

The Implementation of a System Thinking Paradigm to Enhance Road Maintenance in Local Government

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Abstract

The South African government is divided into three levels: national, provincial, and local. The local government is constitutionally mandated to provide sustainable and effective services. In South Africa, roads, among other essentials are basic human rights. However, the state of road infrastructure is in a critical state, with 80% of roads having exceeded their 20-year design life. This presents a challenge to the country's economic growth and the quality of life of citizens. therefore, this study aims to propose a system dynamics model for one of the South African municipalities in Limpopo Province that evaluates the current maintenance practices and simulates sustainable road maintenance under maintenance resource constraints. three objectives were addressed, including evaluation of current maintenance practices, identifying systematic inefficiencies, and proposing adaptive solutions for under-resourced municipalities, leaving a critical gap in scalable and sustainable solutions. The current literature lacks practical models for adaptive road maintenance tailored to under resourced municipalities, leaving a critical gap in scalable and sustainable solutions. Addressing these gaps requires overcoming persistent budgetary constraints, workforce shortages, and institutional resistance to new technology adoption. A mixed-method research design was adopted to ensure the success of this study. A systematic literature review, document analysis, and model development were employed as the research methods. The results revealed the overreliance on a singular maintenance strategy as the primary factor contributing to substandard road conditions. By integrating systems thinking with dynamic modelling, this study offers scalable template for municipalities to optimize limited resources while improving long term infrastructure resilience.

Keywords

Road maintenance, Systems Thinking, System Dynamics, municipalities, and Technological advancement.

Biographies

Sinah Marungane is a Master of Engineering in Engineering Management student at Tshwane University of Technology (TUT) in the Faculty of Engineering and the Built Environment. She has two Bachelor of Technology degrees, one in Civil Engineering and one in Project management, from Tshwane university of Technology (TUT), a National Diploma in Civil Engineering from Durban University of Technology (DUT), and a National Certificate in Municipal Financial Management from the Local Government Sector Education and Training Authority (LGSETA). Before joining the family business, which specializes in consulting and construction, she worked for three Municipalities in Limpopo: Mopani District Municipality in the project management unit, Greater Giyani Municipality in the roads and stormwater section, and Ba-Phalaborwa Municipality in the project management and water and sanitation section. Sinah is a registered member of the South African Institution of Civil Engineering (SAICE) and a Candidate Technologist for Engineering Council of South Africa (ECSA).

Prof. Tshifhiwa Nenzhelele is an experienced academic with more than 27 years of teaching experience. He is currently an Associate Professor and a Head of Department in the Department of Industrial Engineering, Gibela Research Chair, and Interim DSTI NRF SARCH Chair at the Tshwane University of Technology. He holds different qualifications, including a National Diploma up to the Doctoral degree in Industrial Engineering from the Tshwane University of Technology. His research area of interest is in Simulation Modelling, Facilities design and Mathematical modelling. Prof Nenzhelele is keen in shaping the future of this country by adding value to policy development through conducting research that will scientifically informed the decision makers on the status of different sectors of our economy with respect to productivity. Prof. Tshifhiwa Nenzhelele is an experienced academic with more than 27 years of teaching experience. He is currently an Associate Professor and a Head of Department in the Department of Industrial Engineering, Gibela Research Chair and Interim DSTI NRF SARCH Chair at the Tshwane University of Technology. He holds different qualifications, including from a National Diploma up to the Doctoral degree in Industrial Engineering from the Tshwane University of Technology. His research area of interest is in Simulation Modelling, Facilities design and Mathematical modelling. Prof Nenzhelele is keen in shaping the future of this country by adding value to policy development through conducting research that will scientifically informed the decision makers on the status of different sectors of our economy with respect to productivity.

Prof Vusumuzi Malele holds a Doctor of Technology (DTech) degree in Industrial Engineering. He is currently an Associate Professor in Computer Science and Information Systems at North-West University, Vaal Campus. He is also Adjunct Professor at Tshwane University of Technology (TUT) at the Department of Industrial Engineering, Faculty of Engineering and Built Environment (FEBE) and at the Department of Computer Systems Engineering (CSE), Faculty of Information and Communication Technology (FoICT). His research areas are AI, ML, DL; Cybersecurity; IoT, Wireless Communication Network; Industrial, System and Software Engineering; Intelligent and Smart Systems; Technology, Innovation and Engineering Management; Computing and Engineering Education; Future and Digital skills.