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REVOLUTIONIZING URBAN ROADS: A COMPREHENSIVE REVIEW OF PIEZOELECTRIC TECHNOLOGY FOR SMART INFRASTRUCTURE

Vimukthi Tharaka[1], Nilantha Randeniya[2], Sahan Ravindu[3], Vidath Priyankara[4], K.P.G.K. Weerakoona[2], Lal Samarasekara[5]

[1]*Department of Engineering Technology, University of Sabaragamuwa, Sri Lanka.*
[2]*Department of Estate Management and Valuation, University of Sri Jayawardhanapura, Sri Lanka.*
[3]*Department of Computer Engineering, University of Sri Jayawardhanapura, Sri Lanka.*
[4]*Department of Civil Engineering, University of Moratuwa, Sri Lanka*
5Department of Civil Engineering, York University, Canada
vpvimukthi@tech.sab.ac.lk, rjnilantha@sjp.ac.lk, sahanravindumax@gmail.com, senarathnavip.19@uom.lk, kgpk@sjp.ac.lk, alsa@yorku.ca

ABSTRACT - This research paper explores the use of piezoelectric technology for sustainable energy generation and performance monitoring on smart urban roads. Piezoelectric materials convert mechanical stress into electrical voltage, offering high efficiency, durability, and low maintenance. The study investigates the potential benefits and challenges of implementing piezoelectric systems, and creates a framework for their optimal design and deployment. It also explores criteria for selecting urban roadways.

Keywords: Piezoelectric; Smart urban roads; Sustainable energy; Roadway performance; Deployment; Optimization.

1. INTRODUCTION

Smart urban roads have been identified as a promising solution for sustainable urban development, with advanced technologies being integrated to enhance roadway performance (García-Sánchez, Rodríguez-Monroy, Ruiz, & Guillén-González, 2017). Among the critical areas for improvement in urban roads are sustainable energy generation and roadway performance monitoring. The need for sustainable energy generation has become increasingly important due to the rising demand for energy, coupled with the need to reduce carbon emissions and enhance energy security (Liu, Wang, Zhang, , & Lin,, 2021). On the other hand, roadway performance monitoring is crucial for ensuring the safety and functionality of roads as well as optimizing maintenance and repair schedules.

Piezoelectric technology has gained significant attention in recent years as a promising solution to address these challenges by converting the mechanical energy generated by vehicles and pedestrians into electrical energy for various applications, such as roadway lighting and monitoring systems. Piezoelectric materials are able to convert mechanical stress into electrical voltage, which can then be harvested and used for energy generation (Jiang et al., 2020). This technology has several advantages, including high energy conversion efficiency, durability, and low maintenance requirements (Wang et al., 2019).

The integration of piezoelectric technology in smart urban roads can provide significant benefits, such as reduced dependence on non-renewable energy sources, improved roadway safety and performance, and enhanced environmental sustainability (Liu, , Wang, Zhang, , & Lin,, 2021)). By generating electricity from the mechanical energy generated by vehicles, piezoelectric technology can help reduce the carbon footprint of urban roads while also providing a reliable source of energy

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for roadway infrastructure (Yang, , Yang, , & Cao, , 2018). Additionally, piezoelectric sensors can be used for real-time monitoring of roadway conditions, such as traffic volume, vehicle speed, and road surface condition, enabling better traffic management and maintenance planning (Liu, , Wang, Zhang, , & Lin,, 2021). However, the implementation of piezoelectric technology in smart urban roads requires a comprehensive understanding of the technology's principles, performance, and limitations, as well as the potential benefits and challenges associated with its deployment. Several factors need to be considered, such as the design of the piezoelectric material, the installation method, and the energy storage and distribution system. Additionally, the impact of piezoelectric technology on the pavement structure and the durability of the roadway infrastructure needs to be evaluated (Zhang, 2019)

The research paper explores the use of piezoelectric technology in smart urban roads, focusing on sustainable energy generation and performance monitoring. It investigates factors influencing the performance of piezoelectric materials under different traffic conditions and environmental settings. The study also explores optimal design and deployment strategies for piezoelectric systems, aiming to maximize energy generation capabilities and enable effective performance monitoring. The research objectives of this study are:

- To investigate the integration of piezoelectric technology into smart urban roads for sustainable energy generation and roadway performance monitoring,
- To evaluate the performance of piezoelectric materials under different traffic and environmental conditions,
- To develop a framework for the optimal design and deployment of piezoelectric systems in urban roadways.

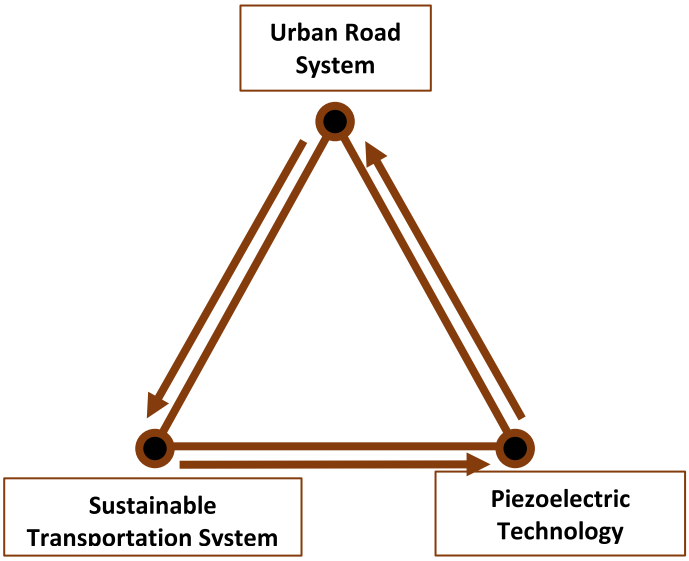

Figure 1. Conceptual framework of the study

The study combines knowledge from Urban Road Systems, Sustainable Transportation Systems, and Piezoelectric Technology to explore the integration of piezoelectric technology in smart urban roads for sustainable energy generation and performance monitoring. It assesses the performance of piezoelectric materials under different traffic and environmental conditions and develops a framework for optimal design and implementation. The goal is to identify innovative ways to harness sustainable energy and improve urban road performance, paving the way for more energy-efficient and eco-friendly transportation solutions.

2. RESULTS AND DISCUSSION

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Urban road selection criteria involve technical and non-technical factors, such as traffic volume, road width, pavement condition, and geometric design. These factors help manage and maintain urban roads by converting mechanical stress into electrical energy. High-traffic roads require wider lanes and stronger pavements, while low-traffic roads may be narrower and require less robust materials. Traffic volume, vehicle speed, and road surface temperature also impact piezoelectric materials' performance.

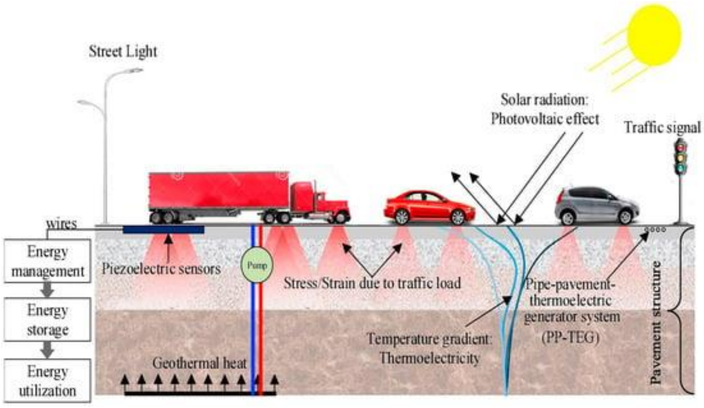

Figure 2. Available energy sources on a roadway (Reprinted with permission from 2018, Elsevier)

Urban road selection involves technical and non-technical factors such as traffic volume, road width, pavement condition, geometric design, land use, community preferences, and environmental impact. Poor pavement conditions can lead to increased maintenance costs and decreased safety. Piezoelectric systems should be built with appropriate material compositions and arrangements to maximize energy generation and performance monitoring. Intelligent control and data management systems are essential for effective energy flow in urban infrastructure. Encapsulation is an effective protective solution for long-term functioning. Interdisciplinary research and development are essential for the effective implementation and optimization of piezoelectric devices on urban roads.

3. CONCLUSION

The literature review on piezoelectric technology highlights gaps that need further investigation. Further research should explore the feasibility of implementing piezoelectric technology in urban road systems, evaluating its cost-effectiveness, dependability, and scalability. It's also important to evaluate the environmental impact of piezoelectric technology and explore potential mitigation strategies. The research may also have policy implications, providing recommendations for incorporating piezoelectric technology into smart city and sustainability plans.

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