Exploring the Feasibility and Environmental Benefits of Green Roofs on Buses

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Abstract

Hong Kong is characterized by one of the highest population densities globally, with areas of intense high density enveloped by vehicular roadways and buildings. According to statistical results from the Environment and Ecology Bureau, approximately 4,100 diesel buses are in operation. “Public buses and taxis generate over 1.4 million tons of carbon emissions each year, accounting for about 4% of Hong Kong’s total carbon emissions (EEB, 2024)”.

Introduction

Inspired by the case study of the projects “Tuen Mun Noise Barrier” (Highway Department) and “Garden on the Move” (Singapore), explored the feasibility of transforming traditional buses into environmentally friendly mobile greenery.

Literature Review

- **Urban Heat Island Effect**

(UHI) effect significantly raises urban temperature levels, It has been reported that “Urban area temperature can be up to 7° C higher than rural areas due to the UHI effect” (Santamouris et al., 2023). Green roofs have been proposed as an effective strategy for mitigating UHI effects by providing thermal insulation and reducing heat absorption.

- **Mitigation Measures**

“Green roofs can lower surface and ambient temperatures by up to 10° C, thus contributing to the alleviation of UHI” (Li et al., 2022). The incorporation of vegetation into urban public transportation, particularly on buses, has been proposed to enhance thermal comfort and improve energy efficiency.

- **Bus Green Roof System**

Structural considerations, plant selection, and maintenance strategies need to be considered when designing a bus green roof system. Research by Yang et al. (2021) highlighted that “a modular green roof system can be utilized to ensure weight distribution and promote plant survival, making it suitable for mobile platforms.”

- **Thermal Properties of Green Roof on Bus**

There is a significant impact of temperature regulation by green roofs: “Green roofs can reduce heat transfer through increased insulation and evapotranspiration, contributing to lower internal temperatures during peak heat” (Kumar et al., 2022).

- **Potential Benefits**

The potential benefits of green roofs on buses include air quality improvement, social benefits, and economic advantages. Bus greenery can promote mental well-being for social benefits purposes, green roofs for long-term savings through the reduction of the costs of energy, and because of the innovation and attractiveness, can also increase the number of passengers (Ahmed et al., 2022).

- **Factors Influencing Green Roof on Bus Upper Deck**

The success of green roofs installed on the upper decks of buses is influenced by multiple factors, including the bus’s loading capacity, plant species, material choices, and wind drag effects, which necessitate robust maintenance protocols and stakeholder collaboration (Elmich, 2023; Arteaga et al., 2020).

- **Hong Kong Traffic Ordinance and Regulation**

”Adhering to the Road Traffic Ordinance is essential to ensure that modifications do not impede safety and operational standards” (Government of Hong Kong, 2023). In Hong Kong, traffic ordinances and regulations must be considered in the implementation of green roofs on buses.

Methodology

- **Structural requirements and technical considerations**

The structure of the bus, body parts, and roof can be designed as a single or double deck or modified into an open deck for tourist buses or theme park parade buses. Therefore, based on the above feasibility, installing green roofs on buses should be feasible.

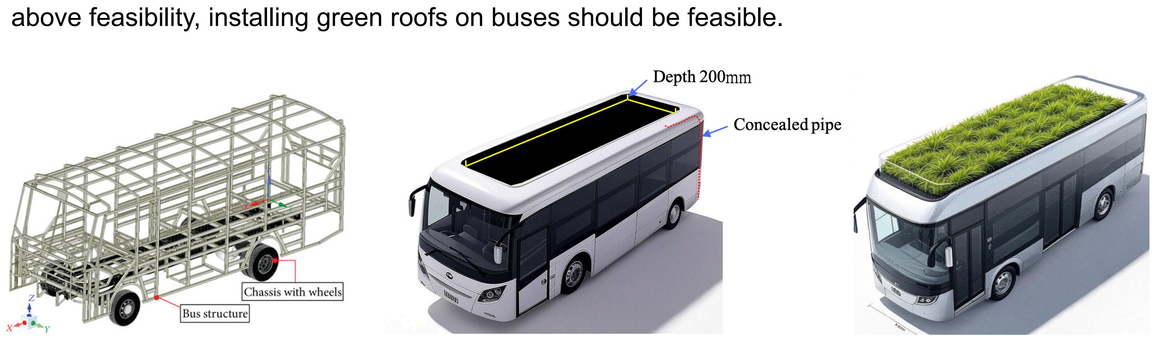


Fig.1 Structure design for planting tray installation and concept drawings

- **Strategies for wind drag reduction**

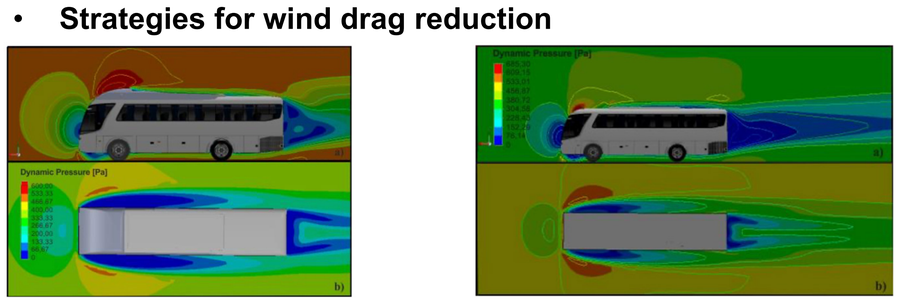
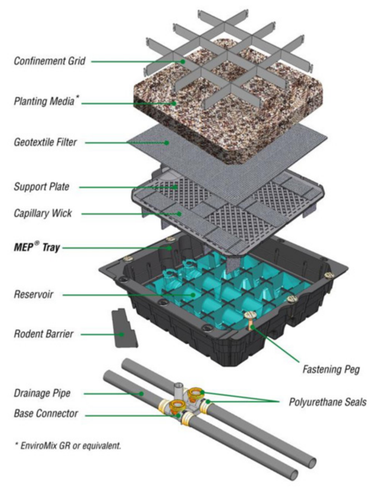


Fig.2 Comparison of the wind deflector reducing the wind drag level

The above side view figures generated by CFD software, show the lower dynamic pressures (highlighted in blue) on the top of the bus model found after installing the front deflector The investigation by Arteaga et al. (2020) was conducted, whereby Computational Fluid Dynamics (CFD) and wind tunnel testing were utilized to assess aerodynamic performance. The significance of aerodynamic design in reducing wind drag coefficients can be effectively reduced from 0.9 to 0.6 through modifications, achieving a 33% reduction in drag force.

- **Planting tray selection – Elmich MEP® Tray**



This planting tray utilizes QwickWick technology, by capillary action, to draw water from a reservoir up into the planting media, ensuring consistent hydration for the plants and maintaining optimal moisture levels. The modular design allows for easy installation, removal, and rearrangement of trays. The planting tray proposed to apply the embedded method, similar to the solar panel installation method, to reduce the transpiration of plants and wind drag.

The growth media-applied pre-mixed formulation keeps it lightweight and retains moisture, and its high cation exchange capacity (CEC) enhances the availability of nutrients. Rich in organic matter and possessing an ideal carbon-to-nitrogen (CN) ratio. Thus, this medium is recognized as an excellent choice for green roofs on buses.

Fig.3 Elmich MEP® Tray (Modular Extensive Planting Tray) system

- **Weight Calculation**

The upper deck with 55 seats, a loading capacity that can be estimated based on the average weight of a passenger. Assuming an average passenger weight of 75 kg: 55×75 kg = 4,125 kg. If all seats from the upper deck are removed, approximately can be reduced by 200 to 500kg (depending on seat design), thus, the upper deck could potentially provide a total of around 4,500 to 5,500kg weight capacity for green roof installation.

Materials	Weight (kg/unit)	Quantity	Total weight
Planting Tray includes Water storage (40L/m²) (Planted and fully saturated)	150kg/m²	36 nos.	5,400kg
Aerodynamic spoiler	12kg	1 unit	12kg
		Total weight:	5,412kg

Table 1. Weight calculation

- **Plant Selection**

After evaluating species references, wind and temperature tolerance, pollution resistance, soil depth, maintenance needs, growth rates, water requirements, and sunlight needs. Chosen species include Euphorbia milii., Ficus microcarpa L.f. 'Golden Leaves', Sansevieria trifasciata ‘Golden Hahnii’, Sansevieria trifasciata ‘Hahnii’, Schefflera heptaphylla, Schefflera arboricola ‘Variegata’, Wedelia trilobata, Zoysia japonica.

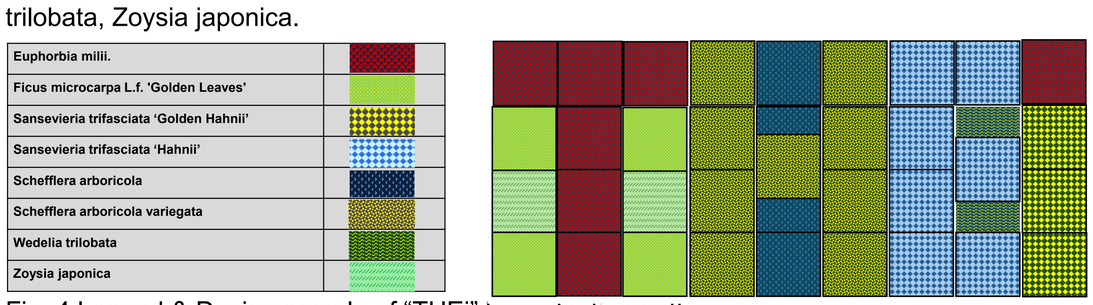


Fig. 4 Legend & Design sample of “THEi” logo planting pattern

Discussion

The feasibility analysis focuses on structural and weight considerations, indicating that lightweight materials such as modular planting trays with self-watering functions, erosion-resistant trays, and advanced planting media can reduce the additional load without compromising safety, especially after detailed calculations are undertaken to ensure load capacity remains within safety structural limits. Additionally, modifications like front deflectors and fiberglass spoilers demonstrate reducing wind drag while the buses are running on traffic roads.

Therefore, after evaluating the transpiration rate, plant stability, and maintaining traffic safety. The result is possible and applicable to install green roofs on buses.

Conclusion

After a comprehensive investigation into the feasibility, environmental impact, plant selection, energy efficiency, public perception, economic viability, and policy implications of green roofs on buses. The research findings will contribute to the development of sustainable urban transportation practices and the adoption of green roofs on buses. To realize the feasibility of green roofs on buses, the focus should be on optimizing design, especially prioritizing a lightweight structure with durability. Hereby, pilot projects should be launched to collect more data for further improvement, including structural integrity, plant health, aerodynamic effects, and energy efficiency. Also, need to actively engage with transportation authorities and regulators to establish clear safety standards and legislative frameworks that support green infrastructure on mobile vehicles.

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