



## Systematic Review

# Digital Twin Approach for Operation and Maintenance of Transportation System—Systematic Review

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**Abstract:** There is a growing need to implement modern technologies, such as digital twinning, to improve the efficiency of transport fleet maintenance processes and maintain company operational capacity at the required level. A comprehensive review of the existing literature is conducted to address this, offering an up-to-date analysis of relevant content in this field. The methodology employed is a systematic literature review using the Primo multi-search tool, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The selection criteria focused on English studies published between 2012 and 2024, resulting in 201 highly relevant papers. These papers were categorized into seven groups: (a) air transportation, (b) railway transportation, (c) land transportation (road), (d) in-house logistics, (e) water and intermodal transportation, (f) supply chain operation, and (g) other applications. A notable strength of this study is its use of diverse scientific databases facilitated by the multi-search tool. Additionally, a bibliometric analysis was performed, revealing the evolution of DT applications over the past decade and identifying key areas such as predictive maintenance, condition monitoring, and decision-making processes. This study highlights the varied levels of adoption across different transport sectors and underscores promising areas for future development, particularly in underrepresented domains like supply chains and water transport. Additionally, this paper identifies significant research gaps, including integration challenges, real-time data processing, and standardization needs. Future research directions are proposed, focusing on enhancing predictive diagnostics, automating maintenance processes, and optimizing inventory management. This study also outlines a framework for DT in transportation systems, detailing key components and functionalities essential for effective maintenance management. The findings provide a roadmap for future innovations and improvements in DT applications within the transportation industry. This study ends with conclusions and future research directions.

**Keywords:** digital twin; operation and maintenance; transportation system; systematic review analysis; air transportation; railway transportation; land transportation; in-house logistics; water and intermodal transportation; supply chains operation; PRISMA guidelines



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## 1. Introduction

The dynamics of the transportation market and the growing demands of customers pose significant challenges for transportation companies in the context of maintaining the durability and reliability of transport means. The transportation industry is subject to continuous changes resulting from various factors, such as technological advancements, changing regulations, and consumer trends. In recent years, the dynamic development of the transportation sector can be observed as driven by ongoing globalization, the growth of international trade, and increasing societal mobility. Transportation companies face intensified competition from both traditional and new, innovative entities. Market dynamics force them to constantly adapt to changing conditions and seek new solutions and technologies to maintain a competitive position [1].

# Systematic Approach To Maintenance Transportation Research Record

**Sebastian Brünink**



## **Systematic Approach To Maintenance Transportation Research Record:**

*Operation and Maintenance of Large Infrastructure Projects* J.S. Jensen, L.J. Vincentsen, 2018-12-19 Major Infrastructure links across water represent large investments The structures and systems must be optimised to keep costs in control Optimisation needs and the tendency to more slender and light structures imply that engineering disciplines like Bridge Aerodynamics and Ship Collision Analysis have an increasing impact on the overall design of links Also the attention to life cycle costs implies Operation and Maintenance must be investigated and planned in parallel to the design and construction of the links The 1998 International Symposium aims at presenting state of the art and future development within the three mentioned engineering disciplines Exploring the many facets of major infrastructure projects this symposium concentrated on developments within organisational strategic and policy areas and both traffic and o m management Contributors to the papers include operators consultants and international experienced owners *Control in Transportation Systems 1986*

M.M. Etschmaier, H. Strobelt, R. Genser, T. Hasegawa, 2014-05-23 This volume investigates developments in and management of transportation systems future trends and what effects these will have on society The book studies transportation systems planning traffic problems and the issue of conservation the use of logistics and the role of computers and robotics in traffic control *Urban Transportation Abstracts*, 1987

**Economic Analysis of Airfield Pavement Rehabilitation**

**Alternatives** Jon A. Epps, C. V. Wootan, 1982

**Needs Assessment Study of the Iowa DOT Maintenance Facility Construction Needs**, 1989 The purpose of this study is to provide recommendations relative to the location and

construction needs for highway maintenance facilities within the state of Iowa These recommendations were to be developed with consideration being given to the public's expectations and priorities for highway maintenance services As a part of the study effort a review was made of the methods used by other states to deliver highway maintenance services To accomplish the study Wilbur Smith Associates undertook a series of tasks These efforts included gathering of data and information to characterize the various maintenance programs and the delivery of maintenance and operations services by the Department We researched the delivery of highway maintenance services in other states Interviews with Iowa DOT maintenance personnel were accomplished A schedule of public hearings was developed and ten hearings were held All the information was integrated and various analyses were made From these analyses we drew conclusions and developed recommendations

*Multi-objective Optimization for Bridge Management Systems* National Cooperative Highway Research Program, 2007 Accompanying CD ROM contains users manual and software for NCHRP Report 590 Multi objective optimization for bridge management systems CD ROM label **Transportation Research Record**, 2000 **Closing the Knowledge Gap for**

**Transit Maintenance Employees** David Finegold, Transit Cooperative Research Program, 1998 This report presents guidelines on evaluating and implementing strategies to improve the skills of the transit industry's maintenance workforce in order to keep pace with evolving technology The report is intended to help maintenance departments develop highly skilled

high performance work organizations Research was undertaken by Rand Corporation to assess technological demands document current practices and examine and propose new approaches to link maintenance staffing practices with evolving technology to improve effectiveness The areas addressed in the research included the range of programs currently in place differences and similarities in current practice analysis of major pitfalls and keys to success an examination of vendor roles and responsibilities in training and the effect of labor relations and work rules An Integrated Systems Approach to the Development of Winter Maintenance/management Systems ,2006 Winter road maintenance operations require many complex strategic and operational planning decisions The five primary problems involved in this intricate planning procedure include locating depots designing sectors routing service vehicles scheduling vehicles and configuring the vehicle fleet The complexity involved in each of these decisions has resulted mainly in research that approaches each of the problems separately and sequentially which can lead to isolated and suboptimal solutions After discussing the complexity of the relaxed subproblems that would need to be solved to optimize the intricate winter maintenance operations the research turns to a heuristic approach to more feasibly address the interrelated problems This report subsequently presents a systematic heuristic based optimization approach to integrate the winter road maintenance planning decisions for depot location sector design vehicle route design vehicle scheduling and fleet configuration The approach presented is illustrated through an example of public sector winter road maintenance planning for a rural transportation network in Boone County Missouri When applied to the real world winter road maintenance planning problems for Boone County the methodology delivered very promising results The solution methodology successfully achieves the objective of a more integrated and less sequential approach to the problems considered The integrated solution would allow the Missouri Department of Transportation MoDOT to maintain the same high level of service with significantly fewer resources The results indicate that this methodology is a successful step towards solving realistic multiple depot problems involving heterogeneous winter maintenance fleets

**Sustainable Winter Road Operations** Xianming Shi,Liping Fu,2018-03-27 The first and only comprehensive guide to best practices in winter road operations Winter maintenance operations are essential to ensure the safety mobility and productivity of transportation systems especially in cold weather climates and responsible agencies are continually challenged to provide a high level of service in a fiscally and environmentally responsible manner Sustainable Winter Road Operations bridges the knowledge gaps providing the first up to date authoritative single source overview and guide to best practices in winter road operations that considers the triple bottom line of sustainability With contributions from experts in the field from around the world this book takes a holistic approach to the subject The authors address the many negative impacts on regional economies and the environment of poorly planned and inadequate winter road operations and they make a strong case for the myriad benefits of environmentally sustainable concepts and practices Best practice applications of materials processes equipment and associated technologies and how they can improve the effectiveness and efficiency of

winter operations optimize materials usage and minimize cost corrosion and environmental impacts are all covered in depth Provides the first up to date authoritative and comprehensive overview of best practices in sustainable winter road operations currently in use around the world Covers materials processes equipment and associated technologies for sustainable winter road operations Brings together contributions by an international all star team of experts with extensive experience in designing implementing and managing sustainable winter road operations Designed to bring professionals involved in transportation and highway maintenance and control up to speed with current best practice Sustainable Winter Road Operations is essential reading for maintenance professionals dealing with snow and ice control operations on highways motorways and local roads It is a valuable source of information and guidance for decision makers researchers and engineers in transportation engineering involved in transportation and highway maintenance And it is an ideal textbook for advanced level courses in transportation engineering

Urban Mass Transportation Abstracts ,1982 *Public Benefits of Highway System Preservation and Maintenance* Andrew C. Lemer,National Cooperative Highway Research Program,2004 TRB s National Cooperative Highway Research Program NCHRP Synthesis 330 Public Benefits of Highway System Preservation and Maintenance examines the current practices for identifying measuring and articulating the public benefits of highway system maintenance and operation and of communicating those benefits that are understandable and meaningful to stakeholders road users elected officials and others who have an interest in the system s performance

*Bearing Capacity of Roads, Railways and Airfields* Andreas Loizos,Imad Al-Qadi,Tom Scarpas,2017-07-20 Bearing Capacity of Roads Railways and Airfields includes the contributions to the 10th International Conference on the Bearing Capacity of Roads Railways and Airfields BCRRA 2017 28 30 June 2017 Athens Greece The papers cover aspects related to materials laboratory testing design construction maintenance and management systems of transport infrastructure and focus on roads railways and airfields Additional aspects that concern new materials and characterization alternative rehabilitation techniques technological advances as well as pavement and railway track substructure sustainability are included The contributions discuss new concepts and innovative solutions and are concentrated but not limited on the following topics Unbound aggregate materials and soil properties Bound materials characteritics mechanical properties and testing Effect of traffic loading In situ measurements techniques and monitoring Structural evaluation Pavement serviceability condition Rehabilitation and maintenance issues Geophysical assessment Stabilization and reinforcement Performance modeling Environmental challenges Life cycle assessment and sustainability Bearing Capacity of Roads Railways and Airfields is essential reading for academics and professionals involved or interested in transport infrastructure systems in particular roads railways and airfields

**Rural Public and Intercity Bus Transportation** ,1993 Life Cycle Costing for Construction J.W. Bull,2003-10-04 The construction industry is becoming increasingly aware of the need to adopt a holistic approach to the design building and disposal of structures With 60 per cent of the total construction budget in most

developed countries being spent on repair and maintenance there is an obvious need to design for reliability and durability with more carefully planned maintenance and repair schedules One important facet is to look at how costs are distributed and spent during the lifetime of a structure an approach known as life cycle costing which has the ultimate aim of minimising total lifetime expenditure As an example choosing an inexpensive coating for steelwork may require maintenance every three years whereas a coating which is more expensive may require repairing only once per decade It is a question of balance taking the lifetime costs of the structure into consideration This new book provides an insight into how whole life costing is affecting our approach to designing building maintaining and disposing of structures The book is written for consulting engineers in the fields of civil and structural engineering building designers architects quantity surveyors refurbishing specialists as well as practising civil and structural engineers engaged in planning design construction repair and refurbishment of structures

**Special Report - Highway Research Board** National Research Council (U.S.). Highway Research Board,1975

**The Handbook of Highway Engineering** T.F. Fwa,2005-09-28 Modern highway engineering reflects an integrated view of a road system s entire lifecycle including any potential environmental impacts and seeks to develop a sustainable infrastructure through careful planning and active management This trend is not limited to developed nations but is recognized across the globe Edited by renowned authority

Introduction to Unmanned Aircraft Systems, Second Edition Douglas M. Marshall,Richard K. Barnhart,Eric Shappee,Michael Thomas Most,2015-10-26 The proliferation of technological capability miniaturization and demand for aerial intelligence is pushing unmanned aerial systems UAS into the realm of a multi billion dollar industry This book surveys the UAS landscape from history to future applications It discusses commercial applications integration into the national airspace system NAS System function operational procedures safety concerns and a host of other relevant topics The book is dynamic and well illustrated with separate sections for terminology and web based resources for further information

**Safety and Reliability of Complex Engineered Systems** Luca Podofillini,Bruno Sudret,Bozidar Stojadinovic,Enrico Zio,Wolfgang Kröger,2015-09-03 Safety and Reliability of Complex Engineered Systems contains the Proceedings of the 25th European Safety and Reliability Conference ESREL 2015 held 7 10 September 2015 in Zurich Switzerland Including 570 papers on theories and methods in the area of risk safety and reliability and their applications to a wide range of industrial civil and social sectors this book will be of interest to academics and professionals involved or interested in aspect of risk safety and reliability in various engineering areas

Management,1978

## The Enigmatic Realm of **Systematic Approach To Maintenance Transportation Research Record**: Unleashing the Language is Inner Magic

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