


# Chapter 15

## Sustainable Innovation for Pothole Detection and Road Maintenance

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### **ABSTRACT**

*Poor road conditions, such as potholes, can lead to accidents and economic losses, particularly in developing countries. This study presents an innovative Arduino-based model for automatic pothole detection and filling to enable sustainable road maintenance. The model uses sensors to identify pavement distress, estimate pothole depths, and subsequently dispense the required filler material, thereby restoring road surfaces. The automated approach increases inspection efficiency and allows authorities to allocate resources optimally for road conservation efforts sustainably. Additionally, a manually monitored mobile application provides operators with remotely configurable control of model movement and operations. Overall, this study demonstrates sustainable innovation in the application of frugal robotics and IoT to intelligent transportation infrastructure management in resource-constrained environments. Sustainable technology solutions balance economic viability, social benefits for road users, and environmental impacts through context-appropriate road maintenance.*

### **INTRODUCTION**

Any country's transportation system is based mostly on its roads, which are essential for moving people, products, and services. In addition to ensuring fast

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and seamless traffic, well-maintained roads support environmental sustainability, public safety, and economic prosperity (Bernas et al., 2018; Blythe et al., 2008). However, several variables, such as excessive traffic, unfavourable weather, and poor maintenance, can cause roads to degrade over time (Fan et al., 2020; Finogeev et al., 2019). Potholes are one of the biggest problems with road maintenance since they may seriously jeopardize vehicle safety and cause collisions, vehicle damage, and higher fuel consumption (Yebe et al., 2021; Yik et al., 2021). Potholes are a major issue in underdeveloped nations since there are often less resources available for road upkeep (Katsamenis et al., 2022; Ma et al., 2022).

The importance of robust road infrastructure extends beyond mere connectivity. Well-maintained roads contribute significantly to a nation's economic vitality by facilitating efficient trade, reducing transportation costs, and enhancing overall productivity (Ke et al., 2020; Quium, 2019). They also play a crucial role in social development by improving access to education, healthcare, and employment opportunities, particularly in rural and remote areas. Moreover, road quality directly impacts environmental sustainability, as smoother surfaces and optimised traffic flow can reduce vehicle emissions and fuel consumption (Bernas et al., 2018; Blythe et al., 2008).

The challenge of road degradation, particularly the formation of potholes, is a complex issue that requires a multifaceted approach (Kim et al., 2022; Omar & Kumar, 2020). While developed nations often have the resources and technology to implement proactive maintenance strategies, developing countries face significant hurdles in addressing this problem (Moharrak et al., 2024). Limited budgets, inadequate infrastructure assessment tools, and a lack of skilled personnel can exacerbate this issue, leading to a cycle of deterioration that becomes increasingly difficult to break. Innovative solutions, such as the use of more durable materials, advanced monitoring systems, and community-based maintenance programs, are being explored to tackle this challenge effectively, particularly in resource-constrained environments (Fan et al., 2020; Finogeev et al., 2019; Katsamenis et al., 2022; Ma et al., 2022).

Conventional techniques for identifying and fixing potholes mostly rely on labour-intensive and human error-prone manual labour (Sri Kakarla et al., 2024; Talha et al., 2024). Additionally, potholes cannot always be found by manual inspections, which might cause repairs to be postponed and the road surface to deteriorate even more (Rupp et al., 1998; Sattar et al., 2018). Due to excessive fuel usage and vehicle emissions, this delay may have detrimental effects on the environment, as well as an increase in accidents and maintenance expenses. Recent advancements in technology have paved the way for automated pothole detection systems, which offer more efficient and accurate results. These systems typically employ various sensors, such as cameras, accelerometers, and GPS devices to collect data on road conditions in real time. By leveraging machine learning algorithms and computer

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