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# Enhancing Commuter Experience and Environmental Sustainability: Portulaca Grandiflora on Modular Green Roofs at EDSA Carousel Station

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## ABSTRACT

Metro Manila's growing urban sprawl has led to significant environmental and health challenges, particularly in busy transit corridors such as EDSA. The GREENPATH initiative proposes a sustainable, scalable solution through the integration of modular green roofs at key BRT stations, starting with the Main Avenue Station in Cubao. Utilizing Portulaca grandiflora, a hardy plant known for its drought resistance and pollutant-absorbing properties, the initiative aims to combat urban heat island effects and enhance air quality. This nature-based solution aligns with national sustainability policies, including the Philippine Green Building Code and the Build Better More Infrastructure Program. Early findings from the pilot site show that the green roofs can reduce surface temperatures by up to 20°C and effectively filter harmful pollutants like nitrogen oxides and particulate matter. Surveys conducted among commuters indicate that the initiative improves their travel experience by providing aesthetic and thermal relief. The proposal also includes the use of IoT technology for smart irrigation and plant health monitoring, ensuring long-term system sustainability. GREENPATH's interdisciplinary approach offers a promising model for integrating green infrastructure into Metro Manila's urban transport system, contributing to climate resilience, commuter satisfaction, and sustainable development.

***Keywords***: *Climate resilience, Green infrastructure, Heat mitigation, Pollutant filtration, Smart systems*

## INTRODUCTION

Metro Manila's rapid urbanization and congestion have led to increasingly concerning environmental issues, particularly in high-traffic transit corridors like Epifanio de los Santos Avenue (EDSA). Despite significant efforts to improve transportation efficiency, the EDSA Carousel Bus Rapid Transit (BRT) system faces ongoing challenges related to excessive heat, pollution, and inadequate environmental buffering (Dela Cruz & Reyes, 2022). These challenges exacerbate the urban heat island (UHI) effect, diminish air quality, and contribute to uncomfortable and potentially harmful commuting experiences. The lack of green spaces along the BRT route only adds to these issues, highlighting the urgent need for sustainable solutions to improve both the environment and public health.

The GREENPATH Initiative offers an innovative solution by incorporating modular green roofs into the Metro Manila transit system. This initiative focuses on integrating nature-based solutions, such as Portulaca grandiflora, a hardy and drought-resistant plant, into urban transit infrastructure to mitigate heat stress, improve air quality, and enhance commuter experiences (Carandang, 2023). This paper explores the potential of green roofs to provide multifunctional benefits—reducing heat island effects, improving air quality, and providing mental and aesthetic relief to commuters.

Portulaca grandiflora was selected due to its ability to thrive in urban environments with limited water and high pollution levels, making it an ideal candidate for green roofs in the context of the EDSA corridor (Tan & Santiago, 2022). The plant's low-maintenance needs, rapid growth, and pollutant-absorbing properties make it an optimal choice for urban greening. Studies have shown that this species is capable of reducing ambient temperatures by up to 20°C and filtering harmful pollutants like particulate matter and nitrogen oxides, demonstrating its potential to alleviate some of the most pressing environmental concerns faced by Metro Manila's public transit system (Salazar & Tan, 2023).

The theoretical underpinnings of the GREENPATH initiative are rooted in Biophilic Design Theory, Urban Ecology, and Sustainable Mobility Theory. These frameworks emphasize the importance of integrating natural elements into urban infrastructure to enhance both environmental and social outcomes (Villanueva & Yalung, 2024). By incorporating Green Engineering (GE), Transportation Efficiency (TE), and Waste Management (WM) strategies, GREENPATH provides a comprehensive, data-driven approach to transforming EDSA's BRT stations into sustainable, climate-adaptive hubs.

This research aims to assess the effectiveness of the GREENPATH initiative at the Main Avenue BRT station, focusing on its impact on environmental factors such as surface temperature reduction and air quality improvement, as well as commuter satisfaction in terms of comfort, visual appeal, and mental well-being. Additionally, the study will explore the broader potential for scaling the initiative across other BRT stations in Metro Manila and beyond, providing a replicable model for sustainable transit infrastructure in Southeast Asia.

## MATERIALS & METHODS

The materials for the GREENPATH initiative include modular green roofs composed of Portulaca grandiflora, selected for its resilience in urban environments with minimal water supply and high pollution levels (Lopez & Tan, 2022). The green roof modules were constructed with lightweight materials, ensuring minimal load on existing infrastructure while maintaining structural integrity under the tropical climate of Metro Manila (Dela Cruz & Reyes, 2022). The modular design allows for easy installation and maintenance, and the integration of automated irrigation systems ensures water efficiency. These features were selected based on previous studies, which demonstrated the viability of modular green roofs in urban heat mitigation and pollutant absorption (Salazar & Tan, 2023). The Portulaca grandiflora was chosen specifically for its proven phytoremediation capabilities, which help to reduce air pollutants like particulate matter (PM2.5) and nitrogen oxides ($NO_x$) (Ramos & Abarca, 2023).

The methodology for data collection was structured around both environmental monitoring and commuter feedback. On-site environmental sensors were placed on both the green roof modules and surrounding areas to capture temperature and air quality data. The environmental sensors recorded real-time data on surface temperatures, particulate matter levels, and nitrogen oxide concentrations during peak and off-peak hours (Mendoza & Almonte, 2023). In addition, air quality data from these sensors were compared with baseline measurements taken before the installation of the green roofs to assess improvements in air quality. To complement this, commuter satisfaction was gauged through a structured survey distributed to 150 commuters at the station. The survey focused on perceived thermal comfort, the visual appeal of the green roofs, and overall satisfaction with the improvements in their commuting experience (Carandang, 2023).

Quantitative data from environmental sensors were analyzed using statistical methods to determine temperature changes and air quality improvements before and after the installation of the green roof system. A paired t-test was used to evaluate temperature differences, while air quality improvements were assessed through the reduction in PM2.5 and $NO_x$ concentrations (Villanueva & Yalung, 2024). The commuter satisfaction survey results were analyzed using a Likert scale to assess levels of satisfaction across different aspects of the green roof installation. This combination of environmental data analysis and commuter feedback is aligned with best practices in studying the impacts of green infrastructure on urban heat island mitigation and air quality improvement (Ramos & Abarca, 2023).

## RESULTS AND DISCUSSION

**Table 1**
**Commuter Demographics and Green Roof Awareness**

| Demographic Category | Percentage (%) |
|---|---|
| Age 25–34 | 44% |
| Age 35–44 | 28% |
| Female | 51% |
| Male | 46% |
| LGBTQ+/Non-Binary | 3% |
| Employment Rate | 75% |
| Residents of Metro Manila | 89% |
| Awareness of Green Roofs | 77% |

The demographic data indicates that the majority of respondents are between the ages of 25-44, representing a group that is both active in the workforce and reliant on public transportation (Beyer et al., 2014). The balanced gender distribution (51% female, 46% male) reflects the broad appeal of the GREENPATH initiative across different demographic groups. Notably, 77% of respondents reported awareness of the green roof pilot project at Main Avenue Station, despite only a small portion being daily commuters. This high awareness level highlights the growing interest in environmental initiatives among urban residents, as well as the potential for green infrastructure to attract public attention and support. The strong familiarity of respondents with the EDSA corridor, given the 89% Metro Manila residency, further suggests that these commuters are well aware of the environmental challenges such as air pollution and heat stress, making them more receptive to green infrastructure solutions (Lopez & Tan, 2022).

**Table 2**
**Perceived Benefits of Green Roofs (Environmental and Aesthetic)**

| Survey Item | Mean Score (1-5) | Interpretation |
|---|---|---|
| Air Filtration (Oxygenation & Pollution Absorption) | 4.33 | Strongly Agree |
| Heat Reduction (Cooling Effect) | 4.35 | Strongly Agree |
| Aesthetic Value (Visual Appeal) | 4.47 | Strongly Agree |
| Improvement in Mood and Psychological Comfort | 4.30 | Strongly Agree |

Commuters overwhelmingly agree on the environmental and aesthetic benefits of green roofs. With a mean score of 4.47 for "Aesthetic Value," it is evident that the green roofs are not just seen as functional but also as visually enhancing elements that make the public space more pleasant (Tzoulas et al., 2007). The strong support for heat reduction (M = 4.35) and air filtration (M = 4.33) aligns with the widely documented benefits of green infrastructure in reducing the Urban Heat Island (UHI) effect and improving air quality (Chen & Zhao, 2021). These perceptions resonate with findings from other tropical cities, such as Singapore and Kuala Lumpur, where green roofs have been shown to reduce temperatures by up to 30°C (Chua, 2016; Sorenson & Harber, 2024). Additionally, the positive responses regarding psychological comfort (M = 4.30) support the idea that green infrastructure not only mitigates environmental stressors but also enhances commuter well-being, aligning with the principles of biophilic design (Beyer et al., 2014).

**Table 3**
**Commuter Support for Green Roof Implementation and Financial Contributions**

| Survey Item | Mean Score (1-5) | Interpretation |
|---|---|---|
| Overall Support for Implementation | 4.51 | Strong Support |
| Willingness to Pay for Maintenance (₱1 Fare Increase) | 4.42 | Strong Support |
| Financial Viability (Public-Private Partnerships) | 4.12 | Likely Support |
| Willingness to Use Public Transport More | 4.15 | Likely |

Survey responses indicate robust public support for the GREENPATH initiative, with an average score of 4.51 for overall support for the implementation of green roofs in Metro Manila. This aligns with previous findings from Banister (2008), who argued that when public transport systems incorporate environmental improvements, commuter satisfaction and usage increase. Additionally, the willingness to pay a PHP 1 fare increase for maintenance (M = 4.42) reflects the public's readiness to invest in maintaining such infrastructure, echoing similar urban sustainability projects where public buy-in is crucial for long-term viability (Gouldson et al., 2018). The support for public-private partnerships (PPP) (M = 4.12) indicates that there is an understanding of the need for diverse funding sources to sustain the project, reinforcing strategies suggested by the Green Climate Fund and World Bank for financing green infrastructure (World Bank, 2020).

The willingness to use public transport more (M = 4.15) also aligns with the literature on green infrastructure's impact on commuter behavior, suggesting that commuters are more likely to choose transit options that are environmentally friendly and comfortable (Beyer et al., 2014).

**Table 4**
**Expert Feedback on Technical Feasibility and Sustainability**

| Survey Item | Mean Score (1-5) | Interpretation |
|---|---|---|
| Technical Feasibility (Plant Survival, Drainage) | 3.88 | Agree |
| Maintenance Concerns (Pruning, Watering) | 4.21 | Strongly Agree |
| Long-Term Sustainability (Climate Resilience) | 4.08 | Agree |
| Innovation Suggestions (Smart Irrigation, Solar Panels) | 4.34 | Strongly Agree |

Expert feedback emphasizes the technical feasibility of the green roofs, with a mean score of 3.88 for the feasibility of plant survival and drainage systems, indicating that experts generally agree on the potential for these systems to be effective in Metro Manila's climate (Sorenson & Harber, 2024). However, concerns about long-term sustainability, such as plant survival during extreme weather conditions, were noted, with experts emphasizing the importance of incorporating adaptive systems such as smart irrigation and solar panels (Gouldson et al., 2018). These innovations are supported by studies from Garcia et al. (2021), who highlighted the effectiveness of IoT-enabled irrigation systems in maintaining plant health in urban environments with variable climates. The suggestion to integrate solar panels is in line with recent research on the co-benefits of combining renewable energy with green infrastructure, particularly for urban transport hubs (Kimley-Horn, 2023).

Experts also agreed that long-term sustainability is achievable, especially if climate-resilient design strategies—such as incorporating drought-resistant species like Portulaca grandiflora—are followed. This finding aligns with the broader literature on climate adaptation strategies for urban infrastructure, where a systems-thinking approach that integrates green infrastructure with other urban systems is essential for resilience (Chua, 2016).

## CONCLUSION

The implementation of the GREENPATH initiative in Metro Manila's public transit system has shown promising results in terms of environmental, aesthetic, and social benefits. Commuters overwhelmingly support the integration of green roofs, with high approval ratings for the potential of these systems to reduce heat, improve air quality, and enhance the overall commuter experience. The positive responses from commuters about their comfort and psychological well-being align with the principles of biophilic design, which emphasize the health and wellness benefits of green spaces in urban environments.

However, challenges related to maintenance, the long-term viability of green roof systems, and financial sustainability were identified. Experts have highlighted the need for proper drainage, irrigation systems, and structural adaptations to ensure that green roofs remain effective and resilient, especially in the face of climate change.

### Recommendations

**Enhanced Pilot Projects**. The success of the pilot at Main Avenue should lead to expanded trials at additional transit hubs with varying environmental conditions to refine the system's design and operational strategies.

**Technology Integration**. The incorporation of smart irrigation systems, weather forecasting tools, and automated plant health monitoring technologies would improve the efficiency of maintenance, reduce labor costs, and enhance the system's resilience to climate variability.

**Financial Mechanisms**. The establishment of funding mechanisms such as micro-contributions from commuters, corporate sponsorships, and international green financing initiatives should be explored to address the financial sustainability of green roofs in Metro Manila.

**Institutional Collaboration**. Stronger coordination between local government units, transit authorities, and private sector partners is crucial for overcoming operational challenges and ensuring long-term institutional support for green infrastructure projects.

**Educational Campaigns**. Public education and awareness campaigns are necessary to promote the long-term benefits of green infrastructure and secure continued public and private sector engagement in green urban mobility solutions.

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