support green infrastructure for traffic safety. Impact speed is profoundly important, as the fatality risk at speeds of approximately 60 km/h is five times higher than 30 km/h[30], and roadside vegetation has been correlated with traffic-calming and reduced speeds that may result from the perception of roadway restrictions[31], also known as visual friction. More broadly, investigators are exploring the role of urban design and cognitive interpretations of the built environment that contribute to driver error and crash behaviors[32]. Better reaction times reduce crash incidence and severity; in research with highway driving simulations, driver attention levels increase with roadside greening and shorter reaction times during emergencies[33]. Vehicle position within the travel lane is influenced as drivers move farther away from the road edge (reducing crash risk) if trees are spaced closer together[34]. In addition, the U.S. national crash data for urban settings indicates *lower* death and injury rates when trees are present[35]. Among areas with potential for vehicle crashes with trees and other objects, safety-conscious Transportation Forestry approaches can incorporate designs and species that are frangible (pliable upon impact) to buffer impact energy, thereby further reducing the overall injury and fatality rate of vehicle impacts with trees and other fixed objects (**Figure 2**). Ultimately, the lack of trees and other vegetation can have the unintended consequence of increasing traffic speeds, exacerbating driver error, reducing safety, and increasing injuries or deaths[31,36].

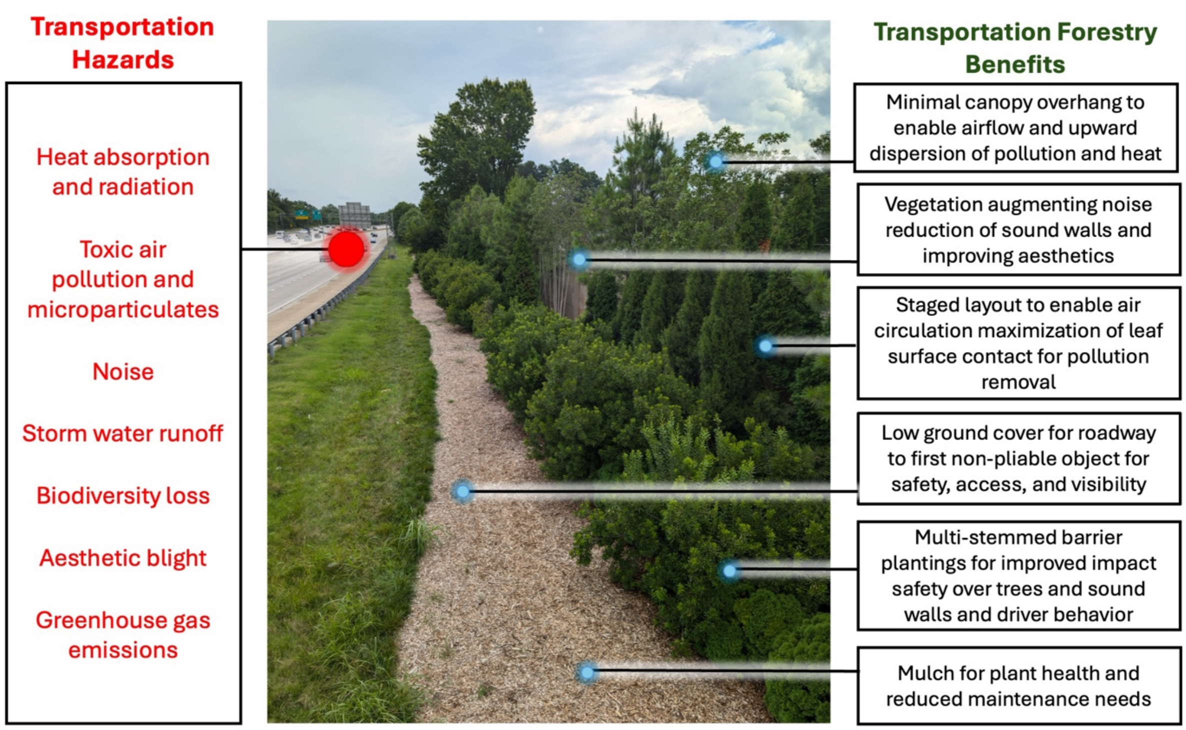

Figure 2. Green Heart Louisville is an example of Transportation Forestry infrastructure installed on high-speed roads, including clear zones free of fixed objects and integrating frangible landscapes that maintain safety and provide other benefits. Image courtesy of the authors.

Beyond the potential safety benefits of Transportation Forestry, urban and community forests benefit drivers and residents' physical and mental health (**Figure 3**)[9,12,37]. Along highways and auto-centric roads, appropriately selected, designed and maintained trees and supporting green infrastructure can represent a viable and cost-effective strategy to reduce exposure to air pollution from traffic emissions[11]. Vegetation can simultaneously block and filter pollutants and particulates from reaching adjacent residential areas, reducing community exposure. However, in dense urban centers and street canyons formed by buildings, vegetation and trees can impede air mixing and lead to wind stagnation, reducing pollution dispersion and increasing downwind pollutant concentrations[38]. Some trees can also reduce air quality and exacerbate asthma by producing allergenic pollen, as well as generate ground-level ozone through biogenic volatile organic compound (BVOC) emissions[12]. Thus, Transportation Forestry requires understanding and engineering/design solutions that maximize general reductions in pollution and particulates and avoid unintended consequences due to increased localized pollution levels. Trees and supporting green infrastructure can also be an effective and aesthetically acceptable option to reduce roadway noise[39]. As with pollution, the noise reduction capacity of vegetative greenbelts can be multiplied with deliberate design, placement, and species selection[40].

Figure 3. Multidimensional evidence-based benefits of Transportation Forestry

Trees and green infrastructure are recognized as nature-based solutions to climate change. Impervious surfaces drive the formation of urban heat islands, and vegetation represents a uniquely efficacious and cost-effective intervention to reduce urban heat in many settings[41]. Urban heat is responsible for the highest number of deaths due to natural disasters caused by climate change, with urban heat islands disproportionately exacerbating the exposure of residents living in underserved communities[42]. Through shading and evapotranspiration, vegetation can counter this effect and mitigate climate change-driven morbidity and mortality. Trees and green infrastructure can also be cost-effective approaches to reduce the burdens of flooding and stormwater runoff related to the extensive paved surfaces of transportation networks[43]. In cities around the U.S., billions of dollars are spent to address stormwater runoff and combined sewer overflows, with needs growing due to climate change-related changes in precipitation patterns[44]. As a partial solution that is cost-effective and provides extensive co-benefits, trees intercept rainfall before reaching the ground level, improving water infiltration and preventing soil erosion.

While forestry provides many direct benefits to communities, the potential for additional indirect health and well-being co-benefits is well documented. Cleaned and greened vacant lots near roadways have been associated with lowered crime and self-reported improvements in mental health[45]. The Green Book and other design guidelines, such as the Urban Street Design Guide, increasingly acknowledge the importance of pedestrian and bicycling mobilities for health and climate benefits[46]. Thus, Transportation Forestry also entails the selection of sites and species to provide shade for pedestrians, cyclists, and public transit users while minimizing safety concerns. Further, green streetscapes provide comfortable shopping environments and improve merchants' relationships with shoppers, resulting in improved revenues[47]. Transportation Forestry introduces more trees as nearby nature in people’s lives, improving public and social health. Living in areas with high rates of tree canopy and vegetation cover is associated with improved sleep quality, birth outcomes, and physical activity levels, reducing the incidence of chronic conditions, diseases, and all-cause mortality[50]. Notably, green neighborhoods are associated with lower blood pressure and cardiovascular diseases, major risk factors and causes of mortality worldwide[50]. Engaging residents as stewards in urban forestry initiatives can promote social cohesion and pride, increased social interactions, and community attachment[49].

Realizing these direct and indirect benefits requires a nuanced understanding of Transportation Forestry practices to avoid unintended negative consequences. For instance, improperly designed green walls can bounce soundwaves back to pedestrians, creating adverse effects of heightened noise levels. Plantings in areas prone to extreme heat must be designed to maximize cooling effects while minimizing restrictions in airflow. Safety aspects must be maintained, including sight lines on crest vertical curves (the tops of hills) and curves, reasonable clear zones commensurate with posted speed limits, limiting overhanging limbs and hazard trees that could fall onto roadways, designing landscapes that minimize concerns about crime, and manage adjacent wildlife habitat to reduce risk of roadway crashes. Shade can promote icy road conditions or slippery vegetative litter in wintertime, increasing crashes.

Natural areas may become informal encampments for unsheltered individuals, and increasing greenery may encourage additional occupants, including those using such areas in unsanctioned ways[51]. Such “green encampments” may weaken support from nearby (housed) residents for forestry initiatives based on objections to undesirable occupancy uses[52], especially in proximity to homes and schools. The complex socioeconomic dimensions of homelessness, in addition to landscape management, must be addressed to reduce potential hazardous exposures and health concerns among vulnerable populations. Associated behaviors that are destructive to vegetation may increase the costs for public and non-profit sectors to maintain Transportation Forestry projects.

4. Pathways Forward for Transportation Forestry

We propose several calls to action to establish the sub-field of Transportation Forestry. First, we call for comprehensive policies concerning roadside trees and green infrastructure that reflect the best available evidence and integrate contemporary professional practices of arboriculture, horticulture and landscape architecture with traditional transportation policies. The first level of policy development and adoption is national agencies, as within many nations, the respective state or province and local government standards and guidelines for transportation implementation adhere to national policy. Experts should engage across agencies; an example in the U.S. would be formal project collaborations, such as a taskforce, between urban forestry professionals in the U.S. Forest Service, engineers from the Department of Transportation and public health officials from Health and Human Services[16]. At the local level, departments of forestry, transportation and public health often work separately[16]. Yet, tree planting, underground utilities, and pedestrian/cycling routes can be better coordinated by restructuring how departments crosstalk and collaborate. We recommend more significant interaction between researchers and policymakers in forestry, sustainability, public health, housing, civil engineering, urban planning and transportation. Strategic initiatives and policies should promote collaboration between fields to address air pollution, noise, stormwater runoff, safety and urban heat along transportation corridors to maximize net benefits.

Second, we call for deliberate multi-sectoral financing approaches for Transportation Forestry. Despite the documented benefits of Transportation Forestry along roadways and local streets, planners and developers may not consider Transportation Forestry mission-critical or a cost-effective approach. To promote Transportation Forestry and achieve the full extent of the cumulative benefits of Transportation Forestry, multi-sectoral valuation and financing strategies are needed. The accounting and monetization benefits of Transportation Forestry should be considered beyond the transportation sector alone and extend across sectors of health, housing, disaster resilience, environmental quality and more. Such multi-sectoral financing would enable widespread implementation of and commensurate cumulative benefits to residents.

Third, we call for the concentrated establishment and practice of Transportation Forestry in communities subjected to the highest harmful transportation externalities, and thereby greatest benefits from investment. Social and environmental divides are essential to Transportation Forestry, as areas with the lowest socioeconomic status also tend to have the lowest levels of tree canopy and vegetation cover[53]. Traditionally underserved communities, often located next to major transportation corridors and interchanges, may benefit more from nature-based interventions than other communities; residents in lower-SES communities who lack mobility options may spend more time in their communities, suffer more from transportation and other cumulative environmental burdens, and have lower baseline health status[54]. Greening initiatives in disadvantaged communities often experience low adoption, maintenance, and tree survival rates, compounded by low levels of feasible planting space. This confluence of imbalanced conditions highlights the need for deliberate and context-tailored investments, especially for plantable public spaces interspersed within transportation systems. Establishing and practicing Transportation Forestry in disadvantaged communities can allocate resources to areas with the most to gain from trees and supporting green infrastructure, yet care must be taken to consider procedural, recognitional, and distributional considerations when implementing tree planting initiatives.[55]

Fourth, we call for developing interdisciplinary professional education and workforce programs to promote broader communication and knowledge transfer. Leadership in Transportation Forestry is needed to develop transdisciplinary expertise and collaborations and to encourage more conversations and collaborations between disciplines, fields, and governmental agencies, with little traditional overlap. Integrated curricula can be offered across undergraduate and graduate-level courses, with cross-listing across departments at universities and community colleges. Coordinated learning materials and case study development will allow discussion of disciplinary-specific challenges and opportunities related to planting along transportation corridors. Experts from relevant disciplines and fields could co-develop training modules to ensure trainees learn from each of these critical sectors. Certificates can be provided to distance education students and professionals seeking continuing education credits. Professional organizations in relevant disciplines and fields, such as the Transportation Research Board's Standing Committee on Landscape Environmental Design, in addition to NACTO and the American Society of Landscape Architects (ASLA), may pursue accreditation standards.

Fifth, we call for increased research to develop evidence-based best practices in Transportation Forestry and to promote design and implementation principles that are best suited across a range of landscape settings. A steadily growing research base supports best practices in U&CF; however, specific research about trees and transportation is limited. Essential topics to support evidence-based practices of Transportation Forestry are:

- **Data on safety, crashes and trees.** Few research articles currently consider road safety when evaluating the benefits of streets, sidewalks, and shade trees[37]. Conversely, transportation industry research on crash circumstances (such as road geometries) and driver behavior (such as safe speed response) emphasize trees as fixed objects with serious safety risks. Rectifying and validating these perspectives across geographies and urban/rural community contexts is critical. Current crash report data are primarily from federal sources and may not fully reflect the conditions faced by local governments[35]. Developing a "Safe System" approach may balance physical constraints with driver cognitive responses, such as attentiveness and posted speed compliance[56], while "crash taxonomies" could inform best practices for crash avoidance and countermeasures[57].

- **Landscape context and multiple transportation modes.** Research based on collaborative perspectives, mobility types and emerging technologies is essential. Examples are the opportunities for trees and green infrastructure to support diverse transportation modes, especially active transportation such as biking and walking, that are integrated into street systems. Eisenman et al. (2021) review these considerations as they relate to bicyclists, pedestrians, and vehicle drivers and discuss how 'travelscapes' may represent some of the most prominent types of landscapes that people routinely encounter, with resulting implications for human health and well-being[9]. Evaluating existing design and policy tools for adaptive use could include "Context Sensitive Solutions" and "Complete Streets" policies, and NACTO design guidelines in the U.S.; "Woonerf" design in the Netherlands; "shared space" strategies in Belgium; and The Manual for Streets and Duty of Care in the United Kingdom Evaluation. Further, the emerging capability and use of assisted- and self-driving vehicles have the potential to fundamentally change considerations of roadways, with researchable implications for near-road vegetation, such as reduced pollution and noise, potential alteration of necessary sight lines for navigation and sensor systems, decreased road widths, increased safety and improved traffic flow efficiency. Implications of emerging technologies and other historically significant trends, such as the shift to remote work and the transition from retail to online shopping, are poorly understood and may fundamentally alter the purpose and design of streets – and associated green space – especially in urban centers.

- **Intersections between greening, ecology, climate and safety.** Disparities in tree canopy and park distribution have been noted across many cities, and the trend appears to extend to roadsides. Aside from reduced access, little is known about roadside greenery in different contexts and its implications on driver behavior. One study found that the number of street trees per mile (within clear zones) was associated with *fewer* crashes in wealthier neighborhoods and *more* crashes in lower-income neighborhoods[58]. Research on the design of transportation corridors as "Safe Systems" rather than focusing solely on the behavior of individual drivers may reduce crash rates while reducing the potential for racially charged exchanges between the police and the public[59]. Meanwhile, research on quantities and qualities of green infrastructure along roadways could inform efforts to balance climate, environment, active and vehicle transportation, and policy or utility constraints. Technologies like self-driving cars with LiDAR or machine learning algorithms applied to 360-degree images may assist with real-time monitoring of urban forests along transportation corridors. Tradeoffs between solar microgrid placement and tree planting spacing may increase as transportation and renewable infrastructure investments continue.

- **Tree growth challenges in roadside conditions.** Arboriculture investigations continually expand recommendations for adequate soil volumes for roots, nutrient needs, water and irrigation management and pruning. The interaction of sub-surface root growth with paving can result in potential hazards and increased maintenance costs. Applied technologies may be used in forensic evaluations, such as using ground penetrating radar to evaluate root architecture and implement repairs before hazards become serious. As the practice of Transportation Forestry and related research grows, so will the knowledge about species selection to minimize damage to pavement and offset maintenance costs. In this context, the International Society of Arboriculture offers important guidance.

- **Effective collaboration between U&CF and Departments of Transportation (DOTs).** Routine updates of best management practices, training certificates, ordinances, and policies will support Transportation Forestry. Input from many fields will be necessary, notably U&CF and DOTs. Focus group studies and case studies of mixed professional groups that have effectively collaborated would highlight better techniques and communication approaches. This and other research topics' findings can be integrated into standards of practice, such as the American National Standards Institute (ANSI) A3000 Tree Care standards for integrated vegetation management. For example, "road ecology" emerged as a multi-disciplinary approach, elevating localized and fragmented knowledge into a broad and inclusive framework for understanding and developing solutions to ecological corridors, particularly for rural wildlife[60]. Transportation Forestry may benefit from research on the challenges and successes in the development of road ecology, including dynamics of communication and practice.

- **Expanding known benefits to other forms of transportation beyond roads and streets.** The potential benefits of trees and vegetation in various transportation contexts remain largely underexplored. Rail lines, light rail systems and airports present opportunities to extend similar benefits and tradeoffs of greening. Like roads, trees along rail corridors could mitigate stress levels for passengers and conductors, akin to their documented restorative effects for pedestrians and drivers in urban environments. Greening around airports may improve traveler well-being by reducing stress and visual fatigue during transit or buffer against noise pollution during take-offs and landings. These scenarios may parallel the benefits observed along roads and streets, but research is needed to determine their translation and unique challenges to these contexts.

5. Conclusion

Establishing Transportation Forestry provides an essential and timely approach to address the complex urban challenges of our time across diverse contexts and groups. Evidence-based policy and consistent budgeting and finance are crucial foundations, ranging from national to local governmental and agency scales. Subsequent implementation will provide extensive co-benefits to urban sustainability, biodiversity, public health, and wellbeing. Developing the collaborations, tools and workforces needed to establish Transportation Forestry will result in healthier and more livable urban communities worldwide.

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