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RESEARCH ARTICLE

Roadside trees species selection model for environmental health and public safety in Malaysia

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ABSTRACT

Selecting right tree species for roadside planting is crucial to balance environmental health with public safety concerns. Roadside trees as a part of urban green infrastructure have the potential to cope with some of these problems in urban environment and provide an array of services such as shade provision and aesthetic creation. Unfortunately, roadside trees are also acknowledged to render disservices. Damaged road surface, pedestrian walkway and underground utilities are a few instances of this. The wrong tree species planted at the wrong place can lead to significant environmental, social and economic consequences. The aim of this study is to develop roadside tree species selection model for reference to the local authorities. Two objectives are to determine additional attributes in urban roadside tree species selection and to examine the relationship between additional and similar attributes in landscape practices. This research employs mixed methods approaches consisting of both qualitative and quantitative approaches. An in-depth interview was conducted in four selected local authorities, namely Kuala Lumpur City Hall, Petaling Jaya City Council, Selayang Municipal Council, and Subang Jaya Municipal Council. The findings are validated by five registered landscape architects, revealing ten (10) additional attributes of root invasiveness and behavior, wood brittleness and branch drop risk, allergenic potential, growth rate and canopy management, compatibility with urban infrastructure, drought and pollution tolerance, fire resistance and flammability, wildlife attraction and pest management, aesthetic consistency and public perception, structural stability and wind resistance that influences the selection of roadside tree species in urban areas. These attributes were integrated into the roadside tree species selection model.

1. INTRODUCTION

In the face of growing urbanization and environmental deterioration, roadside trees are critical to improving urban ecological integrity and public well-being. In Malaysia, where urban heat islands, air pollution, and traffic congestion are becoming increasingly problematic, the presence of well selected roadside trees helps to alleviate these issues. Roadside trees provide a variety of ecosystem services, including carbon sequestration, shade provision, microclimate regulation, noise reduction, and aesthetic enhancement. However, incorrect tree species selection can bring major problems such as root damage to infrastructure, sight obstruction, allergic pollen, and falling branches, all of which can jeopardize public safety and raise maintenance expenses. Roadside trees are important parts of urban green infrastructure because they have many positive effects on the environment, such as enhancing air quality, controlling temperature, lowering stormwater runoff, and sustaining biodiversity (Nowak et al., 2010; Livesley et al., 2016). In tropical nations like Malaysia, planting the right kinds of trees along roads can help a lot with urban heat islands, clean the air, and make people feel better mentally. However, the success of planting trees beside the road depends a lot on choosing species that are well-suited to the local environment, can handle the stresses of city life, and can provide ecosystem services for a long time. Not choosing the right species can lead to higher maintenance expenses, lower tree survival rates, and even harm to the environment (Hitchmough, 2017).

Choosing the right tree species for the side of the road should also take public safety into account, in addition to the benefits for the environment. Inappropriate species might cause problems like roots breaking up pavements, branches falling, or even whole trees failing during storms, which happen a lot during Malaysia's monsoon season (Hashim et al., 2022; Nur Syuhada et al., 2020). These problems not only put people's safety at risk, but they also raise the expense of maintenance and make people less likely to trust urban greening projects. To choose trees that are safe, you need to know about the structural properties, growth patterns, wood strength, and susceptibility to pests and diseases of different species (Sreetheran et al., 2011; Jim, 2020). When choosing species for urban landscapes, it's important to think about public safety. This is how to make sure that the landscapes are both safe and long-lasting.

Right now, Malaysia's urban tree selection processes are still all over the place, with little connections between safety and environmental factors. Local governments sometimes choose species based on what people like or what looks well, without thinking about the long-term hazards or how well they do in the environment (Shukor et al., 2019; Noraini et al., 2021). The lack of established and data-driven criteria makes urban tree management inconsistent, which can lead to bad results like trees failing too soon, more maintenance work, and green spaces that don't work as well as they should. There is a strong need for a comprehensive and evidence-based model that fills in these gaps so that planners and landscape experts may make smart choices. Existing tree species selection models only look at how much shade they provide and how well they adapt to tropical conditions. They don't consider all the environmental and safety aspects. Local governments, the Public Works Department (JKR), and the Landscape Department (JLN) often set rules that help people choose plants based on things like how fast they grow, how their roots are shaped, how tall they are, and how much care they need.

Even with these benefits, there is still a restricted, regulated way to choose tree species for planting beside roads in Malaysia that focuses on the health of the environment. Current standards are generally incomplete and don't use enough scientific data or environmental performance metrics for choosing species. So, the goal of this project is to create a Roadside Trees Species Selection Model that is specific to Malaysia's cities and focuses on improving environmental health. The model will include site-specific, ecological, and physiological factors to help decision-makers choose the right tree species that will help make urban ecosystems healthier. The model is designed to help Malaysian cities plan in a way that is more sustainable and resilient by filling in this gap.

Roadside trees are an important part of city infrastructure because they provide several ecosystem services that help keep the environment healthy and cities sustainable. Rapid urbanization in Malaysia has caused more environmental problems, such as urban heat islands, air and noise pollution, and a loss of biodiversity (Abdullah et al., 2021; Jamil et al., 2022). Roadside trees help lessen these consequences by controlling temperature, cleaning the air, storing carbon, lowering stormwater runoff, and making people feel better about themselves and their surroundings (Livesley et al., 2016; Akbar et al., 2022). However, the effectiveness of these contributions depends a lot on choosing the right tree species that can grow well in cities where there are problems like small amounts of soil, air pollution, and car emissions (Mullaney et al., 2015; Roy et al., 2022).

The goal of this research is to create a complete roadside tree species selection model that is customized to Malaysia's different climatic zones, urban settings, and sociocultural environment. The approach intends to help urban planners, landscape architects, and municipal governments choose tree species that promote environmental health while also ensuring public safety.

The study examines species-specific characteristics such as canopy density, root structure, growth rate, drought tolerance, and potential risks. Furthermore, it evaluates how these characteristics interact with environmental variables such as soil type, rainfall patterns, and road design. There is currently a considerable knowledge and practice gap in Malaysian urban planning policies regarding tree species selection. Existing recommendations are sometimes fragmented and generic, failing to consider the long-term ecological effects or safety consequences of tree planting. Furthermore, decisions are frequently made based on aesthetic preferences or conventional customs, rather than data-driven research. The lack of a standardized, context-specific selection strategy leads to inconsistent methods, which result in poor tree performance, higher mortality rates, and increased hazards to public infrastructure and safety. This study aims to close the gap by developing a species selection model that incorporates scientific, environmental, and urban safety characteristics. The model attempts to improve urban green infrastructure resilience by combining local environmental data and species performance in the field. Finally, the model is projected to contribute to the development of healthier, safer, and more sustainable urban settings in Malaysia, in line with national and global goals for climate resilience, biodiversity conservation, and urban livability.

2. MATERIALS AND METHODS

This research utilizes a mixed methods approach, incorporating both qualitative and quantitative methodologies. An extensive interview was performed in four designated local authorities: Kuala Lumpur City Hall (R1), Petaling Jaya City Council (R2), Selayang Municipal Council (R3), and Subang Jaya Municipal Council (R4). R1, R2, R3, and R4 denote the coding utilized during the interview procedure conducted with the corresponding local authority. The qualitative component comprised comprehensive interviews with key individuals from four selected local governments: Kuala Lumpur City Hall (DBKL), Petaling Jaya City Council (MBPJ), Selayang Municipal Council (MPS), and Subang Jaya Municipal Council (MBSJ). A total of 20 participants were involved in this study, comprising five representatives from each of the four selected local authorities which is Kuala Lumpur City Hall (DBKL), Petaling Jaya City Council (MBPJ), Selayang Municipal Council (MPS), and Subang Jaya Municipal Council (MBSJ). Each group included professionals from key departments such as landscape architecture, urban planning, and tree maintenance. These participants were purposefully selected due to their active involvement in urban greening, roadside tree management, and policy implementation within their respective jurisdictions. The inclusion of multiple professional backgrounds ensured a comprehensive understanding of current practices, challenges, and species selection criteria across different governance levels. This purposive sampling approach aligns with the recommendations of Creswell and Plano Clark (2018) for achieving rich, context-specific qualitative insights in mixed-methods research. The selected local administrations were intentionally picked due to their expertise in urban greening and tree maintenance in Malaysia's rapidly expanding cities. Participants in the interviews comprised landscape architects, urban planners, and maintenance officers responsible for the planting and upkeep of trees. The interviews mostly focused on current methodologies, challenges, safety concerns, species selection, and the implementation of policies. We selected a semi-structured interview methodology to address critical concerns flexibly while ensuring uniformity across all interviews.

Utilized structured surveys and field observations to collect data for the quantitative component. The survey was distributed to an extensive cohort of urban planners and municipal employees to ascertain their sentiments, priorities, and decision-making processes regarding the selection of tree species for roadside planting. Field observations were conducted at specific roadside planting locations within the jurisdictions of the four municipal governments. The observations documented the species types, their spatial distribution, canopy coverage, root exposure, visibility, and any indications of dangers or maintenance concerns. We employed descriptive and inferential statistics to identify patterns and correlations between species characteristics and documented environmental or safety outcomes in the quantitative data.

This research did not entail any medical, clinical, or experimental procedures involving human or animal subjects that would require official ethics approval. The research predominantly utilized professional interviews with officials and practitioners from local authorities, concentrating on institutional processes, policy execution, and technical expertise related to urban tree management. All participants were approached via formal procedures within their respective agency, and participation was completely optional. In compliance with study ethical protocols, verbal informed consent was secured before to each interview. Participants were guaranteed that all responses would be kept anonymous and utilized exclusively for academic and research purposes. No personal or sensitive information was gathered during the procedure. Consequently, this study did not necessitate formal ethical approval from an institutional review board, as it adhered to the established ethical norms for non-invasive social science research.

3. RESULT AND DISCUSSION

The study identified several additional important traits that are often missed when choosing tree species for roadsides. Thematic analysis of in-depth interviews with landscape professionals and city officials, together with data from surveys and field observations, revealed ten important additional traits. Respondents from all four local authorities emphasized that root invasiveness is a persistent problem, particularly in older urban areas with narrow walkways and shallow utilities. Field observations confirmed that species such as *Ficus benjamina* and *Samanea saman* showed aggressive surface root growth, contributing to cracked pavements and drainage blockage (R1, R3), findings consistent with earlier studies linking shallow root systems to infrastructure conflicts (Jim, 1998; Morgenroth and Armstrong, 2012).

Consequently, the selection model must account for root type, growth depth, and horizontal spread. Interviews highlighted increasing public complaints related to pollen allergies from species such as Akasia (*Acacia auriculiformis*). While this attribute is rarely considered during planting decisions, it emerged as a significant concern for public health, particularly in densely populated areas. Survey results showed that 67% of respondents agreed that allergenic risk should be included in future selection criteria (RI , R2, R3, R4). Respondents from Petaling Jaya and Kuala Lumpur reported frequent branch fall incidents during monsoon seasons, especially from brittle-wood species like Rain Tree (*Samanea saman)* and Angsana (*Pterocarpus indicus*) (R2, R3,R4). These incidents pose direct risks to pedestrians and vehicles.

Similar safety concerns have been documented in studies emphasizing wood density and wind-resistance as critical safety parameters in tropical street trees (Nik Abdul Rahman et al., 2019; Tan and Ismail, 2020). Field data supported these claims, with visible breakages and unbalanced canopies in over 30% of trees assessed. Wood density and wind resistance, therefore, were identified as crucial safety-related attributes. The study also uncovered growing concerns over the maintenance demands of certain species. Fast-growing species with dense canopies require frequent pruning to avoid power line interference and visibility obstruction. Compatibility with surrounding infrastructure such as spacing from streetlights, signage, and roads was another critical yet inconsistently applied consideration. This highlights the need for incorporating growth rate, pruning requirements, and structural compatibility into species selection protocols.

Table 1: Additional Attributes in Urban Roadside Tree Species Selection

Attribute	Description	Remarks
Root Invasiveness and Behavior	Roots that damage pavements, drains, and utilities.(RI, R3)	*Ficus benjamina*, *Samanea saman*
Wood Brittleness and Branch Drop Risk	Trees prone to breakage, especially during storms or heavy rain.(R2,R3,34)	*Pterocarpus indicus*, Rain Tree
Allergenic Potential	Trees that produce high-pollen levels, contributing to allergies.(R1,R2,R3,R4)	*Albizia lebbeck*, *Acacia auriculiformis*
Growth Rate and Canopy Management	Fast-growing species requiring frequent pruning; large canopies obstruct visibility. (R1,R2)	Overhead utility interference and traffic safety issues
Compatibility with Urban Infrastructure	Spatial conflicts with buildings, signage, roads, or footpaths.(R3,R4)	Crowded walkways, blocked road signs
Drought and Pollution Tolerance	Ability to withstand heat, limited water, compacted soil, and vehicular emissions.(R1,R2,R3,R4)	*Terminalia catappa*, *Cassia fistula*
Fire Resistance and Flammability	Risk of tree catching fire in hot or dry seasons near roads or industrial areas. (R1,R3,R4)	Species with dense, dry litter discouraged
Wildlife Attraction and Pest Management	Trees that attract excessive wildlife, pests, or cause hygiene issues. (R1,R2,R4)	Large flocks of birds or bats; insect infestation concerns
Aesthetic Consistency and Public Perception	Public-friendly appearance, minimal leaf litter, and year-round appeal. (R2,R3,R4)	*Melaleuca spp.* causes heavy leaf shedding
Structural Stability and Wind Resistance	Resistance to uprooting or limb breakage during strong winds or storms.(R1,R2,R3,R4)	Important during Malaysian monsoon season

Previous studies mostly concentrated on ecological and aesthetic functions, such as shade provision, air purification, and visual harmony (Roy et al., 2020). Nonetheless, these models often poorly depicted practical issues, including maintenance difficulties, infrastructural conflicts, and safety concerns, which are critical in swiftly urbanizing tropical regions. The present findings underscore root invasiveness, wood brittleness, and structural stability as critical criteria, signifying a transition from aesthetics-oriented to risk-based tree management. This study extends the research of Morgenroth and Buchan (2022) by investigating root behavior within Malaysia's compacted soils and shallow utility systems, as opposed to their analysis of root–pavement conflicts in temperate urban environments. Tan and Ismail (2020) and Zhang et al. (2023) similarly emphasized storm-induced tree failures; however, their frameworks omitted brittleness, canopy density, and wind resistance as integrated safety considerations. The current methodology combines environmental resilience with mechanical stability, connecting ecological theory and urban safety measures in tropical environments.

Based on respondents in interviews and surveys with local government officials and landscape professionals, the connection between extra and similar features in urban landscape practices shows that there is a big gap between what is being done now and what urban environments are changing to need. Respondents consistently said that traditional traits like tree size, canopy spread, and general environmental tolerance are always considered (R1, R2, R3, R4) However, they also said that new traits give a better picture of long-term performance, safety, and utility. For instance, some people said that canopy size is used to figure out how much shade an area gets, but it doesn't consider how stable the structure is or how well it can stand up to wind, which are very important for safety during Malaysia's monsoon season. Root depth is another typical factor, but root invasiveness was given more weight because of the regular breaking of pavement and damage to utilities problems that municipal maintenance teams often describe (R2, R3, R4).

Similarly, root depth has long been used as a growth indicator, but root invasiveness has become a more pressing concern due to frequent pavement breakage and damage to underground utilities, as widely reported in tropical urban contexts (Morgenroth and Buchan, 2022; Abdul Rahman et al., 2019). This indicates that new traits aren't new; they're just improved copies of old ones that have been made better by the limits of real-world cities. Respondents also said that their goals have changed to focus more on public health and risk management. For example, while aesthetic value is still crucial when choosing species, more people are realizing that they need to think about how likely they are to cause allergies, especially near schools and hospitals (R1,R2,R3,R4). Respondents also warned that attracting too many animals could pose problems, such as pest complaints and maintenance issues, even though biodiversity support is welcomed (R1, R2, R3, R4). These comments show how important it is to find a balance between environmental goals and public safety and comfort.

The relationship between extra and comparable features, as shown by the responses, shows a shift from planning based on general design principles to planning based on specific situations and performance. Increasingly, professionals know that traditional landscape features need to be expanded to include safety, environmental, and practical aspects. This will make urban roadside tree planning more resilient, efficient, and acceptable to the public. Combining both sets of traits makes sure that we take a complete approach to solving today's urban problems. Table 2 refers to interviews with 5 representatives from each four local authority. Additional attribute decisions were made through mutual agreement during the interview process. These attributes address both functional and safety-related concerns, ensuring that tree selection in urban environments aligns with ecological, structural, and social priorities. Incorporating these ten criteria enables local authorities to develop a comprehensive, evidence-based selection model that balances urban functionality with environmental sustainability (Guo et al., 2024; Yap et al., 2023).

Table 2: Relationship Between Additional and Similar Attributes in Urban Landscape Practices

No.	Similar Attribute in Practice	Additional Attribute	Relationship and Explanation
1	Tree Size and Canopy Spread	Structural Stability and Wind Resistance (R1,R2,R3,R4)	While canopy size is often used for shade benefits, structural stability ensures the tree can withstand strong winds and resist uprooting.
2	Root Depth	Root Invasiveness and Behavior (R2,R3,R4)	Root depth is considered for growth, but invasiveness addresses impacts on infrastructure and pedestrian safety.
3	Shade Provision	Growth Rate and Maintenance Frequency (R2,R4)	Trees with large canopies offer shade, but fast-growing species may require more frequent pruning and care.
4	Environmental Tolerance	Drought and Pollution Tolerance (R1,R2,R3,R4)	General tolerance is often assessed, but specific resilience to urban pollutants and dry conditions is more critical.
5	Visual Aesthetic Value	Aesthetic Consistency and Public Perception(R1,R2,R3,R4)	Aesthetics are valued, but consistency over time (e.g., low leaf litter, symmetrical form) affects public satisfaction.
6	Tree Type	Allergenic Potential (R1,R2,R3)	Beyond leaf type, allergenic traits impact health outcomes—an emerging concern in urban greening.
7	Species Adaptability	Compatibility with Urban Infrastructure (R3,R4)	While adaptability considers survival, compatibility focuses on coexistence with roads, buildings, and utilities.
8	Biodiversity Support	Wildlife Attraction and Pest Management (R1,R2,R3,R4)	Encouraging biodiversity is positive, but over-attraction of pests or nuisance animals may cause human-wildlife conflict.
9	Fire Risk in Urban Design (Rarely consider)	Fire Resistance and Flammability (R1,R2,R3,R4)	Often overlooked, this attribute is critical in high-traffic or drought-prone zones to reduce urban fire hazards.
10	Tree Lifespan	Wood Brittleness and Branch Drop Risk (R1,R2,R3)	Long lifespan is desirable, but if the species is prone to shedding branches, it becomes a long-term safety liability.

3.1 Suggestion Roadside Tree Species Selection Model

To guarantee that trees planted alongside urban roads improve both environmental quality and public safety, the Roadside Tree Species Selection Model is essential when accompanied by other characteristics. Since aggressive root systems can harm sidewalks, road surfaces, and underground utilities, root invasiveness and behavior are among the most crucial factors to consider. Similarly, to avoid mishaps or property damage, particularly in high-traffic areas, wood brittleness and branch drop risk need to be evaluated. Another important consideration is a tree species' potential to cause allergies, especially in crowded urban areas where respiratory health is an issue (D'Amato et al., 2022). Canopy management is an important consideration in the selection process because, although dense canopies and fast growth rates are good for providing shade, they may require more upkeep if not controlled (Nowak and Greenfield, 2020). Tree species also need to be compatible with urban infrastructure, meaning they shouldn't obstruct drainage systems, power lines, or road signs. Characteristics like drought and pollution tolerance guarantee the long-term viability and efficacy of the tree planting program in urban stressor-prone areas. Furthermore, low flammability and fire resistance are required in areas susceptible to heat waves or where trees are planted close to industrial areas. To strike a balance between ecological advantages and human comfort and safety, the model also considers wildlife attraction and pest management. Aesthetic perception and consistency, which must complement the city's visual identity, have an impact on public acceptance. Finally, lowering the chance of tree failures during storms or monsoon seasons requires structural stability and wind resistance. The model facilitates informed, context-sensitive tree selection that fosters safe and sustainable urban environments by integrating these extensive extra attributes.

The Proposed Roadside Tree Species Selection Model offers a systematic approach to enhance urban tree care by including environmental and safety factors into planning and execution. The process commences with the identification of site-specific urban restrictions, including spatial limitations, utility availability, and climatic variables.

The subsequent step is evaluating prospective species based on supplementary characteristics, such root invasiveness, wood brittleness, allergenic potential, and pollution tolerance, to ascertain their appropriateness for urban settings. These properties are evaluated and prioritized using a multi-criteria assessment process based on local priorities such as safety, aesthetics, and maintenance needs, resulting in educated judgments regarding tree planting and management. This methodology provides a methodical, evidence-driven framework for choosing tree species that harmonize ecological efficacy, structural integrity, and community welfare. The methodology improves decision-making for municipal authorities and landscape experts by integrating essential features frequently neglected in traditional practices. Their adoption can result in safer, more resilient, and sustainable roadside landscapes that enhance environmental quality and the long-term livability of Malaysia's rapidly urbanizing towns.

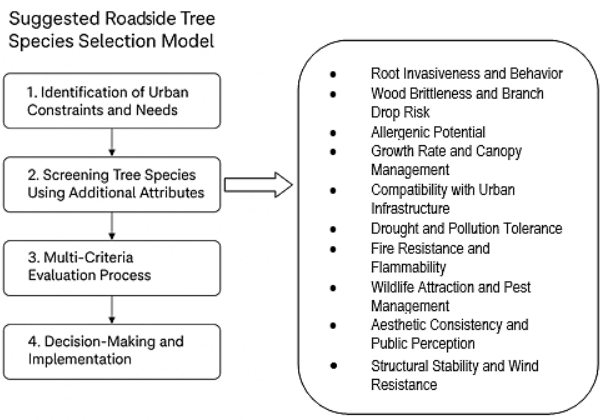

Figure 1: Suggestion of additional attribute for Roadside Tree Species Selection Model

4. CONCLUSION

To sum up, the Roadside Trees Species Selection Model for Environmental Health and Public Safety in Malaysia provides a thorough and situation-specific framework to direct the thoughtful placement of urban trees. Additional characteristics that are frequently disregarded in traditional tree selection, such as root invasiveness, structural stability, allergenic potential, and compatibility with urban infrastructure, are incorporated into the model to address safety and ecological issues. This strategy reduces hazards to infrastructure and public health while simultaneously ensuring the long-term resilience and functionality of urban green spaces. Adopting this model can help Malaysian cities create roadside environments that are safer, healthier, and more sustainable as urbanization increases. These environments will support both community wellbeing and national environmental goals. This model provides municipal planners with a practical framework for choosing tree species that balance safety, environmental health, and urban infrastructure compatibility. The model supports evidence based decision making that can reduce maintenance costs, mitigate hazards, and enhance ecological and aesthetic benefits in cities. Its applicability is particularly valuable for integrating sustainable green infrastructure into urban planning, ensuring that roadside vegetation contributes to public safety while delivering long-term ecosystem services. Future research should test and refine the model across different Malaysian climate zones such as coastal, highland, and inland settings to validate its adaptability and to optimize species recommendations under diverse environmental conditions.

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