ASSESSING THE EFFECTS OF INTERVENTION FREE PERIODS ON RAILWAY INTERVENTION COSTS AND SERVICE

Bryan Adey
Swiss Federal Institute of Technology in Zürich (ETHZ)

Ensuring that railways provide excellent service requires the execution of maintenance interventions. As railway use intensifies, this becomes increasingly difficult due to the conflict between track possession used for train operation and the execution of interventions. One way to improve the consistency of train schedules, and thus the user comfort, is to impose closure free periods, where no interventions are planned. The imposition of closure free periods forces asset managers to group their interventions either before or after the closure free periods. This encourages asset managers to exploit synergies between interventions which can reduce costs and the negative effects on users. It also, however means that maintenance interventions may need to be executed earlier or later than the times suggested when only considering their optimal life-cycles. To deal with this issue, in this paper, we investigate the effect of imposing intervention free periods on the development of intervention programs in terms of intervention costs and disruptions to service. We do this by using a network-flow optimization model to determine the optimal intervention programs for a 5-year planning period without and with the imposition of a minimal 2-year closure free period on a railway line in Switzerland. The effect of the intervention free period on intervention costs and service are discussed, along with the losses of executing interventions at different points in time from those suggested using optimal asset life-cycles.

Prof. Dr. Bryan T. Adey is the Professor for Infrastructure Management, in the Institute for Construction and Infrastructure Management of the Department of Civil, Environmental and Geomatic Engineering, at the), Switzerland. He is also president of the code and research committee 4.3 Maintenance Management: Total System of the Swiss Association for Road and Transport Professionals (VSS), and a member of the Swiss Society of Engineers and Architects (SIA), and the Institute of Asset Management. Prof. Adey's research is focused on improving the effectiveness and efficiency of infrastructure management. This includes the definition and standardization of the infrastructure management process, from setting goals to determining optimal monitoring and intervention programs, and evaluating the performance of infrastructure management organisations. It also includes the automation of parts of the infrastructure management process, e.g. the determination of optimal intervention strategies for single infrastructure objects and the development of algorithms to generate network intervention plans that maximise net benefit. Other themes of his research are estimating the risk related to infrastructure, including estimating infrastructure behaviour when subject to extreme events, estimating the resilience of the infrastructure and the system in which it is embedded, and estimating the optimal ways to restore infrastructure following extreme events. Prof. Adey works on infrastructure management issues related to many types of infrastructure, including road networks, rail networks, water distribution networks, sewer networks and building portfolios. Prof. Adey obtained his Doctorate in Technical Sciences in Civil Engineering from the Swiss Federal Institute of Technology in Lausanne, Switzerland in 2002, his Master of Science in Structural Engineering from the University of Alberta, Edmonton, Canada in 1997, and his Bachelor of Engineering from Dalhousie University, Halifax, Canada in 1995.

AN IN-DEPTH ECONOMETRIC ANALYSIS OF PAVEMENT PERFORMANCE AND SERVICE LIFE BY PAVEMENT REHABILITATION TREATMENT TYPE AND DELIVERY METHOD

Sheikh Shahriar Ahmed
University at Buffalo
in collaboration with Panagiotis Anastasopoulos, Damien David, Md. Tawfiq Sarwar, Grigorios Fountas

This paper conducts a detailed statistical assessment of pavement rehabilitation treatments by delivery methods, by studying their performance in terms of pavement indicators (International Roughness Index, rutting depth, and Pavement Condition Rating) and in terms of their pavement service lives. The data include 812 pavement segments that were rehabilitated under six popular treatments through five popular delivery methods (with a focus on Public-Private Partnerships, PPP) that were let or completed in the United States between 1996 and 2011. The treatments include: 2-course hot-mix asphalt, HMA, overlay with or without surface milling; concrete pavement restoration; 3-course HMA overlay with or without surface milling; 3-course HMA overlay with crack and seat of Portland Cement Concrete, PCC, Pavement; 3-R (resurfacing, restoration and rehabilitation) and 4-R (resurfacing, restoration, rehabilitation and reconstruction) overlay treatments; and 3-R/4-R pavement replacement treatments. The delivery methods / PPP types include: performance-based contracting; cost-plus-time; incentives/disincentives; design-build and their derivatives; warranties; and lane rentals. In order to model and forecast pavement performance, a three-stage least squares (3SLS) approach is used. For the pavement service life analysis, the elapsed time until the pavement crosses a threshold is investigated, using random parameters hazard-based duration models. Separate models are estimated for each combination of delivery methods / PPP type and rehabilitation type, and the model estimation results show that several influential factors, such as traffic characteristic, weather characteristics, pavement characteristics, and drainage condition, affect pavement performance and pavement service life; and these factors differ among pavement rehabilitation treatments and delivery methods / PPP types.

Sheikh Shahriar Ahmed is a PhD Candidate specializing in Transportation Systems Engineering at University at Buffalo – The State University of New York. Prior to pursuing PhD, he received his M.Sc. in Transportation Systems Engineering from University at Buffalo, and B.Sc. in Civil Engineering from Bangladesh University of Engineering and Technology (BUET). His research interests include the use of statistical and econometric methods for transportation data analysis, traffic safety, and emerging technologies in transportation.

OPTIMAL ASSIGNMENT OF SAFETY TREATMENTS TO REDUCED ROADWAY DEPARTURE (RWD) CRASHES.

A. Ricardo Archilla
University of Hawaii at Manoa

This study presents the development of a plan to reduce roadway departure (RwD) crashes on state roads using optimization together with Empirical Bayes (EB) estimates of crash frequencies and Crash Modification Factors (CMFs) for selected countermeasures. The scope is limited to two-lane, two-way State roadways. The frequency of RwD crashes was investigated using ten years of crash data from motor vehicle accident reports of the State of Hawaii, together with detailed roadway characteristics. The assembled dataset was used to develop a comprehensive model to predict the expected number of RwD crashes over 10 years on 0.2-mi highway segments. The model predictions were then used with the observed crash frequencies in an EB analysis for creating the RwD safety plan. The safety plan was developed using two different approaches: Incremental Cost-Effectiveness analysis and Integer Programming. Both approaches provide the same cost-effectiveness curves and equivalent plans. The treatments considered include Shoulder Rumble Strips (SHRS), Centerline Rumble Strips (CLRS), High Friction Surface Treatments (HFST), and Chevron Signs. For any selected investment level, the provided plans provide specific treatment recommendations. The presentation concentrates on how information transformed to make the application of these techniques feasible.

Adrian "Ricardo" Archilla is a Professor in the Department of Civil and Environmental Engineering at the University of Hawaii at Manoa. He joined the department as assistant professor in 2002. Prior to joining the University of Hawaii, he worked as teaching assistant, research engineer, and professor at the National University of San Juan, Argentina where he got his bachelor's degree (1989), and as research engineer at the Turner-Fairbanks Highway Research Center (1995) as part of the loaned staff program of the Pan-American Institute of Highways. He obtained a M.Sc. in Civil Engineering degree with specialization in Transportation (1992) from the University of Calgary, Canada, while working as a teaching assistant, and a Ph.D. in Civil Engineering (Transportation) (2000) from the University of California at Berkeley, while working as research and teaching assistant. Ricardo's research focuses on pavement deterioration modeling, material characterization, traffic safety.

SAFETY INTEGRATED STRATEGIC PAVEMENT MANAGEMENT USING A HYBRID APPROACH OF STOCHASTIC AND DETERMINISTIC PROCESS AS A PRACTICAL SOLUTION IN DEVELOPING COUNTRIES: THE CASE OF ADDIS ABABA, ETHIOPIA

Angelo Asnake
Osaka University
in collaboration with Kiyoyuki Kaito

Road safety has become a global concern as road traffic crashes have devastating impacts on human, physical and financial capital. Every year 1.35million people die due to road traffic crashes, from which ninety percent of the toll has happened in developing countries. Improving or maintaining road infrastructure performance at a lower life cycle cost is another challenge, mainly in developing countries. The deterioration of road networks costs nations a massive amount of money due to the absence of proper pavement management systems (PMSs). Therefore, road agencies need a simple, customizable, and safety cognizant PMS to address the problems. This paper presents a practical method that road agencies can utilize to implement a sustainable and safety-incorporated strategic pavement management system. A two-tiered stochastic process of pavement deterioration and repair is modeled using a Markov-based model. The proposed model is suitable for road agencies with limited data or those who cannot afford to accumulate a vast amount of data due to the urgent need to address the bad road network condition. On the other hand, incorporating the road safety aspect follows the deterministic process. The international road assessment program(iRAP) star rating protocol is used to measure the safety condition in consideration of all types of road users. The approach is empirically illustrated using pavement and safety condition data from Addis Ababa, Ethiopia. The paper illustrates how to establish an appropriate pavement and safety performance goal at the network level, a practicable deterioration prediction model, and a process to analyze the relative life cycle cost and risk of maintenance strategies to achieve the dual performance goals – pavement and safety. In this regard, the proposed PMS approach can be used by road agencies for making informed and safety-conscious decisions to manage their assets proactively with relatively less pavement condition data.

Angelo Asnake is a Ph.D. candidate in the Graduate School of Engineering at Osaka University. Asnake completed his Master of Engineering in Road and transport engineering at Addis Ababa University and his undergraduate studies in civil engineering at Mekelle University. He has more than fifteen years of practical experience, particularly in road construction and asset management. He has worked from site engineer to general manager positions at different levels in governmental and private companies. His professional objective is to contribute to upgrading the lives of marginalized and disadvantaged community groups by implementing his academic knowledge and experience. His dream to become a civil engineer started in his childhood after he saw people carrying a patient with a homemade stretcher from a nearby village due to the absence of a road to use an ambulance. He is interested in research related to public infrastructure management ranging from theory to implementation policy (from prediction modeling to maintenance management framework). His research interest emanates from the intention that public infrastructures have a leading role in improving the economy thereof the standard of life. Moreover, in his research activities, he has keen to encompass the developing countries' challenges. His current research focuses on incorporating road safety into the pavement management system. Asnake is born in Metu town, 600 km far from the capital of Ethiopia. He is a father of three and enjoys watching movies and spending time with his family. He admires nature, mostly forest scenery, and loves pets.

FRAMEWORK TO SUPPORT INFRASTRUCTURE UPGRADES FOR DECARBONIZATION OF U.S. FREIGHT RAIL

Adrian Hernandez
Northwestern University
in collaboration with Max Ng, Pablo Durango-Cohen, Hani Mahmassani

The decarbonization of the U.S. transportation sector presents a considerable challenge for the freight railroads, whose operations are extremely energy intensive and networks span tens of thousands of track-miles. This paper focuses on those alternative fuel technologies that require considerable investments in ancillary infrastructure in order to support rail operations (e.g., battery-electric and hydrogen fuel cell). The joint location and sizing of refueling infrastructure is a non-trivial, and further combinatorial, problem as: (1) refueling facilities are deployed and sized over a network with a large degree of interconnectivity, and (2) regional economics and economies of scale jointly affect the cost of a facility deployment strategy as capital costs depend both on the locations and the capacities of refueling stations. To address this intractability, we present a hierarchical framework to decouple the facility location and facility sizing problems and apply this to the deployment of refueling infrastructure for alternative fuel technologies. The results of this framework are evaluated for two railroad networks, an Eastern and a Western U.S. railroad, over a series of relevant technology deployment scenarios for battery-electric and hydrogen fuel cell locomotives. The results are analyzed with respect to cost of deployment and emissions reductions potentials.

Adrian Hernandez is a current Ph.D. Candidate in Northwestern University's Transportation Program in the Department of Civil and Environmental Engineering. At Northwestern, he is advised by Prof. Pablo Durango-Cohen, and has been conducting research on the decarbonization of freight rail in the U.S. Adrian received his B.S. in Civil Engineering from Cornell University, where he researched algorithms for vehicle routing problems under the supervision of Prof. Samitha Samaranayake and Juan Carlos Martinez Mori. Adrian has been the recipient of the LSAMP Fellowship and is a current GEM Fellow. His academic interests in lie in optimization, operations research, infrastructure management, transportation, public policy, and economics.

LOCAL ANOMALY DETECTION ON SLOPES BASED ON DEEP LEARNING WITH A POINT CLOUD

Taichi Ishikawa
Osaka University
in collaboration with Kiyoyuki Kaito and Kiyoshi Kobayashi

In recent years, infrastructure facilities are rapidly aging, and their maintenance is an urgent issue. From the viewpoint of life cycle cost and risk assessment, preventive maintenance is often emphasized, and early anomaly detection of infrastructure facilities is indispensable for the realization of thorough preventive maintenance. In the case of artificial properties such as bridges, tangible and intangible findings can be used because structural weakness are identified and the deterioration mechanism is revealed. Therefore, it is possible to identify members whose deterioration is progressing and evaluate their lifespan by using tacit knowledge of specialized engineers and statistical deterioration prediction methods based on inspection data, as a result, it is not technically impossible to carry out anomaly detection at an early stage. However, the deterioration process of publicly used natural slopes has various uncertainties, so it is difficult for even specialized engineers to carry out anomaly detection at an early stage. In this situation, the anomaly detection using the data on spatially dense point cloud is expected to be a powerful tool. In the field of civil engineering, laser measurement technologies for obtaining data on point cloud, such as MMS, have been developed. However, with point-cloud data, it is impossible to grasp the deformation and changes in each object easily, so such data have not been utilized sufficiently for practical decision making. In this study, the author proposes a method for detecting anomalies on slopes based on deep learning with a point cloud. Furthermore, the author validates the effectiveness of the method by trying to detect the slope frames with local anomalies, such as deformation and protrusion.

Taichi Ishikawa is a Master's student in the Graduate School of Engineering at Osaka University. He specializes in civil engineering, such as structural mechanics, fluid dynamics, and soil mechanics. He has been studying civil engineering for eight years since college of technology. At a college of technology, he was conducting research on rust, which greatly affects the deterioration of bridges, especially on the estimation of salinity flying from the coast, using computational fluid dynamics(CFD). Currently, he is studying management methods for infrastructure facilities using mathematical statistics and machine learning. In particular, he has been studying the development of anomaly detection systems in slope management, and risk assessment methods for occupational accidents using machine learning. His research interest emanates from the fact that the management of infrastructure facilities, which has been rapidly advancing in recent years, has become an urgent issue in Japan. Moreover, his research objectives are to contribute to the sophistication of management methods for rapidly aging infrastructure facilities in Japan, and to pass on the tacit knowledge of skilled engineers useful for their management to the next generation as explicit knowledge. He is born in Shimane Prefecture in Japan, far from Tokyo, the capital of Japan. He is interested in mathematics, computer science and machine learning, and spends his holidays on reading those books.

INFRASTRUCTURE PREPARATIONS FOR CAV: A CONVERSATION ON DEMAND AND SUPPLY PERSPECTIVES, AND A NUMERICAL CASE STUDY ON DEDICATED LANE DEPLOYMENT SCHEDULING

Samuel Labi
Purdue University

Highway agencies seek guidance on the changes in infrastructure design and management necessary for connected and automated vehicle (CAV) operations, including the deployment of dedicated lanes (DL) for CAVs, and how to schedule these design changes and DL deployments. This presentation identifies some demand and supply perspective of the issue. On the demand side, the presentation discusses the trends and uncertainties regarding CAV market penetration and level of autonomy during the CAV transition period. On the supply side, the presentation suggests a classification for CAV-related roadway infrastructure, discusses the challenges and opportunities associated with infrastructure preparation for CAVs, and identifies stakeholder roles regarding CAV infrastructure provision. Finally, the presentation discusses a case study on CAV dedicated lane deployment scheduling at a given study network.

Dr. Labi is a professor at Purdue University's Lyles School of Civil Engineering, and associate director of USDOT's Region 5 Center for Connected & Automated Transportation (CCAT). His research is guided by an evolving civil infrastructure landscape that is characterized by emergent threats (aging infrastructure, funding limitations, and infrastructure vulnerability) and opportunities (technological advancements, interdisciplinary synergies, and data analytics). Dr. Labi's research work has produced technical reports, guidebooks, software packages and other electronic tools addressing policies, procedures, designs, and materials, and his research clients have included USDOT, National Academy of Sciences, and the World Bank. He has published 140 scientific articles in reputable journals, 50 research reports, and 2 textbooks (Transportation Decision Making in 2008, and Civil Engineering Systems in 2014) published by Wiley. He has given over 350 presentations at international conferences including invited speaker roles and keynote speeches, and served in various editorial roles for journals including Computer-Aided Civil & Infrastructure Engineering, Safety Science, and the ASCE Journals of Infrastructure Systems and Risk & Uncertainty Part A. He is chair of ASCE's Economics & Finance committee, secretary of TRB's asset management committee, and member of ASCE's committees on infrastructure systems and highway pavements. Dr. Labi's major research awards include American Society of Tests and Materials (ASTM)'s Mather Award (2007), TRB's K.B. Woods (2008), ASCE's Masters Award (2014), AASHTO high-value research (team award) (2014), TRB's Grant Mickel (2018) award, and Frontiers journal's Joseph Sussman best paper award (2021).

AUTONOMOUS CONDITION MONITORING-BASED PAVEMENT MANAGEMENT SYSTEM

Jinwoo Lee
Korea Advanced Institute of Science and Technology
in collaboration with Heeseung Shon, Chung-Suk Cho, Young-Ji Byon

Due to high operation cost of dedicated inspection vehicles, conventional pavement management systems (PMS) suffer from limited data quantity collected from periodic inspections. However, increasing market penetration of connected autonomous vehicles (CAVs) offers opportunities to monitor pavement conditions more frequently through sensors, including vision cameras and accelerometers, originally installed for autonomous driving. In this paper, we proposed an autonomous condition monitoring-based pavement management system (ACM-PMS) with real-time data collection using CAVs traveling voluntarily. We presented a novel mathematical framework to evaluate potential benefits of ACM-PMS in reducing social costs for both users and agency, systematically accounting for its unique three advantages: (i) large amount of condition data increases prediction model accuracy; (ii) aggregated measurement of current facility condition improves inspection accuracy; (iii) agency can perform maintenance activities at optimal timings, achieving continuous-time and condition-based policies. Results of numerical examples confirm that ACM-PMS significantly reduces the social cost of conventional PMS.

Jinwoo Lee, Assistant Professor, Korea Advanced Institute of Science and Technology. Dr. Jinwoo Lee is an Assistant Professor in Cho Chun Shik Graduate School of Mobility at Korea Advanced Institute of Science and Technology (KAIST). His research focuses on sustainable transportation infrastructure systems, particularly for electric and autonomous mobility technologies. He received his Ph.D. and M.S. degrees in Civil and Environmental Engineering from University of California Berkeley and his B.S. degree from KAIST. Before joining KAIST, he worked as a postdoctoral associate at New York University Abu Dhabi and a research assistant professor in the Department of Electrical Engineering at Hong Kong Polytechnic University

TRADEOFFS BETWEEN OPTIMALITY AND EQUITY IN TRANSPORTATION NETWORK PROTECTION AGAINST SEA LEVEL RISE

Samer Madanat
New York University, Abu Dhabi
in collaboration with Jiayun Suna

With climate change becoming inevitable, coastal cities are considering the mitigation of the impact of sea level rise on infrastructure. Transportation equity and sea level rise adaptation are usually considered separately. However, research pointed out that these two challenges could have considerable overlap and interaction. The present paper discusses transportation equity issues resulting from the impact of sea level rise and associated protection strategies. A case study of the San Francisco Bay Area points out cases where transportation equity can be negatively impacted when the optimal protection strategy against sea level rise is implemented.
An integrated hydrodynamic and transportation model system is used in the present paper to demonstrate several scenarios where the most efficient protection strategies for the whole region increase the inequity that exists between the disadvantaged communities and other communities. Nevertheless, this impact can be mitigated with a relatively small addition to the protection strategy. The paper suggests that transportation equity cannot be overlooked in planning climate adaptation, as even the protection plan that maximizes benefits for the region may negatively impact the most vulnerable communities.

Samer M Madanat is the Dean of Engineering at NYUAD. He is also the Xenel Distinguished Professor of Engineering Emeritus and former Chair of the Department of Civil & Environmental Engineering (from 2012 to 2015) at the University of California at Berkeley. From 2005 to 2014, he served as the Director of the UC Berkeley Institute of Transportation Studies. He received a B.Sc. in Civil Engineering from the University of Jordan in 1986, and a M.S and Ph.D. in Transportation Systems from MIT in 1988 and 1991 respectively. His research and teaching interests are in the area of Transportation Infrastructure Management, with an emphasis on modeling facility performance and the development of optimal management policies under uncertainty. More recently, his research has focused on the field of the environmental sustainability of transportation systems, and on the protection of transportation facilities from the adverse effects of climate change. From 2001 to 2011, he served as the Editor-in-Chief of the ASCE Journal of Infrastructure Systems. He is Editor of the Journal of Transport Policy and the Associate Editor of the European Journal of Transportation and Logistics. Madanat has served as member or chair of external review committees for the Department of Civil and Environmental Engineering MIT, the ENAC School of EPFL in Switzerland, the Department of Civil Engineering at Nanyang Technological University in Singapore, and the School of Transportation Engineering at Tongji University in China. He has served on advisory boards for the National Academy of Engineering, the World Bank, the American University of Beirut, and as proposal review panels for NSF, USDOT, the Swiss NSF and other international foundations. He has delivered several named lectureships including at MIT, Cornell University, the University of Texas at Austin, and the University of Minnesota. He is the recipient of the Science and Technology Award of the University of California, a prize given annually to one professor in the UC System.

ASSET MANAGEMENT PLANS: STATE-OF-THE-PRACTICE AND RESEARCH OPPORTUNITIES IN STATE DEPARTMENTS OF TRANSPORTATION IN THE UNITED STATES

Sue McNeil
University of Delaware

Aging infrastructure has long been recognized as a significant problem in the United States. A holistic approach to addressing this problem has been the adoption of decision-making frameworks, strategies and tools based of principles of asset or infrastructure management that recognize the service provided by such assets and the limited resources available for preservation and improvement. The requirement that each State Department of Transportation submit a risk-based transportation asset management plan for their National Highway System (NHS) roads and bridges in 2019 is an indication that asset management principles are becoming institutionalized, and a culture of decision-making based on data, performance management, lifecycle cost analysis and risk management is evolving. Between 2020 and 2022, eight virtual peer exchanges convened by the Federal Highway Administration brought together groups of State Departments of Transportation to share strategies used in developing the plans and progress towards submitting updated plans in 2022. Forty-five states (all states except Montana, Nebraska, Oklahoma, Texas, and Wisconsin) and the District Columbia and Puerto Rico participated in at least one peer exchange. The peer exchanges provided evidence of the advances in implementing asset management and identified gaps and opportunities for further research. This presentation briefly reviews the history of asset management at the state and federal level in the United States, and draws on the presentations and discussions from the peer exchanges to report observations and develop a synthesis of the innovations, shared concepts, common themes, strategies and future opportunities. These observations, concepts and opportunities are useful for state DOTs, and other agencies developing and implementing transportation asset management plans, and for asset management researchers to connect their research to end users facilitating technology transfer. Areas range from new technologies for data collection, risk models to better understand vulnerable infrastructure and strategies for integrating lifecycle planning and risk management.

Sue McNeil is Professor of Civil and Environmental Engineering and Public Policy and Administration and Visiting Professional Fellow at rCITI in the School of Civil and Environmental Engineering at University of New South Wales. She is also a Core faculty member in the Disaster Research Center at University of Delaware. She is a former Department Chair, and Director of the Disaster Science and Management graduate program and the Disaster Research Center. Her research and teaching interests focus on transportation asset management. Her most recent research includes the impact of natural hazards and climate change on physical infrastructure and asset management with emphasis on resilience.

INCORPORATING RESILIENCE IN INFRASTRUCTURE INVESTMENT DECISION-MAKING

Rabi G. Mishalani
The Ohio State University
in collaboration with and Benjamin R. Knost

Resilience strategies are important considerations to decision-makers responsible for designing, maintaining, and operating critical infrastructure systems where the consequences of failure in the presence of rare and extreme events are high. Numerous studies have sought to define and measure resilience as a characteristic of a system; represent performance of systems prior to, during, and after extreme events; and quantify a system's resilience, typically in the form of a score or an index. However, limited progress has been made towards operationalizing this approach in practice.

This study seeks to provide infrastructure decision-makers with comprehensive and operationally useful information regarding the resilience of their infrastructure by incorporating the probability of failure of facilities during extreme events, and the corresponding expected losses into a life-cycle cost function that can be optimized to determine the most beneficial balance between resilience to extreme events and the efficiency of day-to-day operations. By incorporating both the cost and benefit of implementing resilience improving strategies within an infrastructure system design and management decision framework, resilience informed decisions can be made by exploring life-cycle cost trade-offs without the use of a stand-alone resilience representation and measurement tool.

The application of the developed framework is demonstrated by investigating the facility hardening and system dispersal resilience improving strategies, in the context of a natural disaster and in the context of an intentional threat. Facility characteristic and damage data from a US Air Force base in Florida hit by a category 5 hurricane in 2018 along with US Department of Defense facility design guidelines in the presence of explosive threats are used to estimate construction cost, operating cost, and probability of failure models. These models are employed in a simulation to gain insights into the nature of the resilience-efficiency trade-off, and to demonstrate the developed framework's feasibility and value to decision-makers.

Rabi Mishalani is a Professor at The Ohio State University with the Department of Civil, Environmental and Geodetic Engineering. His areas of expertise include the application of probabilistic modeling, statistical inference, experimental design and evaluation, and optimization in the field of transportation systems. His interests include infrastructure systems design, monitoring, and maintenance decision-making; public transportation service planning and operations; dynamic transportation network surveillance and management; travelers' responses to mobility services and technologies; and urban logistics. He is the co-founder and co-director of OSU's Campus Transit Lab, a living laboratory (based on the transit system owned and operated by OSU) that supports research, education, and outreach. While on sabbatical leave from OSU, Mishalani was a Visiting Professor at Massachusetts Institute of Technology with the Department of Urban Studies and Planning during the 2017-2018 academic year and a Visiting Associate Professor at MIT with the Department of Civil and Environmental Engineering during the 2008-2009 academic year. Prior to joining the faculty at OSU in September 1997, he was a Research Associate at MIT with the Center for Transportation and Logistics. Mishalani received his Ph.D. and S.M. degrees from MIT in 1993 and 1989, respectively, and his B.E. degree from American University of Beirut in 1987.

OPTIMAL REPAIR POLICIES FOR INFRASTRUCTURE SYSTEMS WITH LIFE CYCLE COST MINIMIZATION AND ANNUAL COST LEVELING

Daijiro Mizutani
Tohoku University
in collaboration with Yuto Nakazato and Shunichi Fukuyama

One of the goals of research of infrastructure asset management is to find appropriate repair policies for infrastructure systems. The annual repair cost of the system may vary when a repair policy meant only to minimize life cycle cost is applied to each facility in the system. Such variance of the annual repair cost leads to the difficulty to procure the budget for system managers; thus, a practically desirable repair policy should reduce not only life cycle cost but also the dispersion of the annual repair cost. In this study, we first formulate a network-level repair policy optimization problem for an infrastructure system comprising a finite number of facilities to minimize the total cost over the planning period, which is defined as the weighted sum of the repair cost and its variance. Then, we propose two solution methods for solving it: i) the exact one based on the Markov decision process, and ii) an approximate one utilizing preventive repair rules. The former can be used in small-scale systems, whereas the latter can be utilized to simplify the repair policy regardless of the size of the system and to determine an approximate repair policy for large-scale systems. The proposed methodology is applied to two numerical studies on i) a small-scale infrastructure system, and ii) a large-scale infrastructure system. In the first case, we find the Pareto frontier of the repair cost and the variance of annual repair costs by the exact solution method and show that the preventive repair rule-based method provides a near-optimal solution. In the other situation, the preventive repair rule-based method leads to a superior policy on the aggregation of the optimal solutions independently found for each of decomposed subsystems.

Daijiro Mizutani obtained his PhD from Osaka University in Japan in 2016 and he worked as a Research Associate in the ETH Zurich in Switzerland from 2016 to 2017. Now he is an Assistant Professor in Tohoku University in Sendai, Japan. His research interests include statistical modelling of deterioration processes and optimization of inspection and repair policies in infrastructure asset management.

DETERMINATION OF POST-DISASTER RESTORATION PROGRAMS FOR ROAD NETWORKS USING A DOUBLE-STAGE OPTIMIZATION APPROACH

Saviz Moghtadernejad
Swiss Federal Institute of Technology in Zürich (ETHZ)

One of the main challenges in the post-disaster management of large transportation networks involves the determination of the priority and the level of service recovery for each damaged asset in the network. Presently, the application of meta-heuristic algorithms in developing restoration programs is receiving increasing attention. These algorithms determine a good quality solution to minimize the consequences of extreme events on the network of study, in a relatively short period of time. This paper investigates the suitability of a Discrete Particle Swarm Optimization (DPSO) algorithm in finding a good solution to a restoration model developed for minimizing the overall direct and indirect costs of post-disaster restorative interventions. This model can consider constraints and limitations on the available budget, work groups and equipment, different levels and speeds of service recovery for assets per damage state, as well as the changes in the traffic flow as the restorative interventions are executed. Moreover, the model has the capacity to process complex networks; hence can be implemented in real-world post-disaster decision making related to the development of restoration programs. The results suggest that the DPSO algorithm is a suitable choice of optimization algorithm in situations where the number of damaged objects is medium to large.

Dr. Saviz Moghtadernejad is a postdoctoral fellow in the Institute for Construction and Infrastructure Management, at the Swiss Federal Institute of Technology in Zürich, Switzerland. She received her M.Sc and Ph.D. in Civil Engineering from McGill University in Canada, where she developed an integrated and systematic framework to maximize the overall performance of buildings. Dr. Moghtadernejad's current research is mainly focused on the provision of digital multi-stakeholder decision-making platforms for enhanced infrastructure management. She works on the determination of optimal restoration programs, to improve asset management schemes for authorities and infrastructure managers and allow for more resilient multi-modal transport infrastructures. Moreover, she studies the application of data-driven methods to estimate the deterioration rate of transportation infrastructure and to provide solutions for tackling measurement errors and discrepancies in real-world inspection data using statistical and machine learning algorithms.

CONCEPTUAL MODEL INTEGRATING TRANSIT ASSET MANAGEMENT AND FINANCIAL PLANNING

Robert Peskin
AECOM

This paper describes a conceptual, analytical approach to integrate transit asset management with financial planning. The transit asset management elements include both the analytical and business process aspects. The financial planning elements address operating and maintenance (O&M) modeling, infrastructure capital programming, planning for major capacity improvements, and development of pro forma financial plans. The paper applies tools already developed to support the transportation planning process (both service planning and travel demand modeling) and recently developed analytical concepts that support contemporary asset management best practice. This approach is suggested as a means to leverage the deep understanding that public transportation agencies have regarding physical asset condition, maintenance experience, and market response to service quality. It applies detailed data and analysis where available and/or the insights of knowledgeable asset managers where such data and analysis are not available.

Robert L. Peskin, PhD, is a Senior Consulting Manager, with AECOM, an international infrastructure consulting firm. Dr. Peskin consults in the areas of transportation financing, planning, and management. A member of AECOM's transportation consulting practice throughout his entire career, he serves the transit industry and government agencies at the local, state, and federal level. He pioneered analytical methodologies in the areas of transportation financial planning, analysis of transportation infrastructure capital needs, and operating & maintenance cost modeling. His work focuses on the application of quantitative information to support transportation decision making. He works with public agency staff in integrating financial, capital, and operating data from all functional areas including planning, engineering, transportation, and maintenance. Dr. Peskin supports transportation agency executive staff and governing boards as they commit limited public resources to major capital investments and make difficult budgeting decisions.
Dr. Peskin supported transportation asset owners in assembling asset inventories, estimating current state-of-good-repair backlog and future SGR needs, and examining the impact on future asset condition resulting from not funding backlog and future needs on a timely basis. He developed a life cycle costs analysis for seawall improvements for the Port of Long Beach. He managed and supported the development of transit asset management plans for transit systems in Los Angeles and Orlando. He managed SGR analyses using several analytical platforms including: AECOM PlanSpend for Victoria, Australia Department of Transport, the Massachusetts Bay Transportation Authority SGR Database and New York Metropolitan Transportation Authority SGR Tool (developed by AECOM), the Regional Transportation Authority of Northeastern Illinois (RTA) Capital Optimization Support Tool (COST), and the Federal Transit Administration (FTA) Transit Economic Requirements Model (TERM Lite). He managed SGR analyses for transit agencies in Los Angeles, New York, Chicago, Vancouver, Dallas, Philadelphia, San Jose, San Francisco, and Miami. The SGR analyses in San Francisco and San Jose contributed to the success of the transit agencies in negotiating with FTA Full Funding Grant Agreements for their New Starts projects. He also supported an SGR analysis of Northeast Corridor assets at Amtrak. Dr. Peskin participated in the development and delivery of the National Transit Institute Course on "Introduction to Asset Management". He prepared and presented the module on infrastructure renewal & replacement cost projections for the National Transit Institute course on "Financial Planning in Transportation". He supported the Federal Transit Administration in developing a reporting tool, as an adjunct to the National Transit Database, for comprehensive reporting of asset inventory by FTA grantees. He developed long-range projections of infrastructure funding needs as part of strategic planning projects for transit agencies in New York and Atlanta. He developed a model for estimating long-range infrastructure needs for financial planning in Los Angeles that was applied for more than 25 years. In 1986, he developed the first-ever long-range projection of infrastructure renewal needs for Metrorail and Metrobus in Washington.

ESTIMATING PAVEMENT FRICTION AT A NETWORK LEVEL

Jorge A. Prozzi
The University of Texas at Austin

Providing highways with good surface friction to ensure the safety of the public is a crucial and complex task for all transportation agencies. This makes it imperative to monitor the skid resistance on a regular basis. However, equipment to measure skid resistance is highly inefficient due to the large volumes of water that are required to collect a few miles of skid data. Recent developments at the University of Texas have demonstrated the feasibility of measuring macro-texture and micro-texture in the field and estimate skid with a high degree of accuracy. This study investigated the development of a system to measure texture in the field at highway speeds and, with information of pavement conditions and characteristics, was able to develop methodology to predict skid with acceptable accuracy. During the study a new system for simultaneously collecting high-definition texture and skid resistance data at highway speeds was developed. This prototype eliminates uncertainty due to a time gap between the data collection for pavement texture and skid because both types of data are collected on the same wheel paths. The prototype was used to survey texture and friction data from 29 different in-service pavement sections in Texas. These data were processed using an array of algorithms to ensure it was of the highest quality. Then, multiple statistics to characterize pavement texture were computed and used to predict friction. Friction is a function of both texture and the type of pavement surface present, thus, the researchers used artificial intelligence (AI) models to accurately distinguish between different types of pavement surfaces. These models were then used to create an AI classifier that distinguishes between different pavement surfaces with a high degree of accuracy using the field data. These predictions alongside texture statistics were then used to create a robust and accurate model that uses field texture data to predict friction. A non-supervised learning agglomerative hierarchical clustering analysis indicated that within the 29 pavement sections surveyed, there were four clearly distinguishable pavement surfaces: chip seals with low texture, chip seals with high texture, dense mixes, and porous friction course. Then, by combining the pavement surface prediction with at least two texture statistics, a robust and accurate friction model could be developed. A multiple regression model with dummy variables was chosen to be the most efficient and accurate method of predicting friction. The model combined two texture summary statistics, skewness and root mean square, and surface type. This type of information allows decision makers to identify low friction pavement sections within the network before they become a hotspot for accidents, and thus schedule proactive maintenance as soon as friction levels are lower than the intervention level. This will result on a safer road network where the potential for wet weather accidents is mitigated as much as possible and many lives of Texan drivers could be saved.

Dr. Jorge A. Prozzi is a Professor in the Department of Civil, Architectural and Environmental Engineering at The University of Texas at Austin. He received his BSc. in Civil Engineering from the Universidad Nacional del Sur, Argentina in 1989. He obtained his BSc. (Hons.) in Civil Engineering from the University of Pretoria (South Africa) in 1996 and his M.S. and Ph.D. in Civil Engineering from the University of California, Berkeley in 1998 and 2001, respectively.Dr. Prozzi areas of research include pavement materials, design and management and the application of probability, statistics and basic econometrics. He is the past chair of the TRB International Activities Committee, the Data Analysis Working Group and the TRB Subcommittee for Latin American Activities. He serves as an expert panel member for projects funded by the National Cooperative Highway Research Program and he is an active member of the American Society of Civil Engineers (ASCE). He is member of several technical committees of the National Academies of Sciences, Engineering and Medicine. Dr. Prozzi is a former Associate Editor of ASCE's Journal of Infrastructure System and the WCTRS's Journal on Case Studies on Transport Policy. He is current member of the Editorial Board of Springer's Journal "Frontiers of Structural and Civil Engineering". He has authored or co-authored 70 refereed archival journal publications, 130 refereed conference proceedings, and 126 technical reports.

JOINTLY OPTIMAL POLICIES FOR PAVEMENT MAINTENANCE, REPAVING AND RECONSTRUCTION: A DIFFERENT APPROACH

Craig Richmond
Swiss National Roads Office's Road Research Funding Program

A paper presented at SIAM 3 in Dubai claimed that a so-called Uniform Network Assumption could significantly simplify the mathematics of optimal strategy calculations in long-lived infrastructures. We illustrate this claim on a problem formulated by Jinwoo Lee and Samer Madanat in 2015. Our scope is limited to steady states. We present a set of nearly complete analytic solutions to the stated jointly optimal policies problem for a small set of concrete versions of the problem. The versions use different sets of assumed functional forms. The optimal values for all of the choice variables other than the integer number of repaving cycles can be expressed as a closed-form function of the parameters of the problem. The latter must be found by testing the closest two integers to the non-integer solution. One concrete version of the problem leads to the duration of repaving periods forming a harmonic series. In a second version, the repaving periods must all be equal. The major contribution of the paper is methodological. We show how optimality conditions linking the marginal cost of repaving periods to the total average cost of the reconstruction period can be leveraged in the solution method. Future topics for further research lie in the expansion of the sets of functional forms for which analytical solutions can be found. However, the currently presented solutions can be used in PMS applications already today.

Craig Richmond completed his Ph.D. in Regional Economics at the University of Pittsburgh in 1997. He worked for various international banks in controlling functions until 2011 when he joined Prof. Brian Adey at the ETH to work on the economic modelling of infrastructure management problems. In 2019 he was hired as the head of the Swiss National Roads Office's road research funding program. Craig retires from that position in May 2022 but hopes to continue some research.

MANAGING INFRASTRUCTURE ASSETS FOR RESILIENCE

Joseph L. Schofer
Northwestern University

Resilience, the ability to resist disruptive assaults and restore functionality rapidly, has become a central element of infrastructure management as the frequency and intensity of natural hazards have increased because of climate change. While the bulk of research, and much of the practice, have focused on modeling and managing recovery from destruction and disruptions, there is a need to focus infrastructure decision making on preparation and prevention: building resilience into new and rehabilitated facilities. This talk will describe a recent study conducted for the US Department of Transportation by the Transportation Research Board to provide guidance on resilience metrics and investment decision strategies for transportation infrastructure and service management. The resilience investment process will be characterized as an integral part of asset management. Essential metrics and data needs will be described, and the practical challenge of supporting decisions that trade near-term and certain benefits for future potential benefits will be considered.

Joseph L. Schofer is Professor Emeritus of Civil and Environmental Engineering at the Robert R. McCormick School of Engineering and Applied Science at Northwestern University in Evanston, Illinois. His research interests are in transportation policy planning, analysis, evaluation, and decision support for transportation and other infrastructure systems, including needs for and uses of data and information, and learning from natural experiments and disruptions. He is actively engaged with the Transportation Research Board (TRB), currently chairing its Standing Committee on Data for Decision Making. He chaired the recently-completed Congressionally-mandated Transportation Research Board consensus study on Investing in Transportation Resilience: A Framework for Informed Choices. He is a fellow of the Institute of Transportation Engineers, a life Member of the American Society of Civil Engineers, and a member of the American Association for the Advancement of Science. Since 2009, Dr. Schofer has hosted the Infrastructure Show, monthly podcast on which he interviews infrastructure experts on problems, opportunities, and innovations in civil infrastructure systems. Schofer earned his B.E. from Yale University and an M.S. and Ph.D. from Northwestern University.

ELECTRIFICATION OF THE VEHICLE FLEET AND ITS EFFECT ON THE GLOBAL WARMING POTENTIAL OF ROADWAYS

Omar Swei
The University of British Columbia

The adoption of electric vehicles has led to a transition towards sustainable mobility. However, there has been a lack of research considering the effects of vehicle fleet electrification on pavement infrastructure. This study quantifies the impact of vehicle fleet changes on the global warming potential of pavement systems across the United States. The case studies encompass a large range of scenarios, including rural and urban Interstate highways, low and high carbon grid mixes, and low and high electric vehicle adoption rates. The inclusion of fleet electrification reduces the global warming potential of typical rural and urban Interstate highway pavements in the United States between 7% and 24%. This finding suggests that the adoption of electric vehicles will lower the global warming impact of the pavement use stage across all regions of the United States. These findings can enable decision-makers to account for the environmental impact of electric vehicles on pavement infrastructure and discern their effects when developing sustainable management strategies.

Omar Swei joined the Department of Civil Engineering at The University of British Columbia as an Assistant Professor in 2018. His research emphasizes the use of operations research methods to improve the design, delivery, and maintenance of infrastructure systems.

CAN SATELLITE DATA BE USED TO ESTIMATE PAVEMENT ROUGHNESS?

Cristina Torres-Machi
University of Colorado Boulder

Accurate and timely assessment of pavement condition is critical in the management of transportation infrastructure, as it determines maintenance needs and funding requirements. Due to the high costs of collecting pavement condition data using ground-based approaches, transportation agencies often limit their monitoring to the major roads of a network, as required by federal regulations. As a result, the condition of the ancillary components of a highway system such as ramps, auxiliary lanes, and frontage road pavements remain unknown to decision-makers. This raises the need for alternative solutions to monitor the condition of ancillary roads in a cost-effective manner. This study explores the capabilities of publicly available satellite data and specifically, Synthetic Aperture Radar (SAR) data, to estimate pavement roughness. This paper introduces a novel framework to address the challenges of using SAR images to evaluate pavement condition. A trunk highway network in Minnesota is analyzed to develop deep learning models that predict International Roughness Index (IRI) and Ride Quality Index (RQI). This analysis found that SAR images have a strong potential in estimating pavement condition. The deep learning models were able to predict IRI with a mean absolute error of 14.6 inches/miles and provide intervals of pavement condition that capture actual IRI with an accuracy of 81%.

Dr. Cristina Torres-Machi is an Assistant Professor in the Department of Civil, Environmental, and Architectural Engineering and a Beavers Heavy Construction Engineering Faculty Fellow at the University of Colorado Boulder. She holds a dual PhD degree from the Polytechnic University of Valencia, Spain and the Catholic University of Chile. Prior to joining University of Colorado Boulder in 2017, she worked as a Research Associate at the Centre for Pavement and Transportation Technology (CPATT) at the University of Waterloo, Canada. Her work focuses on advancing the current management of infrastructure assets, with a focus on highway projects. Her research activities within the field revolve around deterioration modelling, optimization, and decision-making systems aimed to incorporate long-term analysis in transportation asset management. Dr. Torres-Machi has participated in successful projects funded by public agencies and State Departments of Transportation including Colorado, South Carolina, and Minnesota. Dr. Torres-Machi serves as the vice-chair of the Transportation Research Board (TRB) Committee on Transportation Asset Management (AJE30). She is also an active member of the TRB Committee on Pavement Management Systems (AKT10) and the Infrastructure Systems Committee of the American Society of Civil Engineers (ASCE).

CONSIDERING ENVIRONMENTAL IMPACT IN PAVEMENT DESIGN: AN INPUT-OUTPUT MODEL WITH SUBSTITUTION

Jing Yu
Northwestern University
in collaboration with Pablo Durango-Cohen

In industrial manufacturing, a final product is usually built up from various raw materials and sub-assemblies. If some of these materials are substituted for each other, then the product designer is forced to make a choice. In this paper, we develop a computational framework for finding the best ecological friendly combination of alternatives in product design that minimizes the total greenhouse gas emission. To this end, we first develop a product structure framework to keep track of all the required materials for assembling the final product and represent it as a matrix form. We leverage the input-output (I-O) life cycle assessment (LCA) method to analyze the production framework, which results in a redundant system of linear equations whose solution set tracks all possible combinations of alternatives that fulfill the final demand. The product design problem is then formulated as a linear program (LP), whose objective is to minimize the production cost as well as the total emissions. We show that the proposed framework has three advantages: (1) it scales well to the total number of alternatives; (2) it can be efficiently solved via LP algorithms; (3) it allows conducting sensitivity analysis analytically. Eventually, we test our method on a numerical example of designing a pavement with three layers (surface, subbase, and base), each of which can be built using 2 or 3 alternative materials. We first solve the LP and then perform sensitivity analysis on multiple system parameters (e.g., production costs and emission rates). The analytic results of sensitivity analysis are validated by directly comparing with the numerical solutions after changing the parameters.

Jing Yu is currently pursuing her Ph.D. in Civil and Environmental Engineering at Northwestern University. She holds a Bachelor of Science degree in Aviation Engineering and a Master of Science degree in Civil Engineering. Under the supervision of Professor Pablo Durango-Cohen, her research focuses on the life cycle assessment and environmental design of transportation systems. She develops a framework to support the environmentally friendly product design, which can analyze the life cycle greenhouse gas emissions of pavement construction and provide insights of material selection under different scenarios.

OPTIMAL COMMUNITY PLANNING AND POLICIES FOR IMPROVING TRANSPORTATION CONNECTIVITY TO ESSENTIAL FACILITIES AFTER EARTHQUAKES

Yun-Chi Yu and Paolo Gardoni
University of Illinois at Urbana-Champaign

Transportation infrastructure in general, and roads more specifically, are one of the critical infrastructure that support the social and economic activities of communities. However, following an earthquake, roads might be obstructed by debris from damaged adjacent structures. Road blockages hamper emergency services (e.g., ambulance, firefighting, evacuation) in the immediate aftermath of an event and the long-term recovery process of a community. The likelihood of road blockage depends on the road characteristics and building type and size (i.e.,height, width, and length), which is regulated in the land use policy (e.g., floor area ratio and building coverage ratio). There is a need for optimal community planning and policies (including land use policies) that can reduce the likelihood of road blockage to allow the transit of emergency vehicles and support recovery activities. This study proposes a probabilistic model to predict the likelihood of road blockage. The proposed model considers the relevant factors including road characteristics and building type and size (which also affect the predicted damage level for a given earthquake intensity measure). The model is calibrated using a Bayesian approach and data from the 2010 Haiti Earthquake. This study further uses the predictive model for road blockage within an optimization framework to recommend community planning and policies. The two objectives are to maximize the post-earthquake accessibility to essential facilities while maximizing the economic benefit of the housing sector. The formulation considers urban design standards and the total housing requirement as the primary constraints. The proposed methodology is applied to a small virtual example area. The result can be a reference for urban planners and policymakers in the planning process.

Yun-Chi Yu is a Ph.D. student working with Professor Gardoni in the Department of Civil and Environmental Engineering in the Grainger College of Engineering at the University of Illinois at Urbana-Champaign. She is the recipient of the Taiwan-UIUC fellowship. Her research interests include sustainable and resilient infrastructure, reliability, and optimal strategies for natural hazard mitigation and disaster recovery.
Paolo Gardoni is the Alfredo H. Ang Family Professor and an Excellence Faculty Scholar in the Department of Civil and Environmental Engineering in the Grainger College of Engineering at the University of Illinois at Urbana-Champaign. He is a Professor in the Department of Biomedical and Translational Sciences in the Carle Illinois College of Medicine, and a Fellow of the Office of Risk Management & Insurance Research in the Gies College of Business at the University of Illinois at Urbana-Champaign. Prof. Gardoni also has several courtesy appointments including at Loughborough University in the UK, and the Harbin Institute of Technology and Jianghan University both in China. Prof. Gardoni is the Director of the MAE Center, which focuses on creating a Multi-hazard Approach to Engineering and was created through NSF Engineering Research Center funding. He is the Editor-in-Chief of the international journal Reliability Engineering and System Safety published by Elsevier, and the founder and former Editor-in-Chief of the international journal Sustainable and Resilient Infrastructure published by Taylor and Francis Group. He also serves on the Editorial Board of 8 other journals and as the Associate Editor of 3 journals. Prof. Gardoni is a member of the Board of Governors of the Engineering Mechanics Institute (EMI) of the American Society of Civil Engineering (ASCE), the Probabilistic Methods Committee (PMC) of the EMI, the Board of Directors of the International Civil Engineering Risk and Reliability Association (CERRA), the Advisory Council of the International Forum on Engineering Decision Making (IFED), and several national and international committees and associations that focus on risk, reliability, and resilience analysis. His research interests include probabilistic mechanics; sustainable and resilient infrastructure; reliability, risk and life cycle analysis; decision-making under uncertainty; performance assessment of deteriorating systems; modeling of natural hazards and societal impact; ethical, social and legal dimensions of risk; optimal strategies for natural hazard mitigation and disaster recovery; impact of climate change; and engineering ethics. Prof. Gardoni is the author of over 200 refereed journal papers, 28 book chapters, and 9 edited volumes, and has delivered over 60 invited, plenary, and keynote lectures. He has received over $50 million in research funding from multiple national and international agencies including the National Science Foundation (NSF), the Qatar National Research Funds (QNRF), the National Institute of Standards and Technology (NIST), the Nuclear Regulatory Commission (NRC), the Defense Threat Reduction Agency (DTRA), and the United States Army Corps of Engineers. Prof. Gardoni is the 2021 recipient of the prestigious Alfredo Ang Award on Risk Analysis and Management of Civil Infrastructure from the American Society of Civil Engineers. The award was given for his contributions to risk, reliability, and resilience analysis, and his leadership in these fields. Prof. Gardoni has graduated 26 PhD students and 33 Master students. Several of his former students now hold faculty positions in the USA and around the world

VALUE OF INFORMATION FOR FLEXIBLE ASSET MANAGEMENT POLICIES: A GAMMA PROCESS APPROACH

Arnold Yuan
Ryerson University

While Big Data, digital twins, climate change adaptation, and deep reinforcement learning have attracted a lot of research attention in infrastructure asset management over the past couple of years, another important line of investigation focuses on the interaction of information and maintenance flexibility in the context of decision making under deep uncertainty. The key questions are twofold: (1) How do we develop an optimal maintenance plan that can adapt to the uncertain environment, with climate change being a typical example? (2) What kind of data can be collected to support implementing the flexible maintenance plan, and how do we justify the investment in data collection? This paper provides an expository presentation of the author's investigation of these two questions within the COVID-19 period. Using a gamma process deterioration model, the author starts with the most straightforward age-based replacement policy and builds up to the more complicated cases, including single-component problems and network problems under various condition-based maintenance policies. In the end, future research needs on deep reinforcement learning and collaborative deterioration modelling are highlighted.

A structural engineer by training, Dr. Arnold Yuan is an enthusiastic promoter of systems thinking in civil engineering and management. In his mind, systems engineering approaches mean that in solving engineering problems, whether they are design questions or management issues, engineers must take the following four lenses: scale, lifecycle, environment & society, and knowledge. Centering on engineering risk and reliability, his research interests range from infrastructure asset management and construction management to progressive collapse of structures and safety of complex technological systems (e.g. nuclear power plants). He is currently working on collaborative asset management planning using assisted learning and deep reinforcement learning.