Authors	Article Title	Abstract
Fareed Salih; Islam El-adaway	ACHIEVING PROJECT OBJECTIVES AND IMPROVING FUNCTIONS: THE BENEFITS OF AI AND CONSTRUCTION TECHNOLOGIES	The construction industry is increasingly incorporating Artificial Intelligence (AI) and construction technologies into projects. However, it lags behind other industries in terms of digital transformation. One of the reasons for this disparity is the lack of evidence-based information on AI and technologies in construction projects. Hence, this research aims to comprehensively understand the benefits of AI techniques and construction technologies and their role in achieving objectives and improving functions. To this end, the authors followed a three-step research methodology. Firstly, an extensive literature review was conducted to identify 4 AI techniques, 13 construction technologies, and 28 benefits relevant to their implementation in construction projects. Secondly, a social network analysis (SNA) was performed to validate and confirm the findings from the literature. Finally, an industry-based survey was distributed among 52 construction practitioners to achieve two main objectives: (1) assess the benefits of AI and technology and their influence on different project objectives, and (2) quantify the potential improvement in project functions resulting from their adoption. Study results offer evidence-based information on the impact of AI techniques and construction technologies on construction project objectives and help construction practitioners in assessing the benefits that AI and construction technologies can bring to their projects.
Deniz Besiktepe, Ph.D.; Cansu Coskun	A Review of BIM and Advanced Technologies in Facility Condition Assessment	This study aims to review and identify advanced technologies utilized in Facility Condition Assessment (FCA) practices together with Building Information Modeling (BIM). FCA typically identifies the physical properties and deficiencies of the building systems and components. The common practice of FCA comprises visual inspections and walk-through surveys while determining the condition within linguistic definitions. The traditional FCA practices are non-standardized, subjective, time-consuming, resource intensive, and imprecise. Thus, integrating advanced technology has a significant potential to address these challenges with increasing the benefit of FCA in sustaining the longevity of the built environment. Within limited studies, digital twin, Geographic Information Systems (GIS), Internet of Things (IoT), laser scanning and point cloud, and Unmanned Air Vehicles (UAVs) are the innovative technologies used in FCA compared to the traditional practice. This study also suggests future research directions for utilizing advanced technologies in FCA in light of identified challenges in the literature.
Abdolmajid Erfani; Jina Mahmoudi; Qingbin Cui	Measuring Social Equity in Pavement Conditions Using Big Data	Pavement condition significantly impacts a region's socioeconomic status by affecting safety, economic effectiveness, and environmental aspects. The condition of the pavement directly impacts crash rates, fuel consumption, and pollution levels, necessitating equitable access for all, regardless of socioeconomic characteristics. We measured social equity in pavement condition by comparing pavement condition, represented by International Roughness Index (IRI), with community demographics. Analyzing more than 8 million records from Highway Performance Monitoring System (HPMS) data across multiple years, we established links between pavement quality and socioeconomic factors. We found that areas with higher proportion of African American, linguistically isolated population, and disadvantaged neighborhoods—in terms of housing/transportation—have lower access to high-quality pavement regardless of controlling factors such as region, road type, and traffic. Furthermore, a predictive classifier confirmed the influence of sociodemographic factors on pavement quality classification (good, acceptable, poor), emphasizing the need for social equity integration in pavement maintenance planning.
Xiaoyue Zhang; Chengcheng Tao, Ph.D.; Ying Huang	Pipeline Integrity Analysis Through Data-Driven Approaches	Pipelines are the most widely used energy transportation infrastructure in the world. Pipeline failures caused by aging, corrosion, cracks, and damages may result in irreparable societal, economic, and environmental consequences. Therefore, pipeline safety and integrity are crucial to the robustness of modern societies. Robust failure models have the potential to effectively reduce the emergent risk and the probability of hazards in pipeline construction, and extend the service life of pipeline infrastructure. In this paper, we apply a data-driven approach, Gaussian Process Regression (GPR), to predict the failure of the oil pipeline. We train and test the models based on historical public data from a report on European cross-country oil pipelines. The best model type is selected with different variable combinations. Variables such as pipeline diameter, service, and gross spillage volume, are considered in the models. The data-driven pipeline failure model will provide pipeline operators with an effective way to evaluate pipeline conditions and guide pipeline rehabilitation and maintenance. The model can also be used to support pipeline integrity management based on the ASME code, which can extend the service life of the pipeline infrastructure and bring benefits to the environment and the economy.
Sheik Murad Hassan Anik; Xinghua Gao, Ph.D.; Na Meng	Automation in Building Occupant Profile Development: A Machine Learning- and Persona-enabled Approach	The user persona is a communication tool for designers to generate a mental model that describes the archetype of users. Developing building occupant personas has proven to be an effective method for human-centered smart building design, considering occupant comfort, behavior, and energy consumption. The current approaches to developing building occupant personas face a major obstacle of manual data processing and analysis. This study proposes a machine learning-based approach for occupant characteristics classification and prediction with a view toward partially automating the building occupant persona generation process. We investigate the 2015 Residential Energy Consumption Dataset using six machine learning techniques for predicting 16 occupant characteristics, such as age, education, and thermal comfort. The models achieved moderate accuracy in predicting most of the occupant characteristics and significantly higher accuracy (over 90%) for attributes including the number of occupants in the household, their age group, and preferred usage of primary cooling equipment. The results of the study show the feasibility of using machine learning techniques for occupant characteristics prediction and automating the development of building occupant persona to minimize human effort.
Issam Srour; Omar Yamout	PREDICTIVE CONSTRUCTION EQUIPMENT MAINTENANCE USING NEURAL NETWORKS	Construction equipment are subject to several types of breakdown throughout the project duration. The availability of operational data is crucial to understand the breakdown patterns and implement effective maintenance strategies. However, projects often operate with tight profit margins and limited resources; and therefore, access to such data is not readily available. The aim of this study is to establish a predictive maintenance framework based on machine learning (ML), that leverages historical breakdown data with the absence of information relating to the condition of the equipment and any output extracted from monitoring devices and sensors. The proposed approach entails developing and applying a multilayer perceptron (MLP) neural network to a real-life infrastructure project in the Middle East. The collected data include an equipment maintenance log database. The results show a significant improvement in accuracy compared to linear and non-linear models reported in the literature. The proposed framework helps enhancing the overall productivity of construction equipment by minimizing their breakdown rate, thereby reducing the associated operating costs.

Authors	Article Title	Abstract
Da Hu, Ph.D.; Junxuan Zhao	Segmentation and Tracking of Moving Objects on Dynamic Construction Sites	The increasing complexity of construction sites and the growing need for enhanced safety, productivity, and project management necessitate improved methods for monitoring and tracking moving objects. This paper introduces a methodology for moving object segmentation and tracking in construction sites, with the objective of improving site safety, productivity, and project management. A deep learning-based model is utilized for precise object segmentation, while the advanced Observation-Centric SORT (OC-SORT) tracking algorithm is employed for tracking segmented objects. The methodology is assessed using a large-scale dataset of moving objects in construction environments. Segmentation results demonstrate a mean average precision (mAP) of 0.561 and an AP50 of 0.809. Moreover, the approach effectively tracks construction workers and equipment across diverse and challenging construction site situations, including crowded conditions. The implementation of such a system can greatly enhance construction site management, minimizing workplace accidents and optimizing resource distribution.
Yoojun Kim; Youngjib Ham	Heat stress monitoring in construction for risk-informed decision-making	Heat-related hazards present significant challenges in construction. To effectively mitigate these safety risks, timely assessment of heat stress is vital for implementing heat mitigation strategies. Current field measurement approaches, however, encounter temporal and spatial limitations in monitoring heat stress. This study proposes a framework for near-real-time analysis of spatial heat hazards at construction sites. The framework incorporates 3D modeling to address geometric features and a customized weather station to monitor meteorological conditions. The collected meteorological data is transmitted to a server computer, where heat risks are simulated based on the geometric and meteorological conditions in construction sites. Additionally, the study presents preliminary results comparing the accuracy of this simulation-based approach to on-site measurements using a black globe thermometer and net radiometers. The proposed framework is expected to enhance our understanding of heat risks and enable more effective implementation of protective measures in time-sensitive situations relevant to heat risk.
Jinsol Lee; Youngjib Ham	FEEDBACK SYSTEM FOR ENHANCING HUMAN-ROBOT INTERACTION PERFORMANCE IN CONSTRUCTION ROBOT	Many fatal incidents in the construction project occur during the earthmoving phase. Teleoperation has been a promising solution for such dangerous tasks since this method can remove humans from hazardous workplaces. Although humans are not on the job site for safety reasons, teleoperation requires human-in-the-loop automation so humans need to robustly operate the construction robot at a distance. Operating equipment from a distance often reduces task performance and safety performance since spatial awareness of human operators is restricted compared to onboarding control. It is an important issue since the decisions and actions taken by operators directly affect the performance of construction robots. This study proposes the use of a feedback system for the teleoperation of construction robots to improve proximity sensing of risks and improve the human operator's understanding of obstacles in the workplace where robots are used. The proposed teleoperation feedback system is validated with a human subject experiment in the virtual environment. This research will contribute to the body of knowledge on improving teleoperation, human operators' spatial awareness, and human-robot interaction task performance.
Miran Seo; Youngjib Ham	Evaluation of Work Performance, Task Load, and Behavior Changes on Time-Delayed Teleoperation Tasks in Space Construction	A robust teleoperation system has the potential to play a key role in mission tasks relevant to construction in a physically challenging environment. Here, the communication delay generated by long-distance and data transmission in teleoperation systems impacts human-robot interactions and work performances during the teleoperation. There is a need for more understanding of how time delay affects performance in construction activities and human operators' abilities, such as situational awareness and mental workload. This exploratory study aims to provide knowledge on the latency impacts on work performance and task load by measuring and evaluating the relevant human factors. Participants conduct construction tasks under time-delayed conditions in virtual reality environments. We assess the performance (i.e., completion time, success rate) and task load (i.e., mental demand, frustration) and observe manipulation behavior changes to evaluate the relationship between time delay and human factors during construction work. This paper contributes to exploring the signal latency by long-distance teleoperation and assesses its impacts on work performance, task load, and behavior changes while performing construction tasks.
Vartenie Aramali, Ph.D.; Namho Cho; Darrell Mesa	PRELIMINARY STUDY USE OF LARGE GENERATIVE ARTIFICIAL INTELLIGENCE MODELS IN INTEGRATED PROJECT MANAGEMENT	Artificial Intelligence (AI) and Machine Learning (ML) have been embraced techniques in various fields including construction processes and materials, yet rarely applied in Integrated Project Management (IPM). IPM using Earned Value Management (EVM) systems is the grouping of the project management processes to ensure they operate in sync for the success of the project. This paper focuses on exploring the potential use of Open AI's powerful tool, Generative Pre-trained Transformer (ChatGPT) in IPM using earned value management systems. The authors survey industry practitioners to identify the capabilities, limitations, and implications of the use of ChatGPT and similar large generative AI models in these fields, specifically for project management field practitioners. The preliminary survey result shows that there are several considerations and limitations to address when applying it in the field. This paper contributes to researchers and professionals in assisting in the use of such a tool with caution aiming to improve EVM data analysis and the overall EVM profession.
Yeon Chae; Youngjib Ham	Design and Evaluation of Human-centered Visualization Interfaces in Construction Teleoperation	Teleoperation is widely used in hazardous and uncertain site settings, allowing scheduled procedures to be carried out across long distances while workers are away from the sites. Teleoperators in off-sites collect both the site information and feedback from the interfaces which provide synthesized information that a robot collects. This interface mainly conveys visionary information for the operator's intuitiveness such as the spatial awareness of objects and surroundings. To achieve a rich visual understanding of the site, the interface should fully contain and intuitively convey the associated contextual information. Excessive or unintuitive information not only makes it difficult for operators to exert their full potential, but also increases their cognitive load. This study explores how different visual interface configurations affect operators' work performance and their cognitive load during the teleoperation task. The findings from the experimental studies are expected to help develop human-centered interfaces for teleoperation in the context of construction tasks and provide the cornerstone for not only an intuitive but fruitfully informative interface in a provided task setting.
Abdullah Alsuhaibani; Fernanda Leite	The Use of Extended Reality Tools for Construction Design Reviews: A Review	Extended reality is among the disruptive technologies that have been gaining interest in the construction industry, and for the past two decades, it has been the focus of many researchers in the field of construction. Many previous studies have investigated extended reality benefits and its potential uses in various application areas including safety, constructability, design review, maintainability, and operability. However, there are mixed conclusions on how beneficial the technology is for design reviews, and there is no agreement among previous studies on whether extended reality has always had positive impacts on design and construction coordination performance. This systematic literature review paper aggregates the results of previous studies that have investigated extended reality for design and construction review considering different parameters such as the type of project, the experience of participants, and the type of extended reality tool used. Challenges associated with implementing the technology for design reviews that were reported previously are synthesized.

Authors	Article Title	Abstract
Hyun Jeong Koo, Ph.D.; Beatriz C Guerra	Clash relevance prediction in BIM model coordination using Artificial Neural Network	As construction projects become more sophisticated, model coordination is critical to mitigating risk. Even though clash detection is highly automated in existing software systems, reviewing clashes and making corrections are still manual and repetitive workflows. Previous researchers leveraged machine learning and data mining techniques to analyze model coordination data and streamline decision-making. Nonetheless, gaps still remain in the fact that existing studies used limited datasets and mostly focused on MEP systems; additionally, and no previous study identified which clash attributes combination is necessary to accurately predict clash relevance. By applying an Artificial Neural Network multilayer perceptron algorithm with different combinations of clashes' attributes in the dataset, the authors achieved a precision of over 80% in predicting clash relevance. Notably, this study contributes to the body of knowledge by identifying the BIM objects attributes necessary to predicting clash relevance with high precision using all major disciplines of a construction project.
Kasra Banijamali; Ali Kazemian, PhD	Early-age Strength Monitoring of Sensor-Embedded 3D Printed Structures	Concrete 3D printing (C3DP) is a new automated construction technology with a significant potential to reduce construction time and cost. The absence of formwork in C3DP exposes the freshly-printed structures to ambient conditions and potentially excessive water evaporation. The freshly-printed structures should be able to carry the service loads in a shorter time compared to conventionally cast concrete to make it possible to reduce the overall construction time. The destructive testing methods, which are usually time-consuming, are not ideal for this application, and nondestructive methods are preferred. This article provides a review of existing literature on the strength monitoring of concrete, with a focus on the early-age strength of 3D printed concrete. A new automated curing system was used to compare the effectiveness of three different curing conditions. Moreover, a new index for estimating the flexural strength of 3D printed concrete based on electrical resistivity and temperature history is proposed.
Oscar Wong Chong, Ph.D.; Jiansong Zhang	AUTOMATED EXTRACTION OF LOCATIONAL INFORMATION FROM IFC-BASED BUILDING INFORMATION MODELS	Locational information in building information models (BIMs) are essential for providing geographical context to a project as well as the relative spatial context to each and every individual building element that the project is composed of. From a construction automation perspective, one main application is the use of locational data as input for robot-assisted operations in the construction of building components. Nevertheless, obtaining locational information is a time-intensive, laborious, and error-susceptible process. To address this gap, the authors proposed a logic-based approach for examining BIMs and retrieving the positional data of building elements. A duplex apartment was used to test the proposed method which achieved 100% precision and 92.31% recall compared to a gold standard. Building elements, such as columns and beams, from the model were successfully extracted. Results show that logic representation and reasoning can be effectively used for extracting locational information in the context of construction automation.
Yizhi Liu; Houtan Jebelli	ENHANCING HUMAN-CENTRIC PHYSIOLOGICAL DATA-DRIVEN HEAT STRESS ASSESSMENT IN CONSTRUCTION THROUGH A TRANSFER LEARNING-BASED APPROACH	Recent advances in physiological sensors and machine learning have led to the development of non-invasive heat stress monitoring frameworks that can continuously and objectively assess the heat stress levels of workers in the field by analyzing their physiological data. However, variations in the statistical distribution of physiological data due to individual differences in responses to stressors negatively impact the accuracy of the assessment. To address this issue, this study proposed a transfer learning-based framework to improve the performance of non-invasive heat stress monitoring. The framework utilizes autoencoder and domain adaptation-based transfer learning techniques to reduce the deviation of the statistical distributions of physiological data across different individuals, leading to a more robust assessment of workers' heat stress levels. To evaluate the effectiveness of the framework, physiological data was collected from fourteen subjects performing roofing tasks with different heat stress exposure levels (low, medium, and high). Results showed that the proposed framework had a more robust performance on physiological data with distributional shifts, achieving an accuracy of over 89.9% in assessing heat stress levels across different subjects, a 6.3% improvement compared to existing frameworks. This study contributes to the advancement of heat stress assessment for construction workers.
Araham Jesus Martinez Lagunas, MEng; Soroush Abbaspour; Mazdak Nik-Bakht	NLP for Automated Discovery and Assessment of Dominant Construction and Maintenance Work Order Activities in MEP Projects	The installation of Mechanical, Electrical, and Plumbing (MEP) systems for building facilities accounts for up to 40% of the total construction, while Operation and Maintenance activities constitute about 65% of the Facilities Management costs. In this vein, most companies generate and manage vast amounts of construction and operations data in diverse Information Systems, but they lack data-driven insights to plan, analyze and control costs and profit related to construction and maintenance work orders. To tackle this problem, this paper presents a method that helps general contractors and facility managers to automatically discover dominant MEP-related activities from construction data involving 99k work orders of Operation and Maintenance activities and 118k construction work orders executed in several projects across North America. The proposed method involves (i) data preprocessing and automated identification of frequent activities by applying text-mining techniques on free-form text activity descriptions; and (ii) a quantitative analysis of significant activities in terms of cost and profit. Results include the identification of dominant activities and providing quantitative insights on their occurrence frequency. The presented data-driven approach has the capability to identify items in high demand and those carrying significant profitability or cost implications for general contractors and facility managers.
Jinwoong Lee; Kyubyung Kang, Ph.D.	Hot Thermal Discomfort-related Action Recognition Model Validation in Outdoor Construction Environments	Hot thermal discomfort poses significant risks to construction workers in hot environments, necessitating effective measures to mitigate heat-related illnesses. This study validates the applicability of a thermal discomfort action recognition model in outdoor construction environments, addressing gaps in existing research. The methodology comprises four steps: data collection, model training, application, and evaluation. The data collection was implemented by the acquisition of video data depicting hot discomfort-related actions within indoor setting. Subsequently, this video dataset served as the foundation for training a thermal discomfort action recognition model using deep learning-based classifier The model's performance was rigorously evaluated in real-world outdoor scenarios, specifically in construction environments. Results indicate limited accuracy (0.5833) in predicting hot thermal discomfort-related actions outdoors, highlighting the need for further model refinement. However, a detailed analysis based on different angles and postures provides valuable insights for future improvement. The study emphasizes the importance of diverse datasets encompassing various angles and postures to develop a sophisticated model for accurately recognizing hot discomfort actions in outdoor construction environments. These findings will contribute to enhancing the existing hot thermal discomfort model's accuracy when the model is applied to outdoor construction fields, ultimately improving worker safety and well-being.
Rosina Adhikari; Houtan Jebelli	Deep Learning and Reinforcement Learning for Modeling Occupants Information in an Occupant-Centric Building Control: A Systematic Literature Review	The Occupant-Centric Control (OCC) strategy incorporates occupant information in the building facilities control to improve energy efficiency while maintaining an acceptable level of occupant comfort. Predictive control strategies are necessary to implement OCC in slow response systems like HVAC, which pose a significant challenge given the stochasticity of occupant behavior in built environments. Nonetheless, the recent advancement in Machine Learning (ML) and the Internet of Things (IoT) have made data-driven strategies more feasible in OCC of building systems. In this context, Deep Learning (DL) and Reinforcement Learning (RL) techniques have gained significant attention due to their ability to handle large volumes of data and achieve high prediction accuracy. However, the current literature lacks systematic knowledge of algorithm selection in the different OCC contexts. To address this gap, this paper presents a systematic literature review of DL and RL algorithms applied to OCC and provides organized information on the choice of algorithms by classifying occupant information into four levels based on increasing personalization. Subsequently, it identifies the algorithms suitable for each level to establish a systematic foundation for selecting DL and RL algorithms based on the degree of personalization required. The paper also highlights areas for future research in this area.

Authors	Article Title	Abstract
Amit Ojha; Houtan Jebelli	Quantifying the Implications of Humidity and Temperature on Heat Stress Exposure of Construction Workers: A Worker-Centric Physiological Sensing Approach	While the increment in temperature and humidity can alleviate or exacerbate occupational heat strain, the correlations between temperature, humidity, and heat stress exposure level is not well defined across a wide range of hot environments in the construction sector. To this end, this study seeks to quantify the impact of varying levels of humidity and temperature on heat stress exposure levels at construction sites. For this purpose, ten able-bodied workers were prompted to perform common construction tasks (roofing and material handling) while exposed to varying levels of temperature and humidity. During each task, three biosignals, namely photoplethysmography (PPG), electrodermal activity (EDA), and skin temperature (ST), were collected from the workers through wearable biosensors. To assess the workers' heat stress level, various metrics were extracted from PPG, EDA, and ST signals. Correlation analysis shows that air temperature and humidity are highly correlated with the workers' extracted physiological metrics. Analysis revealed compelling evidence for the temperature and humidity ranges that would harm construction workers. This study can inform new plans and policies for occupational health agencies, potentially maintaining health and productivity in a construction site.
Amit Tripathi; Roy E. Sturgill; Gabriel B Dadi; Hala Nassereddine	INVESTIGATING IMPLEMENTATION FACTORS FOR SUCCESSFUL TECHNOLOGY IMPLEMENTATION AT STATE DOTS	The need for secure, dependable, and higher-quality infrastructure systems necessitates more intricate transportation construction and maintenance projects. This research aims to identify six crucial factors for effectively implementing new and emerging technologies in State Departments of Transportation (DOTs). There is a growing interest among DOTs to implement emerging and wireless technologies, as seen and supported in various Federal Highway Administration (FHWA) Every Day Counts (EDC) initiatives. The study employs a mixed-methods approach, using survey responses from DOT personnel to determine the relative importance of technology implementation factors and sub-factors. This study investigates six factors for successful technology implementation: Organization Structure, IT Infrastructure, Data Security, Information Workflow, Personnel Training, and Stakeholder Engagement. The relative importance of People, Process, and Technology was also determined for each of the six factors of technology implementation. The study also evaluates different criteria within each technology implementation factor. The paper aims to provide guidelines to different agencies regarding successful technology deployment by providing an in-depth overview of key factors for successful implementation. It is important to understand the factors of technology implementation to successfully deploy emerging technologies, which eventually increases much-needed efficiency and productivity in highway construction and asset management.
Mohsen Mohammadi; Rayan H. Assaad; Aichih (Jasmine) Chang	An Intelligent and Dynamic Pricing IoT Model to Stimulate the Use of Shared Economies in Smart Cities	There has been an increasing interest in smart cities and digital technology to enhance the quality of provided services, while reducing costs. The "shared economies" notion has been recently introduced, which is a modern business concept highlighting the ability to generate revenue from underutilized assets or resources (such as unused space, buildings, rooms, apartments, etc.) by renting them to others. Smart cities enabled by peer-to-peer internet capabilities – e.g., IoT technology and devices – can fuel the growth of shared economies by improving information transparency and rationalizing resource allocation. This paper proposes a dynamic pricing model developed from an innovative renter reliability index, which is measured by IoT-enabled, real-time data on 10 different indicators. The proposed intelligent dynamic IoT model was demonstrated and tested in a real-world long-term shared economy environment (i.e., a rental space) in New Jersey, USA. The results showed that the proposed model can enhance the transparency and legitimacy of rental pricing in a shared space by identifying and rewarding condition-conscious renters, while penalizing condition-unconscious ones. This paper contributes to the literature by improving the efficiency of the shared products/services, the allocation of resources, and the pricing rationalization, which ultimately stimulates the shared economy in smart cities.
Andres Leonardo Acero Molina; Yilei Huang; Mostafa Namian	Comparing the Accuracy between UAS Photogrammetry and LIDAR in Bridge Inspections	Unmanned Aircraft Systems (UAS) have been increasingly used in the inspections of civil infrastructure due to their superior capabilities of fast deployment, comprehensive coverage, and labor-saving field operations. Depending on the use of the infrastructure, while some of them allow a visual check of the structural integrity, others require accurate inspection and verification of the structural members to resist natural hazards, such as flooding and hurricane. Photogrammetry and LIDAR are the two most commonly applied techniques among UAS inspection approaches. With the vast variety of available UAS airframes, navigation systems, and measurement sensors, the results of UAS inspections are not always consistent and comparable. This study presents the findings of measurements between a commercial photogrammetry UAS system and a customized LIDAR UAS system in bridge structure inspection. The measurements from two UAS systems were compared against the bridge plans and analyzed in terms of the span, deck, and foundation, and the results suggested that most UAS measurements are within 1% of the design values. The findings of the study demonstrate the workflow of using a UAS system for infrastructure inspection with both photogrammetry and LIDAR sensors and provide valuable insights into the accuracy of both UAS inspection techniques.
Md Ala Uddin; Yoojung Yoon; Monique Head; Qozeem Abiona Olatunbosun	Determination of Grouping Factors for Bridge Components Deterioration Analysis	Evaluating the deterioration process of bridges is a fundamental part of a good bridge management program by providing cost-effective maintenance strategies, given agency-defined goals and constraints. The deterioration of bridge structures over their lifetimes depends on various factors, such as material types, design types, geographic locations, and operational and environmental conditions. Grouping bridges at the level of components or elements is necessary to reduce data dimensionality in data analysis and formalize deterioration models through a statistical analysis while producing the same analytical results (i.e., homogeneous deterioration characteristics). However, grouping factors by which bridge structures are believed to show similar deterioration characteristics over time are determined based on the improvised, heuristic classification of bridges. This study conducted a data-driven similarity analysis to statistically determine grouping factors for bridge components. The results of this study demonstrated the effectiveness of the similarity analysis approach used in this paper. This research makes noteworthy contributions by introducing a novel data-driven methodology for identifying factors that facilitate the grouping of bridges, an approach that has not been explored before. Additionally, it enhances homogeneity within bridge groups, leading to improved reliability and robustness of bridge deterioration models.
Qiyang Chen; Nora El-Gohary	DEEP LEARNING-BASED COREFERENCE RESOLUTION FOR BRIDGE REPORT ANALYTICS	Bridge textual reports include massive amounts of data/information about bridge conditions. Extracting and analyzing this data offers opportunities to enhance bridge maintenance decision making. However, utilizing the data/information embedded in textual bridge reports for bridge data analytics remains to be a challenge due to the inherent coreference ambiguities in the text. There is a need for semantic analysis methods to disambiguate coreferences inside sentences to enhance the performance of data/information extraction from multiple types of reports. There is a lack of efforts that addressed coreference resolution (CR) in this domain. To address this gap, this paper proposes a deep learning-based CR model that automatically disambiguates the coreference ambiguities from multiple types of unstructured textual bridge reports and represents the extracted data/information in a structured format to support further data analytics. The proposed model utilizes a deep learning-based bidirectional long short-term memory (BiLSTM); a begin, inside, and outside (BIO) encoding schema; convolutional neural network (CNN) features; and span representations for coreference resolution. The model was tested on multiple types of textual bridge reports including bridge repair manuals, bridge assessment reports, and bridge rehabilitation reports. The proposed model showed promising CR performance and generalizability across different types of reports.

Authors	Article Title	Abstract
Shengyi Wang; Nora El-Gohary	Semantic Segmentation of Bridge Components from Various Real Scene Inspection Images	The infrastructure in the U.S. is deteriorating, which poses severe safety risks to the public. However, the traditional bridge inspection method, which relies on manual visual inspection, is time-consuming, labor-intensive, and could be dangerous. Recent automated bridge inspection approaches aim to utilize unmanned aerial vehicles (UAVs) and computer vision techniques to collect and analyze images to improve the process. A survey of existing literature and tools shows that defect detection/segmentation has been studied extensively. However, there has been little effort focused on segmenting and characterizing the bridge components that have the defects. The identification and characterization of bridge components is essential for bridge inspection, which can contextualize the defects to determine their importance in maintenance decision making. Moreover, existing bridge component recognition approaches lack generalizability in the presence of a variety of bridge types, complex background scenes, and varying shot sizes. To address these gaps, this paper proposes a convolutional neural network (CNN)-based image segmentation method to segment bridge components, which leverages DeepLabv3+ and pre-training from ImageNet to improve feature extraction and generalizability. The proposed method was trained and tested end-to-end on 13 classes based on the FHWA's Bridge Inspector's Reference Manual and achieved decent performance.
Hossein Naderi; Mohammadhossein Heydari; Alireza Shojaei	Applications of Tokenization in the Architecture, Engineering, and Construction (AEC) Industry	The Architecture, engineering, and construction (AEC) industry is widely known for being fragmented. In this situation, blockchain technology has been introduced as a promising solution to bring trust and transparency to the industry. As blockchain technology continues to evolve, it has embraced new capabilities and features, including Fungible-Tokens (FTs) and Non-Fungible Tokens (NFTs), which have recently drawn significant attention in various industries. Tokenization can be seen as a next-generation solution to address challenges in the AEC. However, the application of tokenization for the AEC industry has remained undeveloped. To address this gap, this study provides an overview of tokenization, followed by an investigation of its applications in the AEC industry using a literature review method. By illustrating a clear outlook of the potential advantages and challenges, the study helps to set realistic expectations over the potential improvement that tokenization can bring. This can also serve as a fundamental source for further investigation by researchers and practitioners.
Rafaela Orenga Panizza; Mazdak Nik-Bakht	Labeling Construction, Renovation, and Demolition Waste through Segment Anything Model (SAM)	On-site sorting is a critical task to support construction circularity towards the increase in the diversion of construction, renovation, and demolition waste (CRD) from the landfill. Image recognition technologies have proved their capacity to facilitate on-site sorting activities by automatically identifying the type and location of the generated waste. However, the labeling of images, while a crucial step in training image processing models is a time-consuming and error-prone process task. Consequently, finding a dataset of high quality with a large number of CRD waste images is challenging. Thus, with this in mind, this paper aims to assess the performance of the Segment Anything Model (SAM) in generating masks for CRD waste by assessing the labeling process and performance of the model trained with the SAM labeled dataset. Results of this study have shown that even though the use of SAM slightly damages the level of accuracy of the trained model, the use of SAM dramatically eases the labeling process.
Jinwu Xiao; Dahyun Oh; Ha Kyun Ju; Kyubyung Kang, Ph.D.	Hydrant Segmentation and Extraction Using Deep Learning Models for Large-Scale Urban Point Clouds	This study addresses the gap in research concerning the segmentation of smaller infrastructures, such as fire hydrants, within large-scale point cloud models. The RandLA-Net model, an efficient and robust deep learning algorithm known for its ability to process vast quantities of data while maintaining high accuracy rapidly, was evaluated for this task. A comprehensive dataset was constructed using LiDAR technology to gather point cloud data from diverse urban scenes. The data was manually segmented to assign unique class identifiers to distinct objects within the point cloud. The model was trained using these annotated data, and its performance was assessed using Intersection over Union (IoU), a typical evaluation metric for segmentation tasks. The results demonstrated the model's impressive capability in segmenting different classes within large-scale urban point cloud data. However, segmenting smaller, less distinctive objects like fire hydrants revealed room for improvement. Future work should focus on improving the recognition of complex or underrepresented classes and enhancing training stability. The study's findings provide critical insights into the capabilities and limitations of the RandLA-Net model in the context of large-scale, real-world point cloud data segmentation tasks.
Hossein Naderi; Reachsak Sak; Alireza Shojaei	From Data to Value: Introducing an NFT-powered Framework for Data Exchange of Digital Twins in the AEC Industry	Digital Twins (DTs) have recently drawn considerable attention in the AEC industry and academia. Despite their applications, most models typically represent an isolated DT without considering how they can connect to other DTs, where they can share data. Blockchain-based solutions, and specifically Non-Fungible Tokens (NFTs), have provided various features that can be seen as a promising solution to build the lost bridge for data sharing between different stakeholders in DTs. This study capitalizes on the advantages of NFTs to propose a framework for DT knowledge sharing. This framework is followed by providing future prospects of data management in the DT field. Our solution enables the ownership of various DT components, leading to the establishment of a secure data marketplace within the context of the AEC virtual world. This study can also serve as a fundamental source for further investigation by researchers and practitioners to develop an interoperable built Metaverse, where all DTs, in all Levels of Details, can exchange knowledge.
Amir Sanatgar; Mazdak Nik-Bakht	A Taxonomy for Change Management Process in Construction Projects	The complexity of construction projects and the multiplicity of stakeholders, organizations, and standards involved call for a unified and common language to support linked data and allow for semantic inference among multiple projects/ processes/ actors. While several taxonomies are developed for knowledge management in construction, most of them either have remained at a high level of information exchange or are focused on adapting project data with standards in a specific domain and have served a very narrow and particular range of queries. Although taxonomies that are established at such levels create a broad and general framework for organizing knowledge, they will not enable "cross-analyses" because of incomplete coverage of a particular domain. Hence, this paper proposes a user-level taxonomy, focusing on critical administrative processes in construction projects, i.e., change orders management. Text mining was applied to extract key concepts from the data of past projects focusing on two main facets, namely, processes and actors. Taxonomy has been developed to serve as the foundation of a new ontology that aims to enable organizations to perform cross-facet and cross-phase semantic queries in large construction databases.
Inbae Jeong, Ph.D.; Jisoo Park; Youjin Jang; Kyle Nietfeld	Remote Virtual Inspection of Infrastructure in Metaverse	To assess the condition of infrastructures such as bridges, highways, and pipelines, trained inspectors typically perform visual inspections with site visits. However, this conventional method can interrupt the regular functioning of the infrastructure as well as be time-consuming, laborious, expensive, and dangerous. To address these problems, this study proposes an immersive metaverse-based infrastructure remote virtual inspection platform. Based on a 3D digital twin model created through digital photogrammetry, this study generates an immersive metaverse to support collaborations between stakeholders for remote inspections. In addition, this study synchronizes a virtual reality (VR) headset with an unmanned aerial vehicle to remotely inspect infrastructure conditions at the target location using augmented real-time images mapped onto the digital twin model. The conducted experiments provided evidence that users equipped with VR headsets were able to see the 3D digital twin model of the infrastructure as if they were physically present on the sites. Within the metaverse space, users could easily navigate to specific areas and conduct inspection tasks by viewing both the digital twin model and real-time images through the proposed platform. The outcomes of this study hold the potential to enhance the efficiency and safety of infrastructure inspection.

Authors	Article Title	Abstract
Haui-En Cheng; Thai-Hoa Le; Jacob J. Lin	MULTI-USER MIXED-REALITY COLLABORATION FRAMEWORK FOR ONSITE MEP COORDINATION	Onsite coordination with Building Information Modeling (BIM) could improve collaboration and prevent conflicts between stakeholders during the construction phase. Recent research shows that mixed reality technology can extend the usage of BIM and enhance coordination to the next level. However, current practices often use LOD300, which provides inadequate information for MEP system coordination and can lead to clashes and reworks. On the other hand, the MR interaction is often limited to single-user scenarios. This paper proposes an onsite collaboration framework for multiple MR device users to examine the MEP system from lower LOD models in the construction phase. This framework includes creating an MEP system prototyping, generating an MR interaction module, developing a multi-user collaboration module, and establishing a report model. The system allows managers to check the MEP system's position, communicate issues, make changes, enable design change coordination, resolve clashes, and reduce reworks. We evaluate this framework through a case study, using scenarios such as moving components and measuring distances with multiple devices.
Yogesh Gautam; Houtan Jebelli	Unsupervised Adversarial Domain Adaptation in Wearable Physiological Sensing for Construction Workers' Health Monitoring Using Photoplethysmography	Recent advancements in wearable physiological sensing and artificial intelligence have made some remarkable progress in workers' health monitoring in construction sites. However, the scalable application is still challenging. One of the major complications for deployment has been the distribution shift observed in the physiological data obtained through sensors. This study develops a deep adversarial domain adaptation framework to adapt to out-of-distribution data (ODD) in the wearable physiological device based on photoplethysmography (PPG). The domain adaptation framework is developed and validated with reference to the heart rate predictor based on PPG. A heart rate predictor module comprising feature generating encoder and predictor is initially trained with data from a given training domain. An unsupervised adversarial domain adaptation method is then implemented for the test domain. In the domain adaptation process, the encoder network is adapted to generate domain invariant features for the test domain using discriminator-based adversarial optimization. The results demonstrate that this approach can effectively accomplish domain adaptation, as evidenced by a 27.68% reduction in heart rate prediction error for the test domain. The proposed framework offers potential for scaled adaptation in the job site by addressing the ODD problem.
Divine Agbobli; Yunjeong Mo	Understanding the Impact of the Covid-19 Pandemic on Residential Energy-Use-Related Activity Trends and Patterns Using the American Time Use Survey Data	The Covid-19 pandemic had a massive impact on work-life, with most workers forced to work from home due to Covid-19 lockdown restrictions. This study aims to explore the trends in residential energy-use-related behavior patterns from 2019-2021. Agglomerative hierarchical clustering applied to respondents' daily activity data extracted from the American Time Use Survey data revealed changes in respondents' activity profiles over the period. A time series analysis of the daily energy-use activities patterns in the residential setting showed significant relocation of work-related tasks from the commercial to residential settings. The studies revealed a more than 5% increase in Work from Home (WFH) from 2019-2021 and an over 4% decrease in Work from Office (WFO) from 2019-2021. These findings provide information on residential energy-use-related behavior trends to energy policy decision-makers and can help make critical energy policy decisions that can help lessen the energy bill burden and promote energy equity and justice.
Pouria Mohammadi; Abbas of Rashidi; Sadegh Asgari	Improving Culvert Condition Prediction Models Using Federated Learning: The Case Study of Utah	Departments of Transportation (DOTs) are constantly looking for more efficient ways to inspect culverts. This study proposes a data-driven approach based on federated learning for culvert inspection in Utah. As the Utah DOT (UDOT) had a limited dataset of culverts in Utah, we collected data from several other state DOTs. However, instead of using traditional centralized machine learning techniques, we used a federated learning approach in which data from other DOTs was not shared with UDOT, but rather developed local models based on those datasets were shared. This allows us to keep the data of the DOTs private while benefiting from their collective knowledge. As a result of using federated learning, the performance of UDOT's culvert condition prediction model was improved by 16%. The study demonstrates that DOTs can mutually benefit in scenarios of data scarcity, while still adhering to their preference for not sharing data directly with one another.
Yajie Liu; Kevin Han; William Rasdorf	A Comparison of Accuracy of UAS Photogrammetry in Different Terrain Sites	Unmanned aerial systems (UASs) are now standard tools for 3D mapping across diverse terrains. Despite their ubiquity, achieving consistent and reliable mapping results across varied terrains remains a challenge due to differing site conditions. To ensure consistency and the highest accuracy across terrains, it is crucial to discern the optimal flight configuration (defined as the UAS's predetermined flight pattern and altitude to capture overlapping survey images). This paper delves into four distinct terrains: construction, pit, preconstruction, and rock surface sites, collecting photogrammetry data from varied flight configurations. The research revealed that all sites achieved class A horizontal accuracy, with the best accuracy levels falling within 1-3 times the Ground Sampling Distance (GSD). The findings of this study offer valuable insights to surveyors and other professionals by elucidating the level of accuracy achievable for UAV-based photogrammetric surveying across various sites, enabling them to make informed decisions about flight configurations and data collection methods for more precise and efficient surveying results.
Seongyong Kim; Yong Kwon Cho	Construction Scene Segmentation using 3D Point Clouds: A Dataset and Challenges	With the purpose of facilitating process tracking such as inspection reports and progress monitoring, the AEC industry has adopted an as-built 3D model that is reconstructed using a 3d scanner during or after construction. In response to the laborious difficulties of converting a point cloud into a semantically rich model, e.g., BIM, researchers are attempting to automate this process via machine learning, applying 3D semantic segmentation and parametric modeling. However, there are no publicly accessible 3D datasets that target construction sites, regarded as unstructured and cluttered scenes, thus yielding a barrier to construction scene segmentation development. To this end, this paper aims to generate a 3D construction dataset that can be utilized for machine learning models requiring ground truth and to suggest foundation processing for general scene segmentation on construction datasets. In addition, we identify and discuss several challenges pertaining to construction sites, in terms of 3D semantic segmentation.
Parisa Sanaei; Baris Salman	Use of Photogrammetry and Laser Scanning Technologies in Runway Inspections	Runways are among the most important assets for many airports due to their high life cycle costs and functional importance. Runway inspections are mainly conducted through manual inspections requiring visual identification of distresses. These practices may suffer from potential inaccuracies and biases due to the time- and resource-consuming nature of these inspection procedures. Manual data collection procedures also hinder the potential for adopting more sophisticated approaches to asset management featuring artificial intelligence and digital twin technologies. In this paper, the potential of photogrammetry and laser scanning - two emerging methods to construct 3D models - in improving runway inspection procedures is examined. Results obtained from online surveys of airport authorities and industry leaders and semi-structured interviews are presented. A roadmap is presented to assist airport authorities with adopting photogrammetry and laser scanning technologies to improve their condition assessment procedures. While these technologies have found applications in other domains, their adoption in the aviation sector has been somewhat limited. It is anticipated that this paper and other publications in this area will foster further research and practical applications in the 3D modeling of airport infrastructure, resulting in considerable improvements to airport asset management practices.

Authors	Article Title	Abstract
Kaiyu Huang; Kaijian Liu	Recognizing Daily Human Activities Using Nonintrusive Sensing and Analytics for Supporting Human-Centered Built Environments	Recognizing daily human activities offers a great promise to develop human-centered efficient, assistive, and healthy built environments. However, the state-of-the-art sensing methods for human activity recognition are mostly intrusive: they either rely on capturing private personal information or require humans to wear sensors. Such intrusive sensing often raises privacy concerns or suffers from adherence problems (i.e., people stop wearing the sensors with time). There is, thus, a need for a nonintrusive sensing method to better support daily activity recognition in buildings. To address this need, this paper proposes a novel nonintrusive sensing and analytics method. At the cornerstone of the proposed method is a new multi-purpose sensing system, which captures the composition changes of multiple indoor gases induced by daily activities, without capturing private occupant information and requiring sensor wearing, for supporting activity recognition. As a pilot study, this paper focuses on evaluating the feasibility of the proposed nonintrusive sensing method by testing the significance of the differences in air composition data collected under different daily activities (e.g., cooking, sleeping, and idling). The experimental results show the feasibility of the proposed method to recognize daily human activities in a nonintrusive way.
Nhien Dinh Le, Ph.D; Dan Tran	Use of Non-Destructive Testing Technologies for Highway Infrastructure Inspection	Methodologies for conducting highway infrastructure inspection activities are experiencing a substantial change with the proliferation of technology. Instead of relying on destructive testing methods to perform inspections, state departments of transportation (DOTs) use a wide range of non-destructive testing (NDT) methods for inspecting highway construction projects and assets. However, the varying approaches adopted among the state DOTs can lead to confusion and inconsistency. Therefore, this study aims to provide a comprehensive and systematic overview of several NDT methods available for inspection activities used across the nation. A national survey of 50 state DOTs was conducted to collect data. The results showed that the typical NDT methods used for highway construction inspection include: nuclear density gauges, dynamic test loading for piles, cross-hole sonic logging for drilled shafts, surface profile measuring systems, ground-penetrating radar, and ultrasonic testing. The typical inspection activities during construction using NDT are in-situ material characterization, foundation investigation, structural inspection, and bridge deck deterioration. The top inspection activities involving NDT technologies during asset maintenance include structural inspection, automated pavement distress measurements, and identification of fracture damage. This study contributes to the literature by summarizing and analyzing the NDT technologies for highway infrastructure inspection activities.
Nhien Dinh Le, Ph.D; Dan Tran	Exploring Remote Sensing and Monitoring Technology for Highway Infrastructure Inspection	The integration of cutting-edge technologies has become prevalent, promoting state departments of transportation (DOTs) to progressively adopt an array of digital tools and advanced technologies to improve their highway construction projects. There is a wide range of remote sensing and monitoring technologies, including light detection and ranging (LIDAR)/ 3D laser scanning, radio frequency identification (RFID), remote sensors (RS), infrared sensors (IS), and unmanned aerial systems. However, the varying approaches adopted among the state DOTs can lead to unclearness and inconsistency. This study aims at investigating how state DOTs use sensing and monitoring technologies for highway construction inspection during construction and asset management. This study engaged a research methodology that included an extensive literature review and a survey questionnaire of 50 state DOTs. Results show that 28 state DOTs use remote sensing and monitoring technologies to measure material strength and temperature, capture site photos and videos, and measure construction progress. The main challenges to using sensing and monitoring technologies are a lack of training, device maintenance and user support, a lack of reliable internet connection, and cost issues. This research contributes to the body of knowledge by exploring the use of sensing and monitoring technologies for highway construction inspection.
VAMSI SAI KALASAPUDI, Ph.D.; Bharadwaj R. K. Mantha; Kavyaa Boopathy; Yang Zou	A Survey Based Investigation to Understand the Influence of an Augmented Reality based Application on the Home Remodeling Market	The trend of remodeling living spaces has risen exponentially due to pandemic-led work-from-home culture. Consequently, a sharp rise in material costs, labor shortage, and material lead times were observed. Homeowners increasingly resorted to a DIY (do it yourself) approach to remodel their existing homes. However, they face several challenges such as lack of tools to visualize different designs and a centralized platform to compare products from various vendors. None of the existing applications provide essential information (material availability, costs from different suppliers) and AR features (projecting digital models in real-world) to cater to the diverse needs of homeowners. This study aims to conduct user market research, determine value propositions, and identify multiple revenue streams of such an application using surveys collected from diverse customer segments (e.g., homeowners, contractors, realtors, and suppliers). A major outcome of this study is to gain insights into the unique value proposition of an AR-based application for each customer segment in the home remodeling market. In addition, this study will also try to examine the necessary and supplementary application feature(s) required by the respective customer segments. The findings are therefore believed to transform the home remodeling market.
Shun-Hsiang Hsu; Mani Golparvar-Fard	Requirements for Parametric Design of Physics-based Synthetic Data Generation for Learning and Inference of Defect Conditions	The advancement of Artificial Intelligence (AI)-driven defect detection has already demonstrated promises to boost quality assurance and control, as well as condition assessment in the built environment. However, training defect detection models requires hefty amounts of reality capture data, and labeling is considered expensive. In most cases, such data may not cover all situations of defects. Synthetic data, most recently made with Building Information Models (BIM), is turbocharging model development for learning defect features. Nevertheless, few studies focused on characterizing defects to classify their severity, which is crucial to the condition assessment. To that end, this study explores the requirements for generating synthetic data. Parametric physics-based modeling approaches are carefully examined. Using the underlying geometrical properties of such data, the condition of each defect can be determined. The feasibility of synthetic defect data is validated with a case study of crack segmentation using the transformer-based model, SegFormer. Examples of how different scenarios can be generated photo-realistically with the use of physics-based rendering for creating varying geometrical characteristics, appearance, and viewpoints of defects are presented. The generated synthetic crack datasets can successfully be used to train the SegFormer model and reach promising predictions on real crack images.
Ahmad Akib Uz Zaman; Ahmed Abdelaty	Limitations and Barriers Affecting the Applications of UAVs in Transportation Infrastructure Systems Assessment	Transportation infrastructure systems are subject to deterioration because of several factors, such as traffic loads, weather conditions, construction quality, and age. Therefore, regular assessment and maintenance are required to keep these systems in acceptable condition to provide their intended functions. However, traditional assessment procedures are time, cost, and labor-intensive. Thus, several Departments of Transportation (DOTs) have moved toward more innovative assessment methods, such as Unmanned Aerial Vehicles (UAVs). However, the use of UAVs in infrastructure assessment is still developing, and many DOTs face limitations and challenges in fully adopting UAVs for infrastructure assessment. Thus, this paper aims to identify the DOT's current status of UAV applications and the challenges of these applications in infrastructure systems assessment from five perspectives: Social, Workability, Operational, Economic, and Environmental. A survey has been distributed to 50 state DOTs, and responses from 25 DOTs have been recorded. Based on the survey results, this paper identified and categorized 25 limitations from the five perspectives. Finally, this paper maps the future research needs based on existing limitations and previous research.

Authors	Article Title	Abstract
Behnam M. Tehrani, MSc.; Chao Xie; Aladdin Alwisy	A Framework for Automated Quality Control of Wood-framed Panels in Robotic-based Manufacturing Using Computer Vision and Deep Learning	The advent of robotic systems has brought significant transformations across various industries, increasing the quality of products and services. However, due to construction projects' intricacy and robotic manufacturing's technological challenges, robotics in the construction sector is still in the nascent stages of development. The variability of construction materials presents a major challenge to the integration of robotics-based manufacturing. Lumber misalignments can cause costly reworks to the wood framing process due to lumber damage, structural deviations, and nail gun misfires. This paper seeks to address the critical quality control challenge for robotic-based manufacturing in industrialized construction. The proposed automated quality control system detects alignment issues using computer vision and deep learning technology. Detected misalignments are transmitted through a graphical user interface (GUI) to construction workers to allow them to determine whether corrective actions are required or not. The field experiments illustrated the significance of the proposed system in ensuring a proper framing process and enhancing the quality, safety, and productivity of robotic manufacturing in industrialized construction.
Omobolanle Ogunseiju; Abiola Akanmu	Cognitive Load Within Mixed Reality Learning Environment in Construction Education	Mixed reality has achieved acceptance within higher education owing to its ability to provide experiential learning with enhanced engagement and attention. In construction education, mixed reality environments can serve as alternative learning platforms for jobsite visits and hands-on learning without exposure to jobsite hazards. However, the design of such learning environments is often oblivious to users' cognitive states. As human working memory is limited in capacity, cognitive overload is inherent in such learning environments and inadvertently impacts learning efficiency and knowledge retention. This study presents the assessment of a mixed reality environment for learning sensing technologies in construction education and investigates the effects of cognitive load within the learning environment. The study shows the relationship between cognitive load and students' learning outcomes and the impacts of students' demographics on cognitive load. This study sets precedence for exploring intelligent learning environments that adapt to students' cognitive load for improved learning experiences.
Nidia Bucarelli; Nora El-Gohary	Sensor Locations for Occupant Thermal Comfort State Prediction	Indoor air temperature, which is one of the main factors affecting the thermal comfort of occupants, varies across locations/spaces. However, current occupant thermal comfort models rely on predefined formulas or data-driven approaches that often ignore the importance of the specific location in the room at which the sensor is placed. This research aims to study the impact of sensor location on occupant thermal comfort state prediction. A set of 90-min occupant experiments were conducted in a controlled environment. Multiple temperature and humidity sensors were placed at different locations in the room. During the experiments, the room temperature changed from 19°C to 29°C, and the humidity, mean radiant temperature, and wind speed were controlled. The subjects performed office duties and provided feedback about their thermal comfort periodically. Personal parameter data were also collected. For each sensor location, a thermal comfort state model was developed using the XGBoost algorithm. Each model was tested in predicting the occupant comfort state using temperature and humidity data from other room locations. The results showed that the location of indoor parameter data used for prediction could affect model performances by up to ±7.2% accuracy and ±8.0% F1-measure.
Behlul Kula; Andreana Louise Roxas; Kristen Cetin; George Berghorn; Annick Anctil	Development and Evaluation of an Energy Assessment Process Using Virtual Reality Technology	The U.S. Department of Energy's Industrial Assessment Centers (IACs) conduct energy assessments to increase energy efficiency of small and medium-sized industrial facilities and commercial buildings. However, it is not always possible to have all the necessary experts on-site, leading to lost potential ideas and recommendations. In addition, new energy assessment team members should attend as many assessments as possible to gain experience, but scheduling conflicts may prevent them from attending all. Virtual Reality (VR) could potentially address these issues, but no studies have been conducted on its use for energy assessments. This research aims to develop a virtual energy assessment process for industrial and commercial buildings and evaluate, based on participants' feedback, how well the use of the technology mimics a real-world environment. Virtual environments are created using an infrared scanning device, and participants are trained in how to use VR and conduct energy assessments. Results from participant surveys suggest that VR environments closely mimic real-world environments and can be used for learning and training in energy assessments.
Lei Shu, Ph.D.; Dong Zhao	Data-driven residence energy consumption prediction model considering water use data and socio-demographic data	Data-driven energy prediction models can help urban planners and policymakers evaluate urban energy consumption patterns and then make informed decisions on how to improve urban energy efficiency. Typically, energy use data and building characteristics data were used to train these data-driven models. Few research utilized water use data and socio-demographic data, which have nexus with the energy consumption of buildings. This research utilized energy use data, building characteristics, socio-demographic, and water use data of multi-family buildings in New York City to train Least Absolute Shrinkage and Selection Operator (LASSO), Ridge Regression (RR), Support Vector Regression (SVR), and Random Forest Regression (RFR) machining learning models. The effects of socio-demographic and water use features on the performance of energy prediction were analyzed. Results showed that water use feature had significant positive impacts on the performance of LASSO, RR, and RFR models. Socio-demographic features had obvious positive impacts on the performance of SVR and RFR models. RFR trained with the BW dataset (including building characteristic features and water use feature) performed the best.
Sisi Han; Yuhan Jiang, Ph.D.; Yong Bai	Experimental Evaluation of Convolutional Neural Networks in Asphalt Concrete Computed Tomography Scan Image Analysis	This research proposed a Convolutional Neural Network (CNN) model for Asphalt Concrete Computed Tomography (CT) Scan image classification, which uses SoftMax activation for the output layer to yield the Air Void prediction with a testing accuracy of 0.9684, weighted average precision, recall, and f1-score are 0.97 in the early stopped model, and 0.99 in the best model (smallest validation loss). Moreover, by switching to Linear activation, the CNN model can generate numerical values for Air Void, which has the average percentage difference of 0.42%, -1.47%, 2.87%, 2.3%, 2.27% for Air Void contents of 10.4%, 15.6%, 18.9%, 21.9%, and 25.6%, respectively. Furthermore, by integrating the CT image with Grad-CAM++ generated heatmap, instance segmentation of the Asphalt Concrete CT image as components of Air Void, Binder, and Aggregates is more effective than using image only. The application of using segmentation results for Asphalt Concrete 3D modeling is also presented.
Linjun Lu; Zhenhua Zhu; Fei Dai	An Investigation on Accurate Road User Location Estimation in Aerial Images Collected by Drones	Unmanned aerial vehicles (UAVs) have recently become popular in collecting positional data of road users. In comparison to other tools at ground level, UAVs have the advantages of low cost, wider view coverage, and significantly less occlusion. However, the depth relief of road users and the perspective distortion of the onboard camera induce nonnegligible error while applying UAVs for localization of road users. This study proposed a method for accurate road user localization in aerial images. First, the localization error induced by the depth relief and perspective distortion was examined and modeled. Then, a deep-learning-based method was applied for automatic road user detection and localization in the aerial images by leveraging oriented bounding boxes to achieve higher localization accuracy compared to applying horizontal bounding boxes. Finally, an error compensation strategy was proposed to eliminate the perspective- and depth-relief-induced localization error by rectifying the oriented bounding boxes obtained from the previous step. Field experiments were conducted to evaluate the method's performance. The results demonstrated its promising accuracy for road user location estimation and its potential to improve the reliability of UAVs in traffic applications.

Authors	Article Title	Abstract
Liqun Xu; Xiaowei Luo; Hexu Liu; Fei Dai; Zhenhua Zhu	Synthetic Simulated Data for Construction Automation: A Review	The integration of deep learning (DL) technologies into construction offers great potential for promoting the level of automation in construction. However, the implementation of the DL model requires the acquisition of substantial data, which is error-prone and time-consuming. Additionally, due to safety and privacy concerns, not all real-world data can be retrieved. To address these issues, synthetic simulated data have emerged as promising alternatives, and various methods have been developed to generate such data. However, currently there is neither a summary of synthetic simulated data generation methods nor unified metrics to evaluate these methods. In this paper, a comprehensive review of 129 scholarly articles from Web of Science is conducted. Based on the source of data assets and the techniques employed for their combination, we categorize synthetic simulated data generation methods into seven distinct categories. Furthermore, we summarize seven metrics for evaluating these methods and consolidate the evaluation results in a table. The provided table serves as a reference for practitioners in identifying and selecting suitable synthetic simulated data generation methods for their applications.
Jing Wen, PhD	Review on Digital Twin Applications in Construction by Maturity Level	Digital Twin (DT) refers to a digital technology that virtually represents a physical asset and reflects its behavior in real-time. As the fully implemented DT is largely unachievable, a maturity spectrum has been proposed representing different milestones for DT implementation. DT Enabling technologies vary depending on the maturity level of DT. This paper intends to review DT cases in construction to help DT adopters understand DT-enabling technologies based on the maturity level of their demanded DT. The outcome of this study provides DT adopters with practical insights into how to decide the DT maturity level that meets their demand and what are the enabling technologies that support their DT development. With maturity level, AEC practitioners gain forward-looking insights on how to expand existing DTs or how to strategically apply their technological skillset to explore the potential of creating DTs, rather than solely focusing on their current job scope and needs.
Navid Nickdoost; Juyeong Choi	A Composite Index Framework for Data-driven Decision-making in the Construction Industry	Decision-making in the construction industry involves a high level of uncertainty stemming from numerous external factors, which are outside of the control of decision makers but cause the industry's complex and dynamic behavior. As such, informed decision-making requires identification of various external factors and continuous monitoring and analysis of abundant information derived from them. However, the existing data-driven approaches focus on limited aspects of external factors to understand the industry, which is insufficient for long-term policymaking since more diverse external factors are associated with the long-term prospect of the industry. To address this gap, this study proposes a composite index framework to allow decision-makers to monitor and analyze factors across various aspects of the construction industry. The composite index framework creates a comprehensive hierarchy of all influencing factors, allowing decision-makers to synthesize the data and monitor the dynamic behavior of the industry.
Quan Miao; Meiyin Liu	Vision-based 6-DoF Pose Estimation of Forklift and Load for On-site Stability Check	Heavy equipment contributes to accidents in construction as a major category of causes. Various studies develop simulation models to investigate the correlation between equipment's state variables (e.g., center of mass, orientation, velocity, and acceleration) during movement and the risk of accidents such as tip-over. However, the impact of material attached to equipment is rarely incorporated as the dynamic state variables of the material are not readily available onsite. To address this issue, this research streamlined the process of preparing the training data which enables the implementation of existing vision-based 6-DoF object pose estimation models. An evaluation test is performed to demonstrate the potential of the proposed approach. This research also develops the method to convert the estimated pose from the image's coordinate system to a world coordinate system, which enables estimating state variables in a dynamics simulation. Finally, a simple stability check using the stability triangle is demonstrated using the vision-based approach.
Hani Alzraiee	Road Cross Slope Evaluation Using Surveying and LiDAR Techniques	The cross slope is a critical geometric feature of pavement surfaces as it affects safety due to its relationship to the potential of hydroplaning during wet weather. Appropriate cross slopes provide adequate drainage so water will run off the surface to a drainage system such as street gutters (urban streets) or side ditches (rural facilities). An inadequate cross slope could lead to several safety issues, including hydroplaning, loss of control, and run-off-road crashes. This research study compared two methods of data collection, namely a conventional survey and a LiDAR-based survey using a terrestrial laser scanner, to evaluate roadway surface's cross slopes. Two existing rural road segments in San Luis Obispo County (California, USA) were selected for evaluation. A comparison between the results from the two methods showed that the difference follows a normal distribution, indicating no systematic errors during data collection. Also, the two-sided paired t-test between the traditional survey surveying and LiDAR shows no statistically significant differences between the slopes estimated using the two methods. Moreover, the results indicate that the difference between LiDAR-derived cross slopes and field surveying measurements is less than 0.2% at a 95% confidence level.
Guofeng Qiang; Shu Tang, Ph.D; Jianli Hao; Luigi Di Sarno	A BIM and AIoT Integration Framework for Improving Energy Efficiency in Green Buildings	The green building (GB) sector contends with a significant energy performance gap. Building information modeling (BIM), Artificial Intelligence (AI), and Internet of Things (IoT) technologies can address this issue effectively by optimizing design and accurately predicting and monitoring energy consumption. However, research on integrating BIM and AI of Things (AIoT) for GB is nascent. Intelligent processing and analyzing heterogeneous data schema from various information systems is the main challenge faced by many researchers in GB domain. Thus, this study aims to systematically analyze the application of BIM and AIoT in GB and construct an integration framework for improving energy performance. In addition, this framework illustrates how to exchange, transmit and process massive amounts of heterogeneous data from BIM and IoT platforms by leveraging AI and Semantic Web technologies. Results show that BIM and AIoT integration can assist in intelligent energy-saving decisions through effective data exchange, cloud/edge/fog computing, and user interface (UI). This research contributes to the creation of the BIM-AIoT integration framework. This framework lays a foundation for energy efficiency, facility management, and intelligent construction in the GB domain. Finally, this research highlights the challenges and recommendations related to BIM-AIoT applications in GB.
Ilerioluwa Giwa; Ali Kazemian, PhD	Planetary Robotic Construction Using Large-Scale 3D Printing with Sulfur Concrete	For successful long-duration missions and to establish a long-term presence of mankind on the Moon and Mars, the construction of supporting structures is imperative to protect humans and enable exploratory logistics in the extreme space environment. Extrusion-based Construction 3D Printing (C3DP) offers a large-scale automated construction approach that can be leveraged for planetary construction. Although Portland cement concrete (PCC) is the most common material for C3DP and traditional construction on Earth, it is difficult to obtain on the Moon and Mars. Sulfur concrete is an alternative waterless construction material that is viable for off-world construction due to the availability of its ingredients. This study investigates the behavior of sulfur-regolith concrete as a candidate material for planetary C3DP, by studying the printability and performance of 3D printed samples made with a Martian regolith simulant. Based on the experimental findings, the printability and mechanical performance of sulfur-regolith concrete can be impacted by process parameters such as the printing temperature and interlayer time gap. Furthermore, the performance data for 3D printed specimens under vacuum conditions and temperature variations showed weight loss and flexural strength reduction as a result of sulfur sublimation.

Authors	Article Title	Abstract
Jiansong Zhang, Ph.D.	IFC-based Semantic Segmentation and Semantic Enrichment of BIM for Bridges	The state-of-the-art PDF2BIM algorithms enable semi-automatic creation of 3D geometric building information models (BIMs) of bridges based on 2D bridge plans. However, this 3D geometric model is represented as one entity instance with no semantic information associated with it (e.g., concrete strength, structure type, etc.). To pursue the full potential of Industry Foundation Classes (IFC) representations in BIM for bridges, in this paper, the authors proposed a framework to segment the bridges into different components based on their semantic features and further assign semantic information to them accordingly. The proposed framework was tested on 4 bridges, which shows promising results. The semantically enriched bridge models can enable more accurate analysis and evaluation of bridge performance, facilitate better asset management and maintenance strategies, and enhance communication among stakeholders, including designers, engineers, contractors, and asset managers.
Jiansong Zhang, Ph.D.	Natural Language Processing for Construction Management: A Literature Review	Automation in construction is essential to improve the efficiency of this sector. There have been many advancements in this field and the use of natural language processing (NLP) has attracted increasing interests in recent years. This systematic literature review considers the contributions made in the past decade (2011-2021) in the specific domain of implementation of NLP models in the commercial construction industry to help improve efficiency in project management. The review focuses on identifying relevant research efforts and their contributions, analyzing the NLP techniques used and results achieved, and determining the gaps and limitations based on the literature. Reviewed articles were selected from a total of 566 records retrieved from the Scopus, ASCE, ProQuest and Google Scholar databases. The articles were then filtered, classified, summarized, and analyzed. The review resulted in the identification of 19 most interesting articles in which the developed technologies have potential of immediate applications in different project phases – from documentation and bidding, project close out, to post construction facility management. It was concluded that improving and automating the processes in these project phases with NLP resulted in increased project efficiency. Some gaps in the literature review were identified and recommendations for future research were provided.
Tamoghna Ghosh; Arpit Sethi; Jiansong Zhang, Ph.D.	Automation in Construction Contract Analysis and Management	This study aims to provide a feasible framework in achieving automation of construction contractual clause interpretation and analysis through literature review on recent publications from the turn of the century to date. The concept of 'smart contracts' was investigated in depth regarding its correlation and interoperability with other automation technologies, namely building information modeling, sensing technologies, virtual reality and augmented reality, and construction robotics. As a result, the proposed framework integrates knowledge modelling for computer-interpretable contractual clause formulation, automated reasoning for contractual monitoring and tracking (e.g., for fulfillment of bonds and securities that bind the involved parties), and machine learning for predictive model development for action planning and decision support. Furthermore, the use of blockchain technology proves to be beneficial to support the payment process. Last but not least, the most cutting-edge deep learning technologies such as GPTChat by OpenAI was analyzed in this context. Research and development needs were identified and recommendations were made for future research. This framework opens the door to more extensive research in construction contract analysis and management leveraging cutting-edge automation technologies.
Hang Li; Jiansong Zhang, Ph.D.	Information Extraction for Semantic Enrichment of BIM for Bridge	Current bridge projects mainly rely on PDF plans as the official deliverables and documents to be stored, communicated, and transferred among different stakeholders. With the industry foundation classes (IFC) building information modeling (BIM) standard adopted by the American Association of State Highway and Transportation Officials (AASHTO) as the national standard for modeling bridge and road infrastructure projects, upgrading the documentation of bridge projects to 3D BIM in compliance with the national standard has become an urgent need. In this research, the state-of-the-art PDF2BIM algorithms were leveraged to semi-automatically create 3D geometric models of bridges based on PDF drawings. To enrich the 3D geometric model with semantic information of bridges' components (e.g., structure type, concrete strength), information extraction algorithms based on optical character recognition (OCR) and natural language processing (NLP) were developed to extract data from the bridge plans automatically. It significantly increases the efficiency and productivity of information extraction and enrichment of IFC-based BIM instance models for bridges by leveraging the rich information that already resides in the PDF plans. The results show that it achieved 97.6% accuracy in the information extraction task, and reduced the overall time consumption on processing bridge data by 96.3% compared to the manual approach.
Yara Nassar; Gilles Albeaino; Masoud Gheisari; Idris Jeelani; Raja R. A. Issa	Human-Robot Collaboration Levels in Construction: Focusing on Individuals' Cognitive Workload	Small collaborative ground robots that are efficiently capable of accomplishing a variety of tasks have become more ubiquitous on jobsites. With the advancement in technology and automation, it is expected that close collaborations between humans and such robots will drastically increase in the future. However, there is a need to understand how humans working with robots at different interaction levels may result in different human perceptions and cognitive workloads. In this study, a between-subject experiment was created to explore humans' perception towards robots by measuring their cognitive workload at three different human-robot collaboration levels of coexistence, cooperation, and collaboration when accomplishing a real-world bricklaying construction task. Results showed that collaborating with small ground robots may lead to lower physical demand compared to cooperating or simply coexisting with it. However, mental demand, temporal demand, performance, effort, and frustration did not significantly differ between the three collaboration levels. The outcomes of this study provide a better understanding of the safest and most efficient human-robot collaboration practices on jobsites.
Fangxiao Li, Ph.D.; Ziyi Wang; Yuqing Hu; Robert Leicht	Validation of a Construction Robotics Schema for Site Operation Planning	This paper presents a construction robot schema (CRS) for construction planners to facilitate decision-making and project planning in operating robotics. CRS is a database schema structure that was developed in our previous study, which can facilitate collecting and exchanging data of various construction robots based on the data requirements of the construction domain. We validated the applicability of the schema by the simulation of robotic construction operations. In addition, we conducted interviews with experts from the construction industry to validate the information in CRS. As a result, the schema was validated with minor revisions to some parameters. The characteristic of CRS compared to other types of robot schema are that its development and application are based on the perspective of the construction domain and are designed to cover different construction robots broadly. The conclusions highlight the contributions of the data schema use and applicability for the construction industry.
Yizhi Liu; Houtan Jebelli	STUDYING THE EFFECTS OF BACK-SUPPORT EXOSKELETONS ON WORKERS' COGNITIVE LOAD DURING MATERIAL HANDLING TASKS	Exoskeletons, also known as wearable robots, are being studied as a potential solution to reduce the risk of work-related musculoskeletal disorders (WMSDs) in construction. The exoskeletons can help enhance workers' postures and provide lift support, reducing the muscular demands on workers while executing construction tasks. Despite the potential of exoskeletons in reducing the risk of WMSDs, there is a lack of understanding about the potential effects of exoskeletons on workers' psychological states. This lack of knowledge raises concerns that exoskeletons may lead to psychological risks, such as cognitive overload, among workers. To bridge this gap, this study aims to assess the impact of back-support exoskeletons (BSE) on workers' cognitive load during material lifting tasks. To accomplish this, a physiologically-based cognitive load assessment framework was developed. This framework used wearable biosensors to capture the physiological signals of workers and applied Autoencoder and Ensemble Learning techniques to train a machine learning classifier based on the signals to estimate cognitive load levels of workers while wearing the exoskeleton. Results showed that using BSE increased workers' cognitive load by 33% compared to not using it during material handling tasks. The findings can aid in the design and implementation of exoskeletons in the construction industry.

Authors	Article Title	Abstract
Hieu T.T.L. Pham, Ph.D; SangUk Han	An Application of Cycle GAN for Creating Generated Real Training Images with 3D Excavator Pose Labels from a Synthetic Model	3D excavator poses providing the motion information of the boom, arm, and bucket in 3D space support monitoring excavator activities for safety and productivity management in earthwork. Thus, previous studies have attempted to estimate 3D excavator poses using deep learning relying on the large data with high-quality annotations, which requires time-consuming and manual processes. To address this challenge, this study proposes cycle GAN to automatically create large generated real training images with 3D pose labels from synthetic images. The proposed model is trained on 800 pairs of synthetic and real images and evaluated through pre-trained ResNet50-based 3D pose estimations. The results reveal that 3D pose model trained on generated data, reaching 0.50m key-point loss and 8.53-degree angle loss for testing on generated images, and 9.33-degree angle loss for testing on real images, yielded better results than model trained on synthetic data (i.e., 0.64m, 15.18-degree, and 15.39-degree, respectively). This demonstrates the effectiveness of the proposed method for generating training images from synthetic images for 3D pose estimation. This 3D pose estimated from generated images enables construction managers to monitor excavator safety and productivity in the construction sites.
Zirui Hong; Hubo Cai	AN ONTOLOGY FOR NATURAL COMMUNICATION IN HUMAN-ROBOT COLLABORATION IN CONSTRUCTION	Human-robot co-working is a promising autonomous resolution for alleviating the sufferings from labors shortage, occupational hazards and low productivity. Instructing robots to complete construction tasks using natural language (NL) is a hand-free and straightforward working method. Towards a smooth communication of intentions, ontology can serve as an important knowledge base for the robot to develop its intelligence to correctly interpret NL instructions. However, few studies have explored the use of ontology to facilitate a natural-language-based huma-robot interaction in construction applications. This paper presents a preliminary study on the design of a framework for intuitively controlling an on-site construction robot using NL instructions. The method for building the enabling ontology was discussed and the evaluation results were presented. This paper demonstrates the feasibility of using ontology to enable NL-based human-robot interaction in completing on-site construction tasks.
Ziyi Wang; Yuqing Hu; Robert Leicht	AUTOMATED CONSTRUCTABILITY ASSESSMENT FOR ROBOTICS IN CONSTRUCTION: CASE STUDY OF CANVAS	Advances in robotics represent a potential shift in the construction industry. Construction planning is planned based on craft work; it is necessary to emphasize external factors such as construction robotics. Improving constructability can enhance design-phase construction opportunities, thereby expanding the potential scope of robot operations. However, robotics are often neglected concerning constructability. Previous studies on constructability concentrated on human-based construction methods, hence gaps remain in assessing constructability for robotics. To minimize the barriers in robotic construction, this paper presents a method for using a rule-based framework for robotic constructability assessment checks with the help of BIM. Focusing on CANVAS - a drywall finishing robot, this paper applies a BIM-based object-oriented model integrating with ROS to utilize constructability reasoning about robotic operations. A model of rule-checking for robotics in the case study is demonstrated and tested. The availability of design information in the model containing robotics is discussed, showing the need for assessing robotics-related constructability information to support an automated review of robotic constructability assessment. This paper applies a case study to validate use of the framework for robotic constructability assessment in the design phase, leading to an automated constructability assessment of construction robotics.
Aliu Akinsemoyin; Ibukun Awolusi; Sandeep Langar	Framework For UAV-BIM Integration for Proactive Hazard Identification in Construction	Building Information Modeling (BIM) integration with Unmanned Aerial Vehicles (UAVs) can enhance construction safety through proactive hazard identification to reduce and eliminate injuries and accidents on construction sites. Although numerous approaches exist to improve construction safety, only a handful explore combining BIM and UAVs. This research presents parts of a holistic framework of UAV-BIM integration for hazard identification on construction sites for safety performance improvement. A snowballing process was used to review the existing studies on the different applications of UAVs and BIM. Thereafter, a conceptual framework was developed using the findings of the review. This study contributes to the body of knowledge in a novel way by providing a systematic framework in the areas of technological capabilities, regulatory requirements, and their overlap to proactively determine hazard locations on construction sites. The research findings provide insights into how UAV-BIM integration can be utilized to enhance safety on construction sites.
Jiahao Wu; Yang Ye; Jing Du, PhD	Multi-Objective Reinforcement Learning for Autonomous Drone Navigation in Urban Area	Unmanned aerial vehicles (drones) are widely used for reality capture, data collection, and aerial logistics in multiple industries. Existing research in autonomous drones focuses much on path planning and automated obstacle avoidance. However, in complex environments such as urban areas, a safe and efficient drone navigation depends on many more dynamic constraints, such as layout of buildings, local aerodynamics (e.g., side winds), signal coverage, and malicious attacks. And many of these factors are interdependent, such as the wind field being affected by the geometric features of nearby buildings. This paper proposes a multi-objective reinforcement learning algorithm for the drone's path planning while satisfying a variety of interdependent constraint conditions. The drone will be able to sense multiple environmental and physical conditions of the near field, and develop dynamic policies for prioritizing the navigational decision to optimize the path while minimizing the negative environmental impact. A policy network will be trained to set priority weights for specific environment and physical factors at a given point. A simulation study is performed to test the proposed algorithm in an urban aerial logistics case.
Kinam Kim, Ph.D.; Jainish Shah	MOTION INTENTION RECOGNITION OF CONSTRUCTION WORKERS FOR HUMAN-ROBOT COLLABORATION IN CONSTRUCTION	Construction robots have gained attention due to their potential for automating various construction tasks. Although recent research efforts have been made to develop robotic systems that assist manual work and reduce human intervention with different levels of automation, robots still need human assistance and collaboration for various tasks because of the unique characteristics of construction projects. To facilitate seamless human-robot collaboration in a dynamic and unstructured construction site, it is necessary that robots are able to understand not only the collaborator's behavior in time but also its behavioral intention proactively to perform appropriate collaborative work. To achieve this goal, this study proposes a worker's motion intention recognition method that captures the muscle activity of the workers using surface electromyography (sEMG) and detects motion intention from the muscle activity at the early stage of taking motions using a deep-learning approach. Using the sEMG signals, a deep-learning algorithm is used to predict the motion intention of the workers performing tasks for human-robot collaboration. With the proposed method, it is expected that robots can predict the motion that the worker in collaboration is going to take at the next moment, and ultimately this can improve the contextual awareness of robots for human-robot collaboration.
Fang Xu; Hengxu You; Tianyu Zhou; Jing Du, PhD	Telepresence Robotic Operating System with Mixed Reality	Robots are becoming increasingly important in the construction industry as an augmentation of human capabilities. In many applications, the complexity of a teleoperation task could only be completed alongside the same physical environment to ensure synchronized situational awareness. With the recent advances in mixed reality (MR) and reality capture technologies, a new interface for teleoperating robots with a physical world reference is made possible. This paper introduces an intuitive MR-enabled robot teleoperation interface that can mitigate the gap between the human operator and remote robots by using a HoloLens 2 optical see-through head mounted display (HMD), a Franka Panda 7-DOF robot arm, ranging sensors and Unity game engine. With real-time acquired spatial information, a high-fidelity digital twin of the physical workspace is teleported to the user in MR. Simultaneously, a virtual space around the user is also defined by the HMD with their hand gesture processed as input commands. The two virtualized spaces are then registered together and merger to be organized by the Unity game engine. As a result, the user takes control of the robot's arm through direct manipulation of the virtual/real version of their hand. The system is tested with pipe fitting tasks to validate its performance.

Authors	Article Title	Abstract
Hevar Palani, Ph.D. Student; Aslihan Karatas; Todd Taylor	Cost-Effective Hot Box Apparatus to Measure Thermal Performance of Building Envelopes	A hot bot apparatus is an enclosure system used to test the thermal performance of different items when exposed to controlled laboratory conditions for a period of time. Typically, testing building components are performed using hot box apparatus following the ASTM C1363 standard. However, performing such tests in accordance with the standards by an accredited laboratory can be extremely costly and many laboratories have waiting lists of several months. This is a significant expenditure for small-scale business companies in the construction industry. Therefore, the goal of this study is to construct and test a smaller-scale hot box apparatus to measure the thermal performance of different building components at various climate conditions. The results indicated that the built hot box apparatus is capable to maintain the steady-state temperature during the experiment within ±1℃ meeting the requirement of the ASTM C1363-19 standard and is capable to measure the thermal performance of a building component within an accuracy of ±0.5 ft2·°F·h/BTU. This allows small companies to test several components at relatively low cost and minimum duration.
Xi Hu; Rayan H. Assaad	Automated Heat Stress Monitoring and Water Spraying Robotic System for Improving Work Conditions Using Drone (UAV) Infrared Thermography	Unhealthy working environments, such as high heat stress, can significantly decrease worker productivity, reduce work performance, and lead to unsafe behavior. While embedded/wearable sensors/thermometers can reliably measure the heat stress on construction sites, they can only be implemented locally and are often needed to be deployed for multiple workers, which requires a massive sensor network. To address these issues, this paper proposes a contactless heat stress monitoring and water spraying robotic system that can be deployed repeatedly using drone infrared thermography. Four main components are in the system, including (1) a prototyped quadrotor [i.e., an unmanned aerial vehicle (UAV)] to provide mobility, (2) an infrared camera to take thermal images, along with an environmental sensor to measure air temperature and relative humidity, (3) a spray tank to carry water; and (4) a single board computer to dynamically process the thermal images and environmental sensor readings for controlling the spray tank. Real-case validation results showed that the proposed system could accurately measure the heat stress and automatically spray water to improve thermal working conditions. Ultimately, this paper contributes to the body of knowledge by developing a drone thermography-enabled robotic system for enhancing worker comfort, health, and well-being at construction sites.
Lijun Liu; Yilei Huang; Yuhan Jiang	Developing A Logistic Chain-Enabled BIM System for Material Management in Modular Construction	Although modular construction has become increasingly popular worldwide due to its advantages of offsite production, most construction managers are still inexperienced with such projects compared with onsite construction project management. To facilitate modular construction management, various Internet of Things (IoT)-enabled Building Information Modeling (BIM) platforms have been developed to provide better information visibility and a more collaborative working environment. Nevertheless, such existing platforms have typical shortcomings such as not being able to trace single components and significant work time lost in material missing and locating. This study presents a new logistic chain-enabled BIM system that is designed with a three-layer framework: a material packaging layer, an inventory management layer, and a material locating layer. The logistic chain-enabled framework allows any material modules of a modular construction project to be tracked on route, inventoried in a material management system, and visualized in the BIM model with a barcode scanner prior to installation. This paper provides significant insight on improving modular construction practices by developing a practical logistic chain-enabled BIM system.
Srijeet Halder; Kereshmeh Afsari	Challenges of Human-Robot Partnership in Future Construction Inspection and Monitoring with a Quadruped Assistant Robot	This research explores the challenges of human-quadruped robot partnership in the process of construction inspection and monitoring. Quadruped robots have shown potential in construction inspection and monitoring because of their ability in traversing uneven terrains. Construction inspection and monitoring which is a crucial process in construction can benefit from the use of autonomous robots by collecting frequent as-bult data for facilitating inspection by different stakeholders. However, the adoption of robotic technologies in construction is still in its early stages. To realize the full potential of quadruped robotic technologies in construction inspection and monitoring, it is important to understand fundamental challenges that can restrict its widespread adoption. Therefore, this study uses a qualitative approach to identify the challenges of the adoption of an inspector assistant quadruped robot in construction inspection and monitoring through on-site observations, interviews, and a focus group study. The results of this study identified twenty different challenges grouped into five categories, namely, economical, operational, organizational, social, and other challenges. The findings of the study can facilitate the development and implementation of quadruped robotic technology in construction inspection and monitoring.
Mengjun Wang; Shuai Li	Robotic Assembly of Interlocking Blocks for Construction Based on Large Language Models	Using robots to automate construction processes can enhance productivity and safety and reducing cost. However, the construction robots haven't been widely accepted primarily due to two challenges: lack of data and computational resources to train robots for performing specific construction tasks, and lack of the capability for robots to deal with new tasks. This paper introduces a framework leveraging large language models (LLMs) to enable robots to perform assembly tasks based on in situ worker instructions without extensive prior robot training. By using predefined prompts tailored to specific tasks, the LLM can interpret worker instructions and generate corresponding action sequences and robot functions without additional training. Hence, this LLM-based approach can effectively reduce training costs and facilitate robot adaptability for new tasks and environments through simple prompt modification. To validate this framework, several interlocking block assembly tasks performed by LLM-based robots were evaluated. It is found simple instructions were accurately executed by the robots, but future research is needed to improve the model to handle complex instructions from human. Overall, this study demonstrates the potential of LLM-based robots in performing assembly tasks in construction with human collaboration.
Mohammadhossein Heydari; Hossein Naderi; Alireza Shojaei	BIM and blockchain integration in construction procurement planning	Material procurement comprises a considerable portion of costs in construction projects. In addition to increasing costs, inefficient material procurement can impact a project's schedule and duration. Nevertheless, efficient procurement management use has been limited in the construction industry. A more efficient approach to information management is needed in the construction industry to meet the needs of a growing industry. Digitalization of the construction industry has enhanced the automation of certain processes related to project planning and design. Building Information Modeling (BIM) solutions are often associated with handling high volumes of information. Hence, a data transfer and processing approach must be developed that can be applied to various modeling software applications. Integrating Industry Foundation Classes (IFC) with blockchain provides a basis for facilitating active and secure procurement data exchange and material purchase. This study proposes a framework for effective procurement management by focusing on the automation of processes utilizing IFC and blockchain concepts. The outcomes of this study can be specifically valuable for project managers. This framework provides flexibility in decision-making by being tailored to each project's specific financial conditions and facilitates and automates procurement-related payments.
Reachsak Ly; Alireza Shojaei; Hossein Naderi	DT-DAO: Digital Twin and Blockchain-based DAO Integration Framework for Smart Building Facility Management	Digital Twin (DT) technology provides a comprehensive virtual representation and dynamic mirror of the physical infrastructure which is invaluable for Facility Management (FM) applications. However, its operations and sensitive data are managed by the centralized infrastructure which is relatively vulnerable to being compromised. To address these problems, this paper proposes DT-DAO, a conceptual blockchain-based framework integrating Digital Twin (DT) and Decentralized Autonomous Organization (DAO). Given the immutable nature of blockchain technology, the DT-DAO framework can strengthen the security and resilience of the DT. Moreover, taking advantage of the DAO's decentralized governance mechanism, task automation capabilities, and the real-time sensory data retrieved from the physical assets, DT-DAO can also be used to create an autonomous physical asset (e.g., smart buildings, infrastructure) that can have its operations run automatically and autonomously as predefined in the smart contract. In addition, this paper also provides potential use cases of DT-DAO in smart building FM.

Authors	Article Title	Abstract
Hafiz Oyediran; Kyungki Kim; Pei Chi Huang	Human-Aware Safe Robot Control and Monitoring System for Operations in Congested Indoor Construction Environment	This study presents a framework for human-aware robotic sensing and control for safe human-robot coordination in dynamic construction environments. The framework addresses the critical need for enhanced safety measures in the construction industry, where robots are increasingly being deployed for various tasks. The proposed framework incorporates task-based risk assessments, safety rule definitions, real-time human detection, distance estimation, and adaptive robot control mechanisms. It enables a robot to autonomously adjust its actions based on the estimated distance to the closest human worker, allowing for prompt stopping, speed reduction, or continued full-speed operation as required. The framework enhances safety and fosters trust between human workers and robots in collaborative environments. A prototype application was tested in a simulated residential construction site with a mobile robot with multiple depth cameras to provide 360-degree visibility. The result of the case study demonstrates the potential to safely control autonomous construction robots working around human workers.
Hafiz Oyediran; Kyungki Kim	Information Modeling for Construction Robot Task Planning and Simulation in 4D BIM	The integration of robotics technology with Building Information Modelling (BIM) to plan robot operations is a promising approach for automating construction tasks. While 4D BIM-related technologies are arguably the most advanced method of planning for construction projects, they lack adequate elemental information required by a robot to plan its operations within the spatiotemporal context of the construction site. This poses a challenge to planning robot operations for construction tasks considering their spatial coordination with human workers and site conditions. This study identifies the information required in 4D BIM for planning and simulating construction robot operations. A Robot Operating System based software program was developed to demonstrate the utilization of this information in the planning and simulation of construction robot operations. The program was evaluated in a simulated construction environment, employing a Husky mobile robot to install drywall boards using information from 4D BIM. The simulation demonstrates the importance of information modeling in the integration of 4D BIM with robotics technologies for the planning and execution of construction tasks.
Juan Diego Nunez-Morales; Yoonhwa Jung; Mani Golparvar-Fard	Bi-Directional Image-to-Text Mapping for NLP-Based Schedule Generation and Computer Vision Progress Monitoring	State-of-the-art in construction document analytics and progress detection has experienced accelerated growth over the last decade. However, each area encountered isolated growth, not considering their interactions. Today, progress monitoring practices are often neglected due to requiring manual input of visible progress against schedules. Such a challenge can be attributed to 1) vision-based progress tracking lacking formal construction work templates applied in common construction workflows and 2) research in automated schedule generation and analytics lacking focus on extracting fragnets from a body of existing schedules. This study brings together insights on research trends for automated schedule generation and analytics using Natural Language Processing (NLP) and detection of under-construction objects using Computer Vision. Finally, the AIConstruct system is presented to demonstrate, for the first time, how the integration of text and image can create seamless data synchronization for construction progress monitoring and automated schedule generation, unlocking a new research paradigm.
Fan Yang; Jiansong Zhang, Ph.D.	Application of Graph Convolutional Networks to Classification of Building Code Requirements	A building must meet various requirements during the design and construction process to ensure the benefits of stakeholders and well-being of construction workers and occupants. These requirements may come from different functional areas such as structure, electricity, and fire protection, and focus on different building materials, such as concrete, steel, and glass. They may overlap or even conflict with each other. In order to identify the sources and focus of building code requirements and further clarify the relationships between them, this paper introduces some work on using graphic convolutional networks (GCN) to classify building code requirements. One hundred building code provisions were randomly selected from the International Building Code 2015 and labeled into 6 categories manually, and a cutting-edge GCN model was trained to classify them. Experimental results showed an average precision of 91.67% and an average recall of 94.44% when 10% of the data was used for testing, which is comparable to the 84.30% precision and 97.30% recall of the state-of-the-art machine learning-based approaches applied on construction document classification. The effect of the size of training data on testing accuracy was also discussed in this paper.
Jiannan Cai, Ph.D.; Yuqing Hu; Xiaohong Xu; Shuai Li	Equipment Teleoperation and Its Impacts on Future Worker and Workforce in Construction: Semi-Structured Interviews	Heavy equipment is crucial for construction work and depends on skilled operators to ensure productivity and safety. The inclusion of robotics and its applications, particularly teleoperation, have the potential to revolutionize the construction industry. Via semi-structured interviews, this research explores the current practice of equipment automation technology adoption, potential needs, and benefits on equipment teleoperation, as well as its impacts on workforce diversity. The study highlights the significance of equipment teleoperation on increasing work safety and worker comfort, as well as its importance in improving workforce diversity and reducing labor shortage. With technology limitations being identified as a main barrier to practical adoption, the research also emphasizes the need for user-inspired and worker-centered teleoperation and automation technologies to facilitate implementation in practice. The study contributes to the development of future teleoperation technology by identifying the needs of construction professionals and the potential impacts on both construction work and workers.
Xiaoyun Liang; Jiannan Cai, Ph.D.	Analyzing Human Visual Attention in Human-Robot Collaborative Construction Tasks	Human-Robot Collaboration (HRC) is a promising approach to relieve workers from repetitive and physically demanding tasks and improve safety and productivity in construction. It is critical for robots to understand worker intention in order to adapt their motion to facilitate smooth HRC. Evidence has shown that visual attention reveals human intention. However, it is still unclear how visual attention is distributed in human-robot collaborative construction tasks. In this study, a pilot experiment was conducted to examine human visual attention in a wood assembly task with the assistance of a collaborative robot. A mobile eye tracker was used to collect participants' gaze movements. Data were validated and processed in terms of various metrics to analyze visual attention patterns. It is found that construction workers' visual attention is related to the detailed process of the task – around 30% of the eye gaze is located at the connector areas and the design drawing area, which are primarily relevant to their task. Furthermore, workers' attention could be affected by the movement of the robot, with their gaze following the path of robot arm and gripper during the collaboration. The findings can stimulate further research into attention-aware HRC for intelligent construction.
Simge Girgin; Renate Fruchter; Martin Fischer	A Comparative Case Study to Assess the Costs and Benefits of VR Use during Preconstruction MEP Coordination	Virtual design and construction (VDC) managers must assess the costs and benefits of implementing VR before deciding whether to use it during mechanical, electrical, and plumbing (MEP) coordination to facilitate early issue identification and resolution. We conducted a comparative case study of two facility buildings: one where a VR pilot study was conducted in addition to 3D clash detection, and one where only 3D clash detection was used during MEP coordination. The direct and indirect costs of VR use were determined through observations, interviews, and by comparing MEP coordination workflows with and without VR use. Our analysis of buildability and operability issues identified uniquely in VR revealed that more than 100 field-detected issues, requests for information, and change orders could have been avoided through VR use. The resulting cost savings exceed the cost of implementing VR. As such, our research provides a preliminary method to evaluate VR pilot studies towards deciding on VR adoption during preconstruction MEP coordination.

Authors	Article Title	Abstract
Shanmugaraj S, Ph.D.; Benny Raphael	Computer Vision based Quality monitoring of layer thickness and the buildability aspects of Concrete 3D Printing	Concrete 3D printing (3DCP) is a digital construction technique with the potential to reduce construction time and materials while increasing sustainability. Though 3DCP has many benefits, the technology's output depends on multiple parameters, making quality monitoring and control more essential for large-scale implementation. Buildability is one of the essential properties of 3DCP, which is dependent on the temporal changes in the workability and strength gain of the concrete. The changes can be visualized with the bottom layers undergoing layer thickness reductions due to the weight of the layers printed above them. Individual layer thickness changes affect the overall geometric dimensions and may lead to plastic or elastic buckling failure. This paper proposes a computer vision-based quality assessment method that monitors the temporal variations in layer thickness. Metric such as layer deformation percentage is introduced to continuously monitor and take corrective actions as active real-time feedback to the printing system. The methodology proposed proved to identify the abnormal layer undulations and deformations along the print direction, which ultimately led to the failure of the printed element. Thus, a non-intrusive quality assessment technique for assessing the buildability properties of the concrete 3D Printed elements is developed in this study.
Yuzhen He; Xianzhong Zhao; Weifang Xiao	An intelligent seam detection method for welding robots based on image guided point cloud registration	Welding robots are often employed to improve the welding efficiency and quality of steel structures. In the past few years, weld seam detection technologies based on structured light have undergone huge advances. However, due to the limited measuring range of structured light sensors, high accuracy of workpiece placement is required by most popular approaches in order to avoid invalid sampling. This fails to meet the actual needs of manufacturing. To overcome this burden, a two-step seam detection method is proposed in this study. Firstly, a symbol-assisted 2D digital image contour detection method is employed to obtain the projection of the workpiece in the horizontal plane. Meanwhile, the actual point cloud and the model point cloud of the workpiece are generated based on projected image and CAD model, further calculating the transformation matrix between the two point clouds. Secondly, a linear structured light vision sensor is used to detect weld seams, whose sampling poses are adjusted by the obtained transformation matrix. The robustness and accuracy of the proposed method are demonstrated by simulation experiment results.
Doyun Lee; Kevin Han	UNMANNED GROUND VEHICLE AND ROBOTIC ARM INTEGRATION FOR AUTOMATED WELDING	Construction projects extensively use stainless steel. Welding safety and quality concerns are vital since they are mainly used as structural components. By 2024, the welding industry will be short of 400,000 welders, despite its importance. The labor shortage and the need to provide consistent and efficient welding are strong drivers for the development of an automated welding system. This paper aims to present a method of developing a mobile robotic welding system by integrating an unmanned ground vehicle (UGV) with visual sensors, a robotic arm, and a welding machine. Firstly, the integrated robot navigates to the goal position with collision avoidance. Next, the welding joint is automatically detected with a camera through deep learning algorithms, and the robotic arm is aligned to the detected joint. Then, the robotic arm tracks the planned trajectory for laser scanning. Automatic welding is performed with an adjusted path based on laser-scanned data. The results show that the integrated robot can reach the goal position within the margin of error and demonstrate the consistency and accuracy of welding.
YeSeul Kim, Ph.D; Yong K. Cho	How much distance should a robot keep from other workers at construction job sites?	For autonomous robots deployed in human-populated workplaces, adhering to people’s interpersonal space is a key prerequisite for safe and efficient navigation. Especially in safety-critical work environments such as construction job sites, robots should be capable of not only avoiding collisions but also maintaining a socially acceptable distance from other workers to achieve safety and efficiency. However, what is deemed as appropriate distance can vary based on work contexts. To this end, this study aims to understand the preferred interpersonal safety distance in different construction work contexts such as the size of the workspaces. We developed simulated work environments and conducted proxemics experiments. We found that participants tend to keep a larger minimum distance when interacting with a robot and in a more constrained condition than the normal one. Our findings can be used to develop a more safe, socially acceptable robot path planning in workplaces.
Omobolanle Ogunseiju; Abiola Akanmu; Ebenezer Fanijo; Chuma Nnaji	A Review of Human Robotics Interactions in the Construction Industry	The construction industry is a major contributor to the US economy but is constantly challenged with low productivity, workforce shortage, and health and safety issues. Construction robotics potentially mitigate labor shortages and productivity inefficiencies facing the construction industry. However, construction jobsites are dynamic and ill-structured, and robot integration in such complex workspaces requires a high level of safety for successful collaboration with construction workers. Therefore, understanding existing robotic engagements in construction activities and necessary human-robot interactions for promoting a safe collaborative workspace with construction robots becomes critical. As such, this paper presents a review of state-of-the-art research in human-robot interactions in the construction industry. The paper contributes to the body of knowledge on the different human-robot interactions to facilitate the successful implementation of robotics in the construction industry.
Anto Ovid; Abdullah Alsharef; S M Jamil Uddin; Alex Albert	APPLIED AI AND ROBOTICS FOR CONSTRUCTION OPERATIONS – A SMART REVIEW OF THE STATE OF THE SCIENCE	The rapid advancements in Artificial Intelligence (AI), driven by increased computational power, have revolutionized the engineering industry in recent years. A growing body of literature has emerged, focusing on the application of AI, advanced robotics, and the Internet of Things (IoT) in various sectors. However, the construction industry appears to lag in adopting these intelligent automation technologies for enhancing construction operations. This study aims to examine the current state of AI and robotics adoption within the construction industry for automation purposes. To achieve this, a systematic review of academic peer-reviewed articles on AI and robotic applications in the construction industry was conducted. Keyword-based semi-supervised machine learning was employed to classify the articles according to the phases of construction. Subsequently, an unsupervised machine learning algorithm was utilized to perform content analysis on the articles concerning different construction phases. This analysis enabled a better understanding of relevant AI applications, which could be integrated across construction phases to enhance efficiency. Additionally, this study investigates the various barriers and benefits of adopting AI aimed at improving productivity and safety. Finally, the article discusses the implications of AI, robotics, and automation on job opportunities within the construction sector.
Elnaz Safapour	Workforce Essential Hard and Soft Skills for Construction 4.0	Construction 4.0 (C4.0) technologies have numerous benefits to the architectural, engineering, and construction (AEC) industry.To achieve the full potential of C4.0 technologies,firms and organizationsare required to invest in developing workforce hard and soft skills.The shortage of additionalskilled human resources hinders theeffective implementationof C4.0 technologies as thesetechnologies demand advanced skills compared to traditional practices in the AEC industry. This study aims to explore workforce skills, hard and soft, toadopt C4.0 technologies effectively. For this purpose, a systematic literature review has been conducted. The results demonstrate that critical thinking, problem-solving, teamwork, communication, and self-management are essential soft skills to achieve a successful transition of C4.0 across the industry.The findings of this study will help firms and organizations in the AEC sectorinvest in training programs by collaborating with educational institutions to develop necessary skills in their workforce.

Authors	Article Title	Abstract
Siqi Chen; Shanyue Guan, Ph.D.; Zhen Zhu	UAS-Based LiDAR System For Bulk Pile Volume Measurement	With unmanned aerial systems (UASs) technologies' rapid development in the last couple of decades, UASs have been widely used in different areas including Architecture, Engineering, and Construction industry. Integrating with a high-resolution camera, LiDAR or other sensing system enables the UAS to conduct complex tasks at construction sites such as pile volume quantification. Understanding pile volume is critical to assist construction scheduling. Traditionally pile volume measurement is mostly conducted with manual inspections which is inefficient and expensive. Applying UAS with sensing components onboard provides the possibility of measuring pile volume in a more efficient and affordable approach. In this paper, we introduce a UAS-based pile volume measurement system and conduct experiments measuring the bulk pile volume through a series of field experiments with this system. The volume measurement data collected from the UAS is exported to 3D point cloud processing software for analysis. This software is also used to quantify the bulk volume and record the volume changes over time. The volume measurement results are compared with other records and demonstrate promising accuracy in measuring the pile volume. At last, the performance of the UAS-based pile volume measurement and ongoing investigation to improve the system performance are summarized.
Mohammadsoroush Tafazzoli; Mostafa Namian; Ahmed Al-Bayati	Investigating Barriers to the Application of Automation in the Construction Industry	The escalating challenges in the construction sector, such as comparative lower predictability and productivity, labor shortages, occupational safety, and hazardous working conditions, indicate the necessity and urgency of investing in automizing construction. Identifying the barriers to implementing construction automation and investigating ways to overcome them, can pave the way for a greater use of these technologies in the construction industry which, in turn, could increase its efficiency, safety, and productivity. In this study, a survey was conducted which lead to the identification of 11 major barriers to the widespread application of these technologies. They were 1) job loss, 2) initial investment cost, 3) complexity, 4) limited flexibility, 5) lack of skilled labor, 6) inadequate infrastructure, 7)resistance to change, 8) technical complexity, 9) safety concerns, 10) lack of human interaction, and 11) regulatory barriers. The paper is expected to shed light on how the application of automated techniques in construction projects should modify to better fit the concerns and demands of the industry.
Austin D McClymonds; Somayeh Asadi	Utilizing Parametric Computational Modeling to Generate Masonry Wall System to Facilitate Robotic Task Creation	Building information modeling (BIM) technology in construction has become increasingly prevalent in recent years, and the integration of robotics is seen as a natural step to improve the efficiency of the construction process. To increase the level of development (LOD) of a BIM model to support construction robotics, parametric modeling can be used to create highly detailed models by supplementing and defining geometric and physical properties of construction elements, such as the components' size, shape, and material parameters, which can be used as inputs for designing robotic tasks. Component information are stored as parameters and extractable from the model, allowing a robot to perform highly precise and repeatable tasks. This study develops a framework for implementing computational parametric modeling for masonry wall systems modeled in Revit with Dynamo as the computational modeler. This study tested six wall configurations constructed of 8"x8"x 6" concrete masonry units (CMUs). Dynamo successfully interpreted most wall geometries and placed most full-sized CMUs into the correct design locations. Errors occurred when placing partial-sized CMUs, typically shown at wall intersections, revealing a need for further script refinement. The study shows the careful planning and considerations needed for implementing computational modeling and identifies areas for future work.
Amirpooya Shirazi; Kyungki Kim	Development of Rule-Based Safety Checking System for Autonomous Heavy Construction Equipment	Highway and road construction and maintenance involve operations of heavy construction equipment consistently exposing workers to injuries and fatalities. Frequent collisions between heavy equipment and workers on foot cause many deaths and disabilities. A large portion of these work zone fatalities, such as being struck by equipment and caught in/between equipment, can be effectively prevented by automatically detecting objects around the equipment, determining their poses and movements, and eventually alerting operators and workers about unsafe situations. This study attempts to embed a situational awareness to heavy construction equipment by integrating sensing technologies into heavy construction equipment. This study developed a Robots Operating System (ROS)-based software program to determine the placement of multiple sensors ensuring 360-degree visibility around the equipment and process the sensor data into an accurate 3D representation of the work zone environment to detect predefined unsafe situations. The prototype safety monitoring system evaluated in a simulated road construction environment successfully detected the presences and locations of human workers around the equipment.
xin xu; Kaiwen Chen	Natural Language Navigation for Robotic Systems: Integrating GPT and Dense Captioning Models with Object Detection in Autonomous Inspections	Autonomous Unmanned Aerial Vehicles (UAVs) are rapidly transforming industries requiring inspection and surveillance. However, conventional UAV systems often require complex control schemes and lack adaptability, limiting their efficacy in variable environments such as indoor inspections. This paper introduces an innovative system integrating the cutting-edge Generative Pretrained Transformer (GPT) models and dense captioning models for autonomous navigation and fault detection in indoor environments. Our approach, displaying human-like flexibility, allows the drone to interpret and respond to natural language commands, vastly enhancing its accessibility and user-friendliness. Simultaneously, the drone utilizes object dictionaries derived from dense captioning of its captured images, facilitating an advanced understanding of its surroundings. These capabilities equip the drone to adapt its behavior and effectively handle unexpected scenarios, significantly enhancing the efficiency and accuracy of indoor inspections. This research holds the promise of revolutionizing building inspections, making the process more user-friendly, and localizable to a broader user base.
Hiba Jalloul; Ahmad Alshami; Navid Nickdoost; Jinyeong Moon; Juyeong Choi	Automated Material Separation Activity Identification for Sustainable Demolition Operations	The reusability and recyclability of demolition waste are significantly affected by demolition operations, particularly material separation activities, which are largely driven by productivity considerations. As such, investigating the productivity of demolitions operations is key to understanding the decision-making processes affecting the reusability and recyclability of demolition waste. Traditional approaches for tracking the duration of demolition operations and thereby monitoring their productivity are costly, time consuming, and prone to human errors. To enable more effective and efficient demolition productivity monitoring, this study presents an automated approach for identifying demolition waste material separation activities using the motion data of demolition machinery. As proof of concept, small-scale heavy equipment is used to simulate demolition operations. Inertial measurement unit (IMU) sensors are attached to different moving members of the small-scale heavy equipment to collect angular and linear acceleration data. Collected time-stamped sensor data are preprocessed and subsequently used to train and test an activity recognition model using various supervised machine learning classification algorithms. The output of the developed model facilitates the delivery of actual productivity information, which can be used to optimize demolition planning and decision-making in a way that increases the recycling and reuse of demolition waste.

Authors	Article Title	Abstract
Xin Wang; Dharmaraj Veeramani; Fei Dai; Zhenhua Zhu	Eye Gaze and Hand Gesture-Driven Human-Robot Interaction in Construction	Construction robots are a powerful driving force to enable intelligent processes in construction. User-friendly interfaces to support human-robot work collaboration are critical for increasing adoption of robots. Among different interfaces, eye gaze and hand gesture are effective and reliable interaction cues in the noisy construction environment. This paper proposes a novel context-aware method which integrates eye tracking and gesture recognition for human-robot collaboration in construction. The proposed method employs a two-stream network architecture comprising a first-person view-based stream and a motion sensory data-based stream. The first-person view-based stream models the user's gaze using an attention module to generate an attention map, which helps the stream to focus on the relevant spatiotemporal regions for context extraction. The motion sensory data-based stream is used to process the motion sensory data to extract features related to hand motions. Finally, the extracted vision context and motion features are combined to achieve the gesture recognition for conveying a message between the worker and the robot. This method was tested using a dataset gathered on construction sites. The test results show the proposed method can achieve accuracy and mean class accuracy of 96.8% and 97.7%, illustrating its effectiveness for human-robot collaboration in construction.
Yining Wen; Kaiwen Chen	Autonomous Detection and Assessment of Indoor Building Defects using Multimodal Learning and GPT	Buildings deteriorate over their service life. The early detection of defects such as cracking, spalling, corrosion, and moisture can benefit the preventative maintenance of building systems. Autonomous robotic systems have enormous potential in automating indoor building defect inspections, along with challenges of inaccurate prediction and unorganized information. With the implementation of state-of-art multimodal learning methods and large language model (LLM) techniques, we present a cutting-edge workflow composed of image captioning, landmark documentation, and real-time on-site human-machine interactive path planning. Compared with previous vision and language navigation (VLN) algorithms, our workflow introduces defect prompts to improve indoor inspection captioning performance. These pivotal defect features are extracted by YOLO (You Only Look Once) v5, a PyTorch-based deep learning model. As the robotic system recognize the environment clearly, inspectors are cable of providing target-oriented instructions to control the survey path. By implementing the large language model GPT-3, vocal and textual instructions are transferred to the robotic localization system and summarize a brief inspection report. In this way, with the assistance of GPT, numerous inspections that previously demanded substantial effort can be conducted efficiently and expeditiously.
Sueed Willoughby; Chao Wang	Understanding Fill Factor vs. Fuel Efficiency for Excavator Operation: A Case Study of Bench Loading	The fill factor is a key metric used to evaluate the performance and efficiency of the excavator's autonomous functions and operations. Optimizing the fill factor allows for an objective definition of a 'poor bucket' and provides an opportunity for reducing the emissions from operating heavy equipment. This article aims to study the effect of fill factor (%) on fuel efficiency for a bench loading exercise. Two cases were developed; 'Bucket Normal' where excavation is completed at a pre-selected fill factor, and 'Bucket Return' where initial excavation is returned to achieve 100% fill factor. The task efficiency of different fill factors was reported, and the statistical analysis shows there is no difference in fuel efficiency at 70% fill factor and above. This indicates an optimal fill factor where it is no longer energy efficient for an automated excavator to return the poorly excavated load. The optimal fill factor and relationship with fuel efficiency can be incorporated into existing algorithms for teleoperated and automated excavators to improve the productivity and energy efficiency of soil excavation.
Wei Han; Fei Dai; Zhenhua Zhu	VISION-BASED TURN SIGNAL RECOGNITION FOR AUTOMATED FLAGGING	Flaggers work closely to open traffic lanes which makes them a high-risk profession. They might get hit by distracted, speeding, or intoxicated drivers, leading to severe or even fatal injuries. To address this safety issue, the concept of Automated Flagging System Devices (AFSDs) was proposed. In an AFSD, one of the essential components is to recognize the turn signals of the vehicles in the lanes. However, most existing studies for vehicle turn signal recognition focused on autonomous driving to help autonomous vehicles interpret the intents of the vehicles in front. Little work has been conducted for AFSDs to guide traffic. This paper presents a novel method for recognizing vehicle turn signals using the video camera on an AFSD at the roadside. The method first relies on object detection and tracking models to locate the vehicles and headlights in the video frames. Then, the detected headlights are matched to the vehicles. For each vehicle, the luminance features of its headlights are further extracted. Based on these luminance features over frames, the flashing patterns of the headlights could be recognized to determine vehicle turn signals. The method was tested with real traffic videos, showing that its overall recognition accuracy could reach 80.32%.
Chonnapat Opanasopit; Joseph Louis	Automated Detection of Roadway Obstructions using UAVs and Reference Images	Natural disasters such as wildfires, landslides, and earthquakes result in obstructions on roads due to fallen trees, landslides, and rocks. Such obstructions can cause significant mobility problems for both evacuees and first responders, especially in the immediate aftermath of disasters. Unmanned Aerial Vehicles (UAVs) provide an opportunity to perform rapid and remote reconnaissance of planned routes and thus provide decision-makers with information relating to a route's feasibility. However, detecting obstacles on roads manually is a laborious and error-prone task, especially when attention is diverted to needs that are more urgent during disaster scenarios. This paper thus proposes a computer vision and machine-learning framework to detect obstacles on a road automatically to ensure its possibility in the aftermath of disasters. The framework implements the YOLO algorithm to detect and segment roads on images from UAVs and reference images from publicly available datasets. The images retrieved from UAVs and reference images are segmented and counted pixels of the roadway for comparison of the difference in pixels to identify the obstruction on the road. In addition, the method is proposed to automatically detect obstructions found in the region of interest (ROI) only on a roadway with images and videos from UAVs.
Chris Rausch	Digital Fab-to-Field: Regenerative BIM for 2D Panelized Construction	The pursuit of construction projects with error-free design, streamlined manufacture and assembly, and rework-free construction is often dominated by project management best practices. Yet this paradigm can be increasingly supported by cyber-physical systems that include elements such as generative design, laser scanning, computational algorithms, and digital fabrication, thus closing the gap between design and reality. This paper presents a regenerative BIM system that adapts 3D geometry in real-time to match field conditions, thus achieving the ability to digitally fabricate to field conditions (i.e., "digital fab-to-field"). Such a system is particularly useful in 2D exterior panelized construction (e.g., curtainwalls and composite metal cladding), which frequently undergo design iterations and onsite rework due to geometric inconsistencies between site interfaces and manufactured components. The proposed framework is demonstrated using a digital mock-up of an exterior cladding assembly, which is shown to adapt to changing site conditions as described by a 3D point cloud.
Bing Han, Ph.D.; Caroline M. Clevenger	Pilot Testing a Model-independent Indoor Augmented Reality Wayfinding Assistant for Grocery Stores Applications	Augmented Reality (AR)-enabled wayfinding applications have been widely implemented in complex building environments. These applications require a precise building information model of the service area and, therefore, are not applicable to the majority of existing buildings in the US, such as grocery stores. This paper presents an AR-enabled indoor wayfinding assistant app that visualizes the locations of typical destinations in building environments. Instead of building models, the app utilized data on relative spatial relationships that nonprofessionals can collect with minimal training and easily accessible tools. Therefore, spatial maps of different building environments can be developed with a crowdsourcing approach, and standardized data will be maintained in a cloud database. The feasibility of the data collection method and AR app was validated by a case study conducted in a grocery store. This paper contributes to the body of knowledge by replacing models with relative spatial relationships in indoor AR wayfinding apps. The app enables economical indoor wayfinding solutions for existing buildings that do not have accessible and up-to-date models.

Authors	Article Title	Abstract
Deirdre Edward; Minerva Bonilla, M.S.; Junseok Kim	Machine Learning Predictive Model: Prioritizing Expenditures in Public Transportation Based on Transportation Emissions	The United States (U.S.) is the largest Greenhouse Gas (GHG emitter globally, with its transportation sector being a major carbon dioxide contributor. This is a matter of significant concern, given the impact of these emissions on climate change. Prioritizing emission-reducing transportation projects is crucial to address this problem. Currently, such policies are generally discussed at the national level. However, since individual states have varying infrastructure and priorities, this paper proposes studying carbon dioxide emissions at the state level of granularity. To achieve this, ensemble methods such as Random Forest, Extremely Randomized Trees, AdaBoost, and Gradient Boosted Decision Trees, along with a meta-estimator, are used to predict statewide carbon dioxide emissions using variables related to statewide transportation systems. Based on this analysis, we suggest that states should discourage car dependency in a way that is feasible for local characteristics, as well as promote public transit to reduce carbon dioxide emissions.
Ping Xu; Xinghua Gao, Ph.D.	Agent-based Discrete-event Simulation Platform Using BIM for Robotic Studies	As robots advance, their application in facility management tasks such as cleaning, maintenance, security, surveillance, warehouse management, and customer service is expanding. As buildings become smarter, robots will likely either replace or assist humans in maintaining them, leading to more complex interactions between robots and buildings. To accurately simulate and predict these interactions, we propose a conceptual framework for a simulation platform. This framework comprises four main components: occupants, robots, building systems, and a digital twin. The digital twin receives data and requirements from the other three entities, issuing commands to meet these needs. This research underscores the importance of viewing robots as occupants and promoting the coordinated development of smart buildings and robots. Future studies could focus on designing various types of robots to meet occupants' and building systems' needs, as well as creating smart buildings that account for robots' convenience and efficiency.
Rita Awwad; Mohamed Eid, Ph.D; Amr Mekki	AN AGENT BASED MODELING APPROACH FOR EVALUATING DYNAMIC RISK BEHAVIOR IN COMPETITIVE BIDDING	The risk attitude of contractors impacts their bid values in competitive bidding. However, the existing literature assumes a static risk behavior for the contractors, and that competitive bidding does not alter the risk attitude of contractors. To this effect, this paper aims to represent the influence of external (market competition; project information, etc.) and internal (financial performance; need for work, etc.) factors on the adaptive risk attitude of the contractors, their submitted bid values, and their survival in the market. The paper's objective is to develop an agent-based model (ABM) that represents the competitive bidding environment and that relies on data gathered through the literature on the importance and impact of multiple factors that drive the risk behavior of contractors within the bidding context. The presented ABM is an important tool to help contractors understand and evaluate the importance of adapting their risk behavior to their internal and external bidding conditions in order to ensure their survival in the market.
Sena Assaf; Fatima Alsakka; Mohamed Al-Hussein	Simulation-based Analysis of a Precast Factory Layout to Reduce Labor Travel Time and Production Time	Inefficient facility layout in construction manufacturing leads to process waste, thereby increasing production time. In particular, it results in unnecessary movement of workers to transport materials/tools during production. The research presented in this paper examines the impact of a precast concrete factory's layout on three parameters in the production of precast concrete panels: labor travel time, activity cycle time, and production time. Recommendations are proposed to reduce process waste regarding each of these parameters, i.e., relocating the material preparation mills and introducing a cart-based material/tool handling system. The benefits are quantified using a discrete-event simulation model of the process. It shows a 10% reduction in the production time of a single panel and a 39% reduction in the labor hours incurred in transportation activities when compared to the current state. It also shows that 6.9% of the labor hours in the current state is allocated to unnecessary non-value-added transportation activities.
Noelia Molinero-Perez; Tatiana García Segura; Laura Montalban-Domingo; Amalia Sanz-Benlloch; Jordi Mansanet; Eugenio Pellicer, Ph.D.	ARTIFICIAL INTELLIGENT TECHNIQUES TO IMPROVE PAVEMENT MAINTENANCE MANAGEMENT	Pavement maintenance management requires artificial intelligent techniques to evaluate pavement condition automatically, predict pavement deterioration, and optimize maintenance actions under restrictive budgets. This paper presents three techniques that address the three objectives raised. First, Convolutional Neural Networks (CNN) are used to analyze images obtained by a camera installed on a vehicle. Several CNNs are trained to detect, classify, and quantify the 3D distresses. Second, pavement deterioration is predicted by Feed-forward Neural Networks (FNN). Pavement Condition Index (PCI) throughout a planning horizon is estimated from the information obtained by the inspection and the traffic and climate conditions. Third, heuristic optimization algorithms are used to determine the optimal maintenance plan. This plan indicates which sections should be repaired each year of the planning horizon and the treatment that must be used to optimize the maintenance cost, the CO2 emissions, the user cost, the network condition, and the accidents. These techniques are presented and discussed in this paper.
Hengxu You; Yang Ye; Fang Xu; Jing Du, PhD	Adaptive Scanning for Improved Stacked Object Detection with RGB and LiDAR	The increasing requirements of using robots in construction sites has brought great challenges related to understanding the complex environment and completing the downstream tasks with timeliness. Focusing on stacked object detection, which is a general complicated scenario in construction site, this paper proposes a novel framework by using both RGB and LiDAR for object clustering with low storage occupation and high detection speed that support real time implementation. A RGB camera is firstly used to capture an image of overall scene and a pretrained CNN network is applied to give the rough prediction of region-of-interests (ROIs) along with their confidence scores. The ROIs are linearly sorted based on their scores to select the potential stacked areas with low confidence. The center locations of ROIs are then transferred into LiDAR system with the calibration matrix and a Velodyne-16 scanner is used to perform adaptive scanning on the ROIs for detailed object clustering and detection. The result shows that given the pre-detected ROIs from RGB, the scanning time and computational time of clustering could be largely reduced. Furthermore, a confidence-based criterion is illustrated to linearly determine the required scanning frames to get desired detection results.
Jaehyun Park, Ph.D.	Framework for Managing Multiple Common Data Environments	Building Information Modeling (BIM) technology streamlines the establishment of systematic methodologies for managing built asset information effectively throughout each asset's entire life cycle. The recently introduced ISO 19650 series provides standardized processes and guidelines to facilitate the efficient management of such information. In this context, the ISO standards advocate for using a common data environment (CDE), which serves as a centralized repository for collecting and managing all graphical and non-graphical construction project data for the entire project team. Ideally, a single CDE should be utilized and maintained throughout the life cycle of each project. However, due to practical and technical challenges, multiple CDEs are frequently employed and managed concurrently in actual projects, leading to significant issues such as data inconsistencies, duplications, and missing information. This paper presents a framework for managing multiple CDEs, which enables the preservation of data integrity. The proposed framework is anticipated to foster the progression of BIM maturity levels in real-world projects.
Reihaneh Samsami, Ph.D., P.E.; Amlan Mukherjee; Colin N Brooks	AS-BUILT BUILDING INFORMATION MODEL (BIM) DEVELOPMENT FOR HIGHWAY CONSTRUCTION PROJECTS USING UNCREWED AERIAL SYSTEM (UAS) DATA	In the last few years, Building Information Model (BIM) has become a construction industry standard for exchanging as-built information for construction assets. BIM can be integrated with data collection technologies, such as Uncrewed Aerial System (UAS), to reduce manual errors and improve the efficiency in information retrieval processes. Traditionally, BIM feature extraction from UAS collected images is done manually. This process is time-consuming, costly, and tedious. There has been a growing interest in automating this process, utilizing tools such as Computer Vision and Machine Learning. The objective of this paper is to develop an as-built BIM from UAS data, using these tools. This paper describes a foundational methodology to collect, process, and analyze the UAS data, stored as raster Geo-TIFF format files, where digital elevation models (DEMs) are used to create an as-built3D model of the project. The three steps of the described methodology are: (a) Data Collection and Processing, (b) Data Analysis, and (c) As-Built Development in Civil 3D, illustrated through a MDOT highway construction project. The outcome of this research can be leveraged by project managers as a record of work completed, beyond the construction phase of the project.

Authors	Article Title	Abstract
Chi Tian; Yunfeng Chen; Yiheng Feng; Jiansong Zhang	Fine-Tuning Vision Transformer (ViT) to Classify Highway Construction Workers' Activities	Accurate construction workers' activity detection distinguishes workers' activity efficiency and identifies activities with high risks, which enhances construction productivity and safety management. Automated construction workers' activity has become feasible in the construction industry since the emerging of computer vision techniques. However, few studies explored workers' activity detection in transportation-related work zones (e.g., mobile work zone operations) which have their unique characteristics and different requirements than building construction job sites. Previous studies in the construction domain usually used convolutional neural networks (CNN) for computer vision-related tasks. The transformer-based model achieved higher performance in computer vision tasks after it was first applied in 2020. However, few studies have applied the transformer model for worker activity identification. Therefore, this study aims to detect construction workers' activities in mobile work zones using a pre-trained Vision Transformer (ViT) model. This study starts with the video data collection of construction workers. Then, a dataset containing different activities is developed by manual labeling. Next, the ViT model is fine-tuned using the dataset developed in this study. The results show the model has 94.17% overall accuracy and achieves 100%, 100%, and 84% precision in detecting "placing mix", "shoveling" and "walking" respectively, and outperforms a CNN-based classification model.
Ahmed Gouda Mohamed; Mohamed Marzouk	A Semantic Hybrid Scheme for Efficient Building Facilities Management	Maintaining and operating building facilities constitutes a substantial portion of the overall lifecycle costs, which, if not befittingly handled, can yield immoderate expenditures and a shortfall of financial resources. The evidence implies that building facilities are degrading due to inadequate knowledge of building facilities and fallacious management procedures. This paper proposed a Building Information Modeling (BIM) framework to enhance the effectiveness of BIM open standards for facility management operations. The study expands to creating a comprehensively integrated framework that provides a paradigm apropos to employing BIM capacities that manage and retrieve Operation and Maintenance (O&M) data to engender a semantic repository of multiple existing building facilities and their peculiarities information. The proposed framework incorporates six chronological stages to ensure prime findings for the O&M phase and unerringly exhibit the distinctive attributes of the maintenance data paradigm. Facilities managers can employ the presented framework as a blueprint for implementing the proposed strategy for incorporation, exploitation, and handling of building facilities-based knowledge throughout the O&M phase into practice.
Morteza Ghasemi; Mohammad Sadra Rajabi	Automation of Multi-Tower Crane Location Optimization in Pre-Fabricated Construction Sites: An Application Programming Interface Approach	Cranes play a significant role in construction cost and time management. Tower cranes are highly used in dense urban residential construction sites due to congestion and lack of enough space for the crane's foundation. However, optimizing the location of tower cranes in construction sites with multiple cranes and multiple trailers in an integrated application core is still a gap in the literature. This study aims to fill this gap by developing an application programming interface (API) for Navisworks, a common software in building information modeling (BIM), to facilitate practical use. The focus of this paper is on prefabricated structural elements that are planned to be lifted by tower cranes. The research utilizes VB.net language to develop the API and connects an access database containing tower cranes' information for the optimization process. A case study is presented to validate the outcomes of the API. The results show the best locations for tower cranes and the least possible cost and time based on the database factors and each crane's pick-point location. This application has the potential to significantly save construction budget and time.
Yasser Jezzini; Rayan H. Assaad; Islam El-adaway; Mohamad Abdul Nabi	An Accurate-Pricing-Estimate Game-Theoretic Model for Determining Price Escalations in Construction Projects during Economic Uncertainties	Economic market uncertainties, such as those experienced during the COVID-19 pandemic, can make determining accurate prices estimate for construction materials a challenging task. While previous research focused on the contractual aspect of this issue by studying price escalation clauses, there is still a gap in the literature when it comes to proposing an accurate pricing model. Thus, this study develops an accurate - pricing-estimate game-theoretical model that can efficiently and competitively account for escalations in construction materials prices during uncertain market conditions. First, data on past Producer Price Indexes (PPIs) of different construction materials were collected. Second, the percentage changes in the prices of 4 common construction materials including asphalt, aggregates, non-reinforced concrete, and steel reinforcement were calculated. Third, an algorithmic game theory model that leverages learning from historical bid data was proposed. The findings provided insights on how to account for construction materials price escalation under uncertain market conditions. Overall, this study contributes to the growing body of research related to construction materials price escalation under uncertain market conditions by proposing a practical approach that combines predictive modeling with game theory models.
Yasser Jezzini; Rayan H. Assaad	Mitigating the Social Challenges of Green Infrastructure: A Social Vulnerability Index	Investments in green infrastructure (GI) can greatly improve the well-being and resilience of urban areas. However, the implementation of GI also has different challenges, including social considerations. Therefore, GI solutions need to recognize those social challenges and plan spaces where uses are complementary rather than conflicting. Existing research has suggested potential strategies to address the social challenges of GIs, however, little-to-no studies have focused on modeling the vulnerability to GIs' social challenges. This study aims to fill this research gap by proposing a GI social vulnerability index (SVI). A list of 35 indicators was identified. Then, the weight for each indicator was assigned using Principal Component Analysis. Finally, the weights of the 35 indicators were used to develop the SVI. The findings offered insights into the most vulnerable/susceptible Census tracts in NYC. The results also provided insights into the relative importance of different indicators that should be considered when implementing GI initiatives. This study adds to the body of knowledge by helping city planners and policymakers target areas for interventions and mitigate the social challenges of GI. The research also provides a better understanding of how GI implementation can impact urban areas and the residents.
Kofi A.B. Asare; Rui Liu; Chimay J. Anumba	Facilities Management Professionals' Perceptions of Digital Twins as Intelligent Realities	Recently, intelligent realities (IRs) - integrated systems that combine advanced analytics technologies such as digital twins (DTs) and artificial or virtual reality technologies, have emerged as a value-adding enhancement of DTs for facilities management (FM). However, DT-based IRs for maintenance are yet to be studied to determine their fitness for purpose from a practice perspective. The lack of practitioners' perspectives on the development of DT-based IR poses a potential disconnection between desired end user preferences for interaction with a DT for maximum application benefits and the theoretical development of this emerging knowledge field. This paper presents FM professionals' ex-ante evaluation of a conceptual prototype for a DT-based IR system. Using an electronic survey among selected FM professionals from educational and transportation facilities, it was found that the proposed solution can improve the visibility of managed assets, enhance predictive maintenance (PdM) practice, and provide cognition and judgment aid for FM professionals when they are mobile. The study provides relevant insights for developers of DT solutions and researchers on the preferred end user interaction modalities.
Kareem Mostafa; Hani Ahmed; Tarek Hegazy	Prioritizing and Work Packaging of Multi-Facility Rehabilitations using Text Mining	Facility management systems aim to maintain an acceptable level of service for the facilities through timely inspections and proper rehabilitation decisions. While inspection reports and maintenance requests embody the key data for all decisions, the manual and subjective nature of this data introduces errors and inconsistencies that complicate rehabilitation decisions. This paper enhances the utilization of inspection and maintenance data for rehabilitation purposes using data mining. Text mining is used to prioritize the components in most need of rehabilitation and trace fault patterns across multiple facility components to facilitate work packaging and crew assignment. An example of a 600-villa housing compound with over 2000 maintenance requests was used to demonstrate the developed system. Analyses results based on component or type of work are then provided, as well as means to schedule required repair work. The paper aims to streamline the rehabilitation work packaging and delivery processes for large facility owners.

Authors	Article Title	Abstract
Da Hu; Mengjun Wang; Ruichen Guo; Shuai Li	Bridge Deck Condition Assessment Using GPR: System Configuration and Defects Characterization	This study evaluates Ground Penetrating Radar (GPR), a non-destructive method, for inspecting and assessing concrete bridge deck conditions. Despite GPR's potential to detect diverse bridge deck defects, a comprehensive review of its optimal configuration and scanning parameters for effective deployment is lacking. Moreover, the extent of GPR's ability to detect various bridge deck defects remains unclear. This study focuses on identifying suitable GPR parameters and analyzing GPR signal characteristics associated with different bridge deck defects. The study first establishes suitable system configuration and scanning parameters, enabling efficient GPR data collection. Subsequently, GPR scans reflecting different defects (e.g., cracks and delaminations) are analyzed to assess GPR's capabilities. Computer simulations and laboratory experiments reveal signal patterns associated with rebar corrosion and concrete deterioration, as well as limitations in detecting certain types of delaminations.
Fam Saeed; Kareem Mostafa; Mostafa Soliman; Tarek Hegazy	Agent-based Simulation of Multi-Crew Allocation to Scattered Repetitive Projects	Scattered Repetitive Projects (SRPs) such as multi-school or multi-bridge rehabilitations are rising in numbers, complexity, and costs. To properly allocate resources for these complex projects, efficient planning and simulation become necessary. At the detailed level, Agent-Based Modeling and Simulation (ABMS) is among the powerful techniques that can be used to analyze the impact of crew movements and behaviors on task productivity. To support efficient allocation of crews to SRPs, this research developed an ABMS model using the AnyLogic software to simulate multi-crew allocation to scattered units, incorporating crews' travel times among the units using GIS. The paper discusses the model and its implementation on a case study of scattered linear projects where the activities in each location are sequential. Model validation against a powerful schedule optimization model proved its flexibility and applicability. Future integration with a powerful repetitive scheduling engine is highlighted to consider more complex networks at different locations.
Ruqayah Alsayed Ebrahim; Yitong Li; Wenying Ji	Evaluating Road Utilization During Hurricane Evacuation: A Case Study of Hurricane Ian	When disasters such as hurricanes approach, residents rely on transportation infrastructure to evacuate. Evaluating road utilization is essential for emergency evacuation as it facilitates timely traffic congestion identification and alternative route selection. The objective of this research is to evaluate road utilization during Hurricane Ian (2022) in Lee County. In detail, traffic data, population distribution data, and sociodemographic data were collected, and the road utilization of government-declared evacuation routes was evaluated using road volume to capacity ratio and road density. The findings highlight the unbalanced use of roadways during hurricane evacuation. Specifically, interstate highways were highly congested during the evacuation period while other highways and county roads remained underutilized. The findings can be used by emergency planners and management teams to design efficient evacuation plans and improve existing road designs to adapt to higher evacuation needs.
Diego Peñaranda; Jose Guevara; Sergio Cabrales	Fourier series for seasonal traffic forecasting: an application to a real toll road concession in Colombia	Toll road concessions are instruments used by governments to transfer risks and finance infrastructure projects needed to sustain economic development. However, these projects are plagued by heavy uncertainties, in part because their free cash flows are affected by unreliable traffic demand forecasts. Accordingly, this study analyses the literature on the field of project evaluation in concessions to extract common practices when forecasting traffic demand. From this information, this research assesses the most common traffic forecasting methods and proposes a new approach that might address flaws in the estimation methods existing in the literature. Thus, the study compares Geometric Brownian Motion (GBM), Mean Reversion (MR), and Fourier series models (FSM). The comparison evaluates the best-fit patterns in traffic demand forecasts given the long-horizon feature of toll road concessions and uncertainty. The models use the historical traffic demand of a real concession initiative within Colombia's Fourth Generation Roads Concession Program (4G). The results indicate that the Fourier series outperform GBM and MR when forecasting seasonal traffic. Because this finding was obtained from a real toll road with marked seasonality, the study opens a path for further research in traffic forecasting for seasonal behavior.
OSAMA AL-MAABREH, M.Sc.; YONG-CHEOL LEE	Digitizing Disaster Resilience Requirements for BIM-based Resilience Validation	Diverse components and properties of the disaster resiliency-related features need to be explicitly defined and satisfied within a BIM model. Revealing building resilience rules and BIM validation processes, however, remain elusive. To ameliorate this challenge, this paper aims to unravel logical resilience features embedded in the building codes and building standards and define a formalized logic for representing the categorized rules. In addition, this study defines an XML schema for flood-based building regulations to broadly distribute the formalized resilience requirements. The methodology adopts a functional structure of flood disaster-resilience regulations for single-family houses into the validation process of BIM data that removes restrictions on predefined queries, transforming related flood features in BIM data into an open and quarriable database. This study also involves the development of an automated BIM-based validation system that is designed based on the identified rule logic. The expected outcomes and validation system provide automated resilience assessment and reporting of related building design data checking.
Moeid Shariatfar; Yong-Cheol Lee	Development of Urban-Level Infrastructure Information Delivery Manuals Using Knowledge Modularization for Enhanced Smart City Data Exchanges	Smart cities provide intelligent services to enhance infrastructure systems' performance and community well-being. The heterogeneity of the 3D model data formats in their infrastructure systems, however, frequently hinders seamless data exchange, sharing, and integration. Model View Definitions (MVD) and Information Delivery Manuals (IDM) have been broadly used to develop interoperable data schemas that can address this heterogeneity. For developing IDM/MVD of a smart city, generalized standards and streamlined approaches that can avoid inconsistencies and redundancies of complicated infrastructure systems and features remain elusive. Particularly, existing domain-specific standards primarily focus on data exchanges within individual infrastructures, overlooking underlying interactions and interrelated functional operations between multiple systems. Thus, a unified system that contains necessary relationships of each infrastructure system covering sub-domain standards is required to represent the interactions and exchanges between urban-level infrastructures of a smart city. In this regard, this study provides a framework that integrates various infrastructure domains based on modularized knowledge of infrastructure systems and their smart functionalities. The expected outcome also includes a unified ontological data structure for functional elements and properties. The framework connects functions, elements, and properties for each specific use case that enables the development of an interoperable environment at an urban level.
Yuhan Jiang, Ph.D.	Using Weakly-Supervised Semantic Segmentation for Post-Disaster Scene Understanding	Creating semantic segmentation datasets is more time-consuming than the preparation of image-level classification labels. This paper presents a cost-efficient pixel labeling method and experimental results of using Grad-CAM generated heatmap for weakly-supervised post-disaster site semantic segmentation. It starts with training CNN binary-classification models, then removing non-target objects, reducing searching regions according to the distributions of heatmap values, and assigning the pixel-level label to the highest heatmap value regions as segmentations. The proposed CNN model architecture has a 1×1 convolutional heatmap layer with a suitable number of channels to fit the target objects. Testing results showed the 16-channel heatmap layer reached the best building-background classification performance (F1-score 0.89) and the 128-channel had the best building-damage classification performance (F1-score 0.78) among the evaluated options of 4, 8, 16, 32, 64, and 128 channels. Furthermore, the proposed pixel labeling method can understand complicated post-disaster scenes by correctly locating target objects (buildings and damages) in aerial images via repetitions of searching the target objects in regions of higher heatmap values.

Authors	Article Title	Abstract
Mehdi Torbat Esfahani; Ibukun Awolusi, Ph.D.; Chukwuma Nnaji	Using Virtual Reality to Enhance Construction Workers' Response to Alerts from Wearable Sensing Devices: A Review	Recent studies have shown that using sensing technologies like wearable sensing devices (WSDs) can potentially mitigate the high rate of worker injuries in the construction environment. When warning alerts that assist workers in recognizing the hazards are provided by WSDs, workers respond based on their consciousness, pre-training, and experiences. However, some workers may not respond and/or react to the alerts because of a lack of knowledge about how to respond and/or react. Virtual reality (VR) can be utilized in educating and training workers to understand hazardous activities and their related sensor alerts to potentially enhance their safety behavior. This study uses a literature review to highlight WSD and VR features to identify their possible and practical integration for the aforementioned worker safety improvement application. The study presents a conceptual framework that can be validated and implemented to potentially enhance workers' understanding of response and reaction to warning alerts from WSDs or sensing technologies for injury, illness, or accident prevention.
Mohamed Taha Ramadan, MSc.; Ossama Hossny; Khaled Nassar	Support Vector Autoregression and Neural Network for prediction of Construction stock prices in Egypt	Accurately predicting stock prices in the construction industry is crucial as it can help reduce losses for construction companies and mitigate the impact of economic downturns on the industry. However, uncertainties often lead to inaccurate predictions in the Egyptian construction industry. To address this issue, researchers used mathematical models and machine learning models to predict stock prices and assist decision-makers in responding to sudden changes. The main challenge is identifying the factors that drive stock prices. This paper proposes two models: artificial neural networks and support vector auto regression to provide predictions for construction companies' stock prices, which can be useful tools for contractors and construction material companies to predict and understand fluctuations in major construction stock prices and take appropriate measures to avoid negative impacts on their stability. The aim of this study is to provide a comprehensive evaluation of different methodologies in predicting stock prices in the Egyptian construction industry.
Ziming Liu; Tolulope Sanni; Jun Liu; Yangming Shi	A MULTIMODALITY VR TRAINING SYSTEM FOR FUTURE ELECTRICAL VEHICLE EMERGENCY RESPONSES	The human society's mobility tool is shifting the paradigm from combustion engine vehicles to electric vehicles (EV). The wide adoption of EVs will benefit the sustainability of society by improving fuel efficiency, lowering fuel and maintenance costs, and reducing carbon emissions. However, the rise of EVs also brings challenges, particularly in EV emergency responses, in which EV fires burn hotter and longer than traditional vehicle fires, and most first responders are not well prepared. This paper introduces a multimodality virtual reality (VR) training system designed to help firefighters understand EV fires. The proposed VR system allows the user to visualize different phases of the thermal runaway process during EV fires. The proposed system has four modules to enhance the fidelity and improve the presence for the user to understand the EV emergency response scenarios. The results from the preliminary evaluation case confirmed the usability and feasibility of the proposed system.
Taewoo Ko; Rabin Shrestha; Jeehee Lee	Pro-active Allocation of Project Requirements through Natural Language Processing (NLP) and Project Information System Integration	Effective project requirement management is one of the significant tasks for the success of project planning and execution in complicated and dynamic construction environments. For improved requirement management, it is recommended to identify and allocate project requirements at an early stage prior to construction for appropriate project progress monitoring and control with little effort and cost. Current requirement allocation practices rely heavily on time-consuming and error-prone manual processes due to a sheer volume of free-formatted project documents and the necessity of practitioners' judgment based on their experience and expertise. This paper aims to propose a systematic approach to assigning and clarifying project requirements to appropriate project parties. The proposed approach employs natural language processing (NLP) technique to automatically assign project requirements to responsible project parties. The allocated requirements are then incorporated into project geographical information system to present associated project requirements along with geo-spatial information. By integrating the information system with classified project requirements through NLP techniques, pro-active requirement allocation will further facilitate both managing of a variety of requirements and the real-time dissemination of them to all project parties.
Anisha Deria; Pedram Ghannad; Yong-Cheol Lee	Deep Reinforcement Learning-based Optimization for Crew Allocation in Modular Building Prefabrication	Off-site construction has been steadily gaining popularity due to significant potentials and benefits in repeatability and standardization of processes. Since most of the construction activities are manually executed by labor force, it decreases productivity and manufacturing capacity. To this end, this study proposes a Deep Reinforcement Learning-based decision-making tool for optimizing labor allocation to each ongoing activity with the aim to improve production pipelines by reducing delays and cost overruns. The study includes a framework that models the interdependencies between workstations and dependence on productivity of available labor and material resources to determine the optimal number of workers at various workstations, thereby reducing the make-span. The model utilizes the Q-learning algorithm along with real-time data on labor and material availability, current progress status, and deadlines of modules in the queue for predicting best possible action regarding distribution of workers to different workstations in facilitites. The developed framework is elucidated through a case study to demonstrate the capabilities of the proposed model in automated handling and management of resources. The proposed framework contributes to the body of knowledge by: 1) considering all renewable and non-renewable resources involved, 2) accounting for uncertainties, and 3) providing critical information required for decision-making in real-time.
Ashrant Aryal; Hussein Al Jebaei	Black-Box model for predicting HVAC energy consumption and PCM State with different Melting Temperatures of PCM for small office buildings	Heating, Ventilation, and Air-Conditioning (HVAC) operations consume around 40% of buildings' energy consumption (EC). To reduce this consumption, Phase change material (PCM) can be incorporated in buildings' envelopes. However, the effectiveness of PCM varies depending on its thermophysical properties and climate conditions. Conventionally, finding the optimal PCM properties requires a computationally extensive parametric study of white-box model, which may not always provide accurate results due to input simplification. To overcome this shortcoming, machine learning (ML) algorithms can be developed to identify optimal PCM properties based on predicting HVAC loads and PCM state. The best performing models for predicting cooling and heating energy consumptions were achieved by Artificial Neural Network (ANN) with MAE around 8% and Random Forest (RF) with MAE around 45%, respectively. As for classification, RF with Polynomial kernel PCA showed an accuracy of 81.5%. These results demonstrate the potential of ML algorithms to optimize building energy efficiency.
Sogand Hasanzadeh, Ph.D.	A Novel Digital Twin Architecture for 3D Concrete Printing in the AEC Industry	Additive Manufacturing (AM) is rapidly transforming various industries. In the construction sector, 3D Concrete Printing (3DCP) is gaining traction as a solution to address problems like labor and housing shortages. While other industries successfully embrace digitalization, such as Digital Twins (DTs), to improve AM processes, its implementation in the construction industry is in its infancy. This paper aims to pave the way for future DT implementation in 3DCP by proposing a DT architecture, including necessary components, and layers (physical, digital, sensing, computing/perception, communication, devices, and control/actuation) throughout project phases (design, preconstruction, construction, postconstruction). The findings revealed that the current literature focused solely on the preconstruction phase and the use of "Building Information Modeling" (BIM) for 3DCP. This paper provides insights into the DT architecture system for understanding the main components and tools essential for starting future implementations of DT for 3DCP and reducing the digitalization gap between construction and other industries.

Authors	Article Title	Abstract
Yueyan Gu; Farrokh Jazizadeh	Digital Twin-Assisted Anomaly Detection for Smarter Built Environment Management: A Literature Review	Improving the reliability and efficiency of anomaly detection is important for establishing and maintaining a resilient built environment. Meanwhile, Digital Twins (DT) have attracted increasing attention in the built environment management. In this study, through a structured literature review, we compiled and categorized existing DT-assisted anomaly detection methods applied in built environment based on three anomaly detection criteria (scope, target, approach) and three key attributes of DT (integration level, fidelity level, and decision speed). In doing so, we presented the current research trends and analyzed how DTs contribute to the built environment management with different anomaly detection approaches. This study lays the foundation for establishing DT-assisted anomaly detection frameworks utilizing Digital Twins of different integration and fidelity levels to tackle anomaly detection problems with different approaches. Moreover, it shows the efficacy of Digital Shadows (one directional DTs) in built environment anomaly detection and calls for future research endeavors in high-integration-level DT applications and DT-assisted hybrid anomaly detection methods.
Saurav Shrestha; Yongwei Shan; Paul M. Goodrum	Identify Best Practices of Project Bundling for Highway Construction Projects	As an innovative contracting strategy, project bundling has been used by state Departments of Transportation (DOTs) and other Local Public Agencies (LPA) to combine multiple projects that are of similar type, size, and in a similar geographical location into a single contract. Previous studies on project bundling have claimed its expected savings in cost and project delivery time. However, little research has been conducted to guide DOTs on the effective utilization of bundling in a holistic approach. This study aims to extract the best practices of project bundling that allow DOTs to implement project bundling more efficiently. The paper addresses this issue using a qualitative approach that involves semi-structured interviews and follow-up correspondence with 16 different DOT representatives and a public agency. The analysis of transcribed interviews, using NVivo, reflected the main themes for the study, including the variation of bundling methods among DOTs (optional-tie or mandatory-tie), different bundling approaches (scope-based or location-based), assessment of projects' suitability for bundling, unbundling strategies, etc. The paper concludes with a set of best practices and a comprehensive strategy that serves as a valuable guide for DOTs in effectively implementing project bundling for various construction projects.
Islam El-adaway; Ramy Khalef	Analyzing the Impact of DB Versus DBB on Cost Performance in Airport Development: A Data-Driven Approach	The construction of airport projects can be complex and costly due to the many stakeholders involved and associated strict timelines. Traditional delivery methods, such as Design-bid-build (DBB), employed in airport projects often result in major cost overruns due to multiple facets. Design-Build (DB) is a construction method that combines design and construction under a single entity, and it has the potential to improve cost performance. None have evaluated DB from a cost perspective in the airport sector. This research fills this gap. First, the data is collected and assessed for validity. Second, risk ratings for cost performance are computed. Finally, the data is analyzed through statistical methods. Results reveal that low level of team collaboration is the most impacting factor to cost performance in DBB airport projects as compared to DBB. Ultimately, the findings will be valuable for airport stakeholders as they seek to improve cost performance through DB implementation.
Bahaa Chammout; Islam El-adaway	A Contractual Approach to Resolving Disputes Arising from Failure to Achieve Green Certification	Green construction is an approach to reducing the environmental impact of resource-intensive construction. Several certification systems have been devised and are globally recognized to provide green building rating frameworks. While a building can be designed to achieve a green rating, the rating is achieved based on the completed facility's actual measured performance. There had previously been limited attempts to give an in-depth examination of the remedies for unrealized green ratings. As such, this paper addresses this knowledge gap using a multistep research methodology. First, the authors analyzed and classified the nature of damages resulting from failed green certification under the commonly used standard form of contracts for green buildings, namely the ConsensusDocs 310-2011: Green Building Addendum, and the American Institute of Architects (AIA) E204-2017: Sustainable Projects Exhibit. Second, the authors examined relevant judicial dispute cases. Third, based on the contractual and legal analysis, the authors developed a checklist to help the contract parties in allocating and handling damages if the intended green certification is not achieved. Ultimately, the findings of this study will strengthen and support the balanced contractual perspectives of project participants involved in disputes over green and sustainable construction projects.
Yomna Mansour; Mohamed Eid, Ph.D; Hesham Bassioni	DIVISION OF COST DEVIATIONS IN INTEGRATED PROJECT DELIVERY SYSTEMS USING COOPERATIVE GAME THEORY	Several contract forms such as the ConsensusDocs 300, AIA-C-191, etc. were developed to provide a relational agreement between the stakeholders of an Integrated Project Delivery (IPD). Nonetheless, none of the standard contracts provides a methodology for the fair division of cost deviations. As such, this paper proposes a model that fairly distributes cost savings and/or overruns by applying cooperative game theory, specifically the Shapely Value. The proposed approach first utilizes the project's earned value calculation to account for each stakeholder's cost deviation. Then through Shapely Value, the authors were able to calculate each stakeholder's fair share of the cost deviation, beyond the contract target band. The mechanism was applied to a case study and the results were assessed for a better visualization of the concept. The research contributes to the body of knowledge by introducing a fair distribution mechanism of cost deviations based on the stakeholders' marginal contribution throughout the project's duration. This approach thus acts as a constant motivator for the stakeholders to further collaborate in the IPD.
Abdolmajid Erfani; Kunqi Zhang; Qingbin Cui	A Stakeholder-Centered Approach to Measure the Market Resiliency in Transportation Projects using Social Network Analysis	As the market for major transportation projects in North America evolved over the past few decades, major players have taken over a large share of the market, leaving fewer opportunities for small and medium-sized firms. As a result of this business climate, bankruptcy, failure, or withdrawal of major players generate a significant concern. The withdrawal of two seasoned players, Skanska and AECOM, from the US public-private partnership (PPP) market raised the alarm. In light of these events, what effects will the changing structure of the market network have on the U.S. infrastructure market going forward? This study introduced a stakeholder-centered approach to measuring market resiliency for infrastructure projects using social network analysis. Resiliency of a network addresses its capacity to absorb, adapt, or transform in the face of changes and shocks. Building on this concept, the authors quantified market resiliency to characterize the structure of connection of stakeholders such as public agencies, consultants, funders, equity holders, joint ventures, and major contractors. Findings revealed that the PPP market offers more resiliency based on applicable metrics such as node degree distribution, path diversity, network connectivity, and robustness compared to the Design-Build and Design-Bid-Build markets.
Mohamed Khalafalla, Ph.D.; Jorge Rueda-Benavides	Value for Money Based Project Selection Framework using Multi-Attribute Utility Theory	Multi-attribute utility theory (MAUT) is a non-monetary approach used to quantify the difference between distinct alternatives considering decision-makers preferences to outcomes by assigning utility measures for each alternative. The main objective of using MAUT when evaluating different alternatives is to achieve Value for Money (VFM), meaning the best possible results based on the money spent. This paper describes the development of a decision-making framework proposed to assist the Florida Department of Transportation (FDOT) with selecting contractor compensation provisions in resurfacing Design-Bid-Build (DBB) projects. The framework facilitates the trade-offs among four decision objectives, if satisfied, to demonstrate value-for-money in FDOT resurfacing investments. The model is illustrated through a hypothetical resurfacing project. The development of the model includes defining four decision objectives. Six measures were proposed to evaluate the level of achievement of the four decision objectives.

Authors	Article Title	Abstract
Phuong Nguyen, Ph.D.; Daniel Tran	Implementing Bayesian Networks in Delivery Selection for Highway Construction Projects	Selecting an appropriate project delivery method (PDM) is a complex decision that typically involves assessing many variables and the relationships between them. One of the main challenges in PDM selection is to accommodate changes in the relationships among variables when more information becomes available as the project is involved during the project development process. The objective of this paper is to develop a Bayesian decision-support model for PDM selection in highway construction by using cost performance data of 177 highway projects delivered by design-bid-build, design-build, and construction manager/general contractor. The conditionally probabilistic inferences associated with these delivery methods were evaluated to determine an appropriate PDM. The model was validated using the k-fold cross-validation and case projects. This paper contributes to the body of knowledge by demonstrating the implementation of Bayesian networks as a data-driven decision-making tool in the construction industry and supporting transportation agencies in their PDM selection process.
Evan Dicks; Keith Molenaar	Identification of Critical Transportation Risk Factors using DEMATEL	Risk management on major transportation engineering and construction projects is a recognized necessity for successful delivery. Accurately identifying and assessing the probability and impact of each risk is complex. Risk events are often assumed to be independent, but neglecting the interactions and relationships among major risk factors can result in inaccurate risk ranking or cost and schedule model underestimates. This study explores the causal relationships between primary transportation risk factors using sentiment analysis of over 5000 risk statements, and attempts to identify the most critical factors using the Decision-Making Trial and Evaluation Laboratory (DEMATEL). The findings identify seven critical risk factors that have higher than average importance and are in the net cause group. Coordination with state and local agency stakeholders was the most critical factor, ranking highest in importance and fifth in its degree of effect on the network. The results can be incorporated into project risk assessments to more comprehensively evaluate the risk severity not only as an individual event, but considering its effect on the network of risk events as a whole.
Phuong Nguyen, Ph.D.; Daniel Tran	Development of A Practical Project Delivery Selection Tool for Airport Capital Projects	Alternative project delivery methods, including Construction Manager at Risk, Design-Build, Progressive Design-Build, and Public-Private Partnerships, have been increasingly used in airport capital projects to improve the speed and efficiency of the project delivery process. However, the selection of these alternative project delivery methods has been primarily conducted based on an intuitive sense of their advantages/disadvantages without applying a systematic decision-making process. This study aims to propose an automated and practical selection tool that helps airport agencies select an optimal delivery approach for a given project based on project characteristics, goals, risks, and constraints. The proposed decision tool was developed using individual interviews and a survey sent to thirty-nine airports across the United States. The results of this study are expected to assist airports of all sizes in selecting an appropriate delivery method given a project's specific needs, goals, and risks and allow agencies to document the rationale behind their decision-making.
Sepehr Khorshid; Siyuan Song; Xi Chen; Solomon Ajasa	The Future of Housing: Modular Construction And its Potential for Affordable living in the US: A Case Study	The United States is currently facing a significant problem with the lack of affordable housing, which affects both low-income families and millennials entering the housing market. The cost of living, including housing, is influenced by various global political and economic decisions, but innovative solutions need to be considered to address external factors affecting housing prices. Modular construction is being considered as a potential solution, and this study evaluated its viability through a thematic descriptive analysis of two case studies. The Phoenix Rising Project in Auburn, Washington, and Live on 1st in Titusville, Alabama was analyzed for their community characteristics and project implementations. The results demonstrate that modular construction has the potential to be an effective and viable solution for affordable housing in the United States. The study provides recommendations for the widespread implementation of modular construction in affordable housing to address the ongoing problem of housing affordability.
Timothy Carl Becker, Ph.D.; Jennifer S Shane; Anthony Lamanna; Mark Van Buren; James Scheer	Results of a Groundbreaking Integrated Delivery Project: Multi-stakeholder Assessments and Lessons Learned from the Waaban Crossing Bridge	The Waaban Crossing bridge project located in Kingston, Ontario, Canada, was delivered with an Integrated Project Delivery (IPD) approach. In 2020, it was recorded that this project was the first major public infrastructure project in North America to be contracted with a tri-party agreement and managed through an IPD approach. The project stakeholders selected an IPD for various and differing reasons, including risk reduction, collaborative decision making, and fiscal transparency. As the project was completed in December of 2022, project stakeholders can reflect on the outcomes and lessons learned. Online surveys and semi-structured interviews of project stakeholders surface hits and misses for the project. Project participants' answers are revealed and documented to determine the extent to which initial goals and objectives for the project were realized. Data are collected individually, so that the unique perspectives of owner, designer, prime contractor, and specialty contractor are contrasted. The project was reported a success by all stakeholders, yet fundamental business drivers that can put entities at odds with one another were present. The findings can inform planners of IPD projects on how to manage project delivery and to structure financial incentives that address the business needs of all key stakeholders.
Hala Sanboskani; Dean Steven Papajohn; Mounir El Asmar	Implementation of Post-Award Contract Administration Tools in D-B and CM-GC Highway Projects: The State of Practice in the Design Phase	Many state departments of transportation (DOTs) are executing design-build (D-B) and construction manager-general contractor (CM-GC) projects. There is a need to identify and disseminate successful practices in administering these contracts, particularly in the post-award phase. The National Cooperative Highway Research Program (NCHRP) funded the development of guidebooks and implementation training related to tools and strategies for effective contract administration, including eight interactive workshops involving 235 participants from 33 DOTs. Training introduced participants to the tools for post-award contract administration and included peer-exchanges with 18 experts. This paper describes the workshops and shares experiences implementing these tools by various DOTs in the design phase. Qualitative content analyses identified reasons for use, processes, and examples of experts' implementation resulting in advice to inform practitioners. The paper contributes by providing guidance for efficient implementation of tools to achieve successful contract administration, enhanced communication, and better owner-contractor relationships in D-B and CM-GC projects.
Andria De La Cruz; Jeyoung Woo, Ph.D.; Ghada M. Gad	Public/Private Works Contracting: Factors Influencing Contractor Participation in Southern California	Over 21,000 General Building (GB) contractors have active B-licenses' in Los Angeles (LA) County in California but less than 800 are competing in public works. This paper aims to identify the gap between GB contractors competing in private and public projects and factors that affect this trend. The scope of this paper is limited to GB contractors who are based out of and actively performing in public projects in the Southern California counties. The authors analyzed data from the Contractors State License Board (CSLB) and the California Department of Industrial Relations (DIR). The percentage of GB contractors performing in public works in each county is as follows: LA (3.5%), Orange (5.5%), Riverside (5.7%), and San Bernardino (5.6%). In addition, identifying factors that affect the lower percentage learned from interviews include payments, financial capabilities, benefits, and availability. This paper provides insight into the realm of public and private contracting.

Authors	Article Title	Abstract
Jeongyoon Oh; Ali Touran; Daniel D'Angelo; Baabak Ashuri	A comprehensive analysis of change orders based on project progress in design-build highway construction.	Understanding the nature of change orders is crucial for optimal project performance. However, limited research exists on change orders in the design-build (DB) context and their impacts considering the timing of change order occurrence. This study aims to investigate change orders in the DB environment regarding their frequency, schedule impacts, cost impacts, and the primary reasons for their occurrence, considering project progress. A scaling technique, parametric statistical tests, and classification were conducted utilizing 275 change orders from 29 US highway projects. The main findings indicate that project progress significantly affects change order frequency, while no statistically significant mean differences were observed in schedule delays and cost overruns based on project progress. Furthermore, this study identified principal change order reasons, including high-frequency/high-risk or low-frequency/high-risk types, based on their frequency, cumulative, and average impacts. This research contributes to the knowledge of change order impacts on project performance in alternative project delivery.
Tolulope Ibilola Ogundare	CURRENT PRACTICES IN THE DEVELOPMENT OF GUARANTEED MAXIMUM PRICE (GMP) CONTRACTS	Owners and practitioners are leveraging Guaranteed Maximum Price (GMP) as an innovative contracting method to better control project costs, mitigate risks, and improve project performance. Despite the protection GMP contracts provide against cost and time overruns, there are limited studies on the current practices of this contracting strategy and its application to the construction industry. Through an analysis of interviews with industry practitioners, this paper strives to explore how large general contracting firms are approaching GMPs on the traditional Design-Bid-Build, Construction Management At-Risk (CMAR), Design-Build (D-B), and Progressive Design-Build (PDB) project delivery methods among others. This study examines the different approaches used in the utilization of GMP on construction projects, as well as different strategies used in the implementation of the pricing methods, how cost categories and milestone estimates are addressed in GMPs, and adjustments that have been made to the current unprecedented market conditions resulting from supply chain disruptions and price escalation. The findings would be useful to show areas of consistency across the industry and existing varieties for owners.
Fahad K. Alqahtani, PhD; Abdullah Alsharef; Abdullah Bin dakhel; Hamad Alshaya; Ahmed Gouda Mohamed	Implementation and Challenges of Utilizing the Smart Contracts Automation Tool in the Construction Industry	Construction contracts are often perceived as complex and lengthy documents, making information extraction significantly challenging. Smart contracts are recently introduced as an alternative to handle the contracts' provisions, duties, and clauses. However, smart contracts are not yet widely adopted in the construction industry. This study reviewed the literature to understand smart contracts better and how they can benefit the construction industry. After that, the study utilized and designed an analytical approach-based quantitative survey to gather experts' comments to evaluate the limited adoption of smart contracts in the construction industry. Study findings outlined the benefits and drawbacks of utilizing smart contracts, particularly emphasizing the Saudi Arabian construction industry and the challenges stakeholders must overcome. The study findings assessed the barriers to adopting smart contracts in the construction industry and will benefit the industry which is known for being slow to adopt new technologies.
Wedad Baker Abu Adi, Ph.D.; Jennifer Shane; Bryan W Franz; Allison M Breunig; Susan M Bogus; Dominica Bennett; Daniel M Hall; Marcella M Bonanomi	Exploring the Design-Integration Manager's Role on Design-Build Projects: A Comparison of the Building Construction, Highway, and Industrial Market Sectors	There are differences in implementing a design-build approach across the building construction, highway, and industrial sectors. These differences affect many aspects of a project, including the role of the Design-Integration Manager. A Design-Integration Manager is an employee of the designer-builder who serves as a bridge between design lead and construction manager. The role of a Design-Integration Manager was explored through virtual research charrettes, surveys, and one-on-one interviews. Participants in these activities included academics and subject matter experts (SMEs) from industry with sector-specific knowledge on design-build. From the qualitative data collected, unique characteristics of the industrial and highway sectors were identified that differentiate their projects from projects in the building construction sector. The results show that the complexity of highway and industrial projects differs from building construction due to different factors such as project scope and size, construction phasing, and public involvement for highway projects. For industrial projects, facility design is dependent on process design, uncertainty in design persists longer, and time to market is extremely important. The results of this study show how the practice of design management in design-build will need to change to accommodate the differences between market sectors.
Won Kyoung Seo, Ph.D.; Youngcheol Kang	Auto-summarization for the Texts of Construction Dispute Precedents	For the effective construction dispute management, it is important to quickly identify the similar precedent cases as it helps practitioners make decision for the direction to respond appropriately to disputed issues. However, it is difficult to promptly and accurately grasp texts of precedents related to construction disputes due to their vast length and specialized content. This study develops a model that automatically summarizes the texts of precedents related to construction disputes through NLP-based analysis. Built on Python, this tool generates the summary reports for 300 US construction dispute precedents obtained by Westlaw database. During the preprocessing stage, case texts are processed based on the construction knowledge. For validating the most appropriate model for construction dispute text summarization, various summary models using BERT (Bidirectional Encoder Representations from Transformers) and conventional ranking algorithms such as TextRank and RexRank are compared. Such summarized result can be evaluated not only with general ROUGE algorithm but also with the readability ratings from domain experts. The result from this research can assist practitioners to manage dispute-related documents in timely manner by automatically summarizing them.
Minerva Bonilla, M.S.; William Rasdorf	Construction Inhibitors of Alternative Intersections and Interchanges	The use of Alternative Intersections and Interchanges (AIIs) is crucial for transportation infrastructure because AII enhances traffic flow, increase capacity and safety, and account for future traffic demands. One challenging problem is that AII designs are negatively perceived in the construction industry since they are perceived to result in additional construction time and cost compared to projects with conventional designs. To assess this concern, the identification of construction inhibitors affecting AII projects was investigated using claims and supplemental agreement data using AIIs and conventional design projects. Findings indicated inhibitors that most affected project performance and top five inhibitors were utilities, additional work, work delays, safety for workers, and weather impacts. By understanding the potentially negative impact of these inhibitors, the constructability of AII projects can be enhanced and transportation agencies can opt for more sustainable solutions.
Kaylyn Cardinal; Mohamed Khalafalla, Ph.D.; Jorge Rueda-Benavides	Development of a Stochastic Risk Assessment Protocol for Analyzing the Impact of Fluctuations in Crude Oil and Fuel Prices on Asphalt Prices in the State of Alabama	This paper examines the long-held hypothesis that the price of asphalt is related to the price of crude oil and fuel. A stochastic risk assessment tool using a modified cumulative sum (CUSUM) statistical analysis method was used to determine their relationship using monthly-posted asphalt, crude oil, and fuel price indexes by the Alabama Department of Transportation (ALDOT) and U.S. Energy Information Administration (EIA). The results indicated that the most likely time gap between crude oil and asphalt price indexes was three months, and the percent change was 58%, and two months and 46% between fuel and asphalt price indexes. The risk assessment tool enables the prediction of the timeline of asphalt price changes along with the magnitude of the changes and risks associated with those changes based on relationships with crude oil and fuel.

Authors	Article Title	Abstract
Mamdouh Mohamed; Daniel Tran	Examining Risk-based Construction Inspection Practices in Transportation Agencies	State departments of transportation (DOTs) are facing the challenge of high rates of attrition and the loss of knowledge as seasoned construction inspectors retire or the agency workforce is downsized. Many DOTs are increasingly using risk-based inspection approaches to offset the shortage of their staff. These approaches prioritize inspection of construction activities based on criticality, which may create a considerable variation in DOT's perception of critical activities. This variability leads to the problem of inconsistency in inspection practices among DOTs. The current study addresses this problem by comparing and analyzing inspection activities of eight DOTs. A content analysis of DOT documents such as inspection guidebooks and construction manuals was conducted to identify DOT's risk perception and compare their critical inspection activities. Focus groups with DOT participants were then conducted to investigate the available strategies to alleviate the risk associated with these activities. The result showed that there is a variation in DOT's risk perception, where a high-risk activity in a DOT inspection may be a low risk in another DOT. Optimizing inspection frequency, documentation, and inspector experience are the top recommended strategies to mitigate inspection risk. This study may help DOTs develop risk-based inspection approaches and adopt risk-mitigating strategies.
Huu T. Huynh; Fatemeh "Raha" Ashrafi; Mohamed S. Eid; Gunnar Lucko, Ph.D.	Concurrent Delay Analysis via Cooperative Game Theory	Despite various attempts throughout past decades to deal with concurrent delays in construction project schedules, they continue to be a vexing issue that has eluded an unambiguous solution. Prior studies have resorted to the prime contract, which only binds general contractor and owner, cannot be proven to be fair, and may even be biased. Therefore, this paper adopts a concept from cooperative game theory, the Shapley value, which apportions profits (which project participants seek to maximize). Creatively applying it to liquidated damages (which they seek to minimize), the model uses all participants' actual finish dates as input to gain percentage shares of liquidated damages as output. Analyzing all possible coalitions among participants and assigning weights comprehensively assesses their marginal contributions to the project finish date. This generalized view of participants explicitly includes subcontractors, whom prior approaches typically ignored. An example demonstrates how the model also implies an early completion bonus. This yields compelling implications for real-world incentives that can be cast into future contract clauses.
Yi Su; Shabtai Isaac; Gunnar Lucko, Ph.D.	Cruciality: Role of Network Topology in Schedule Resilience to Delay Propagation	Construction schedules are widely modeled and analyzed as networks that consist of activities within a dependency structure of sequential and parallel paths. All future activities carry duration uncertainty that is caused by diverse risk factors. But worse, by being linked, activities can cause a 'ripple effect' of delays that propagate through the remainder of a project. This paper studies this phenomenon systematically: It captures topology with the intuitive concept of reachability. It formalizes an index, cruciality, as the product of reachability and scaled covariance of any two activities within a schedule. And it simulates various test schedules with probabilistic activity durations to answer two related questions: How does schedule topology determine vulnerability to delays? And what ways can schedulers take to design more resilient schedules? It differs from research on the static critical path and forecasting the project duration; instead this work seeks to stabilize said value. Two strategies can be used to reduce the potential propagation: Reduce uncertainty in high-risk activities. Or reroute, combine, or even delete links if this is technically feasible. A more parallel topology is beneficial, because it reduces potential interactions. In practice this could be realized through strategies like modular design or task-dedicated resources.
Mateo Manzano-Alvarado; Laura Montalban-Domingo; Tatiana García Segura; Amalia Sanz-Benlloch; Eugenio Pellicer, Ph.D.	TIME AND COST OVERRUN IN CONSTRUCTION PROJECTS IN ECUADOR: MAIN CAUSES AND RISK FACTORS	The analysis of the causes of time and cost overruns in construction projects has attracted much attention worldwide in recent decades. These causes usually vary from country to country and depend on aspects such as the kind of project, the environment, the construction company's features, etc. This study aims to identify the main causes of delay and cost overrun in Ecuador's construction projects and analyze the main factors influencing their occurrence. A total of 72 causes were collected from a literature review. Through the Delphi method, a group of experts identified Ecuador's most important causes. Subsequently, the information from 53 civil engineering and building projects was gathered through a questionnaire survey to identify and evaluate the risks of project delays and cost overruns perceived by construction professionals in Ecuador. Descriptive statistics and non-parametric analyses were performed. Results highlighted that the main causes of time and cost overrun are the weather, unexpected conditions in the construction site, design changes from the owner, incomplete drawings, and mistakes or incomplete designs. However, these results vary significantly depending on the project type and the company size.
Mingshu Li; Qiu Zheng; Baabak Ashuri	Quantifying the Impact of Covid-19 on Transportation Construction Industry Using Regime Switching Models	COVID-19 has unprecedentedly impacted the transportation construction industry. Highway agencies are facing great challenges posed by the pandemic, including labor shortage, project delays, and increasing costs. The research objective of this paper is to quantify effects of COVID-19 on U.S. transportation construction material prices. Markov switching regression and causality inference were used to empirically analyze the relationship between transportation construction material prices and indicators monitoring different aspects of COVID-19 effects and government response. The results reveal the lasting adverse impact of the pandemic on volatility in material prices. The extent of recovery was highly dependent on the degree of economic support and lockdown measures. Causality test confirms that stringency index, economic supports, and number of confirmed cases are leading indicators of transportation construction material prices. This research contributes to the body of knowledge by (1) establishing a statistical method for quantifying impact of COVID-19 on transportation construction industry, and (2) analyzing material prices in transportation construction industry before, during, and after COVID-19. It is anticipated that the results will help policymakers grasp the impact of COVID-19 on transportation construction activities and design more effective policies to respond to future pandemics.
Ghiwa Assaf; Rayan H. Assaad	Predicting Construction Costs Under Uncertain Market Conditions: Probabilistic Forecasting Using Autoregressive Recurrent Networks based on DeepAR	Projects often experience cost overruns due to market uncertainty and price escalations. Traditional cost estimation methods that rely on point estimation are incapable of providing prediction intervals as well as probabilistic assessment. Thus, there is need for an innovative approach to predict the changes and uncertainties in construction material costs. This paper proposes a novel stochastic model to estimate construction material costs by applying probabilistic forecasting using autoregressive recurrent networks. First, price data was collected for four different construction materials. Second, data was divided into a training set (pre-COVID-19) and a testing test (post-COVID-19). Third, the state-of-the-art DeepAR algorithm was implemented to provide probabilistic forecasts for construction material prices under uncertain post-COVID market conditions. The results showed that the proposed stochastic model provides accurate cost estimates with a mean absolute percentage error of 1% for concrete products, of 2% for concrete ingredients, of 3% for paving mixtures and blocks, and of 4% for steel and iron materials. This paper adds to the body of knowledge by proposing a new approach for estimating construction material by providing probabilistic forecasts in the form of Monte Carlo samples that can be used to compute quantile estimates, which offers better protections against rising costs.
Payam Mohammadi, Ph.D. Student; Claudia Garrido Martins	Cost/Benefit Analysis Model for Implementing Virtual Reality in Construction Companies	Immersive technologies (ImT), like Virtual Reality (VR), have several potential applications in the construction industry. However, the absence of a cost-benefit analysis discourages construction decision-makers from implementing these technologies. In this study, we proposed a primary model for conducting a cost-benefit analysis for implementing virtual reality in construction companies. The cost and benefit factors were identified through a literature review and considered input variables for the model, and then using synthetic data, a Monte Carlo simulation was performed to generate a distribution of outcome. Given the uncertainty in input parameters, this distribution reflected the potential range of total net benefit. Considering synthetic data and input factors obtained only through literature and assumptions, VR implementation could be a promising decision based on the results. This study's results would benefit decision-makers in construction companies about the costs and benefits of implementing VR and other researchers interested in this field.

Authors	Article Title	Abstract
MD Shah Jamal; Ahmed Abdelaty; Joseph Shrestha	Improving the Reliability of Adverse Weather Day Estimation in Project Planning: A Framework Utilizing Daily Work Reports	The transportation construction industry is one of the most critical components of every country's economic growth. However, several projects nationwide faced schedule delays because of weather conditions and other factors. Therefore, considering accurate weather-related delays and establishing a reasonable construction time is essential in project planning and schedule management. Thus, this study proposes a framework for estimating weather delays using historical daily work reports (DWRs). Project data from 161 projects, including 29,539 DWRs, were collected from a state highway agency. These projects were delivered between March 2017 and February 2023. The data collected are used in this study to develop a framework to estimate historical adverse weather days. The framework analyzes DWR to determine how many weather delays occurred each month by location by searching for keywords in DWRs. Finally, fifteen case studies were conducted to validate and measure the proposed framework's accuracy in detecting adverse weather days from DWRs. This study helps state highway agencies determine an accurate account for weather delays based on historical data to estimate construction time better.
Mennatallah Soliman; Elkhayam Dorra; Ossama Hosny	The integration of supply chain finance in the construction industry and its influence on the Contractor’s cash flow	In a traditional construction project, there tends to be a negative cash flow as the Contractor might need to pay advance payments to suppliers prior to receiving payment from the Owner. If the Contractor awaits payment from the Owner to pay the suppliers, the project could be delayed. Consequently, Contractors resort to financial institutions such as banks to finance their negative overdraft. However, banks typically require collaterals which Small and Medium Enterprises (SMEs) might not be able to provide. Also, banks impose high interest rates which reduces the Contractor’s profitability. This study investigates how the integration of Supply Chain Finance (SCF) tools can influence the cash flow of construction projects. The proposed study compares the traditional financing cycle to an alternative cycle that involves SCF as means of materials financing. The comparative analysis is conducted by developing two multi-objective optimization models with the aim of maximizing the profit margin and minimizing the negative overdraft. The two models are tested on five hypothetical construction projects. Results of the study indicate that SCF could act as a valuable tool for enhancing the overall health of a Contractor’s cash flow.
Jennifer Shane, Ph.D.; Andrew Gatto; Kelly Strong	A Comparison of Department of Transportation Progress Scheduling Specifications from Across the Nation	One of the primary determinants of project success is completion of the project on, or ahead, of schedule. Owners are constantly concerned about schedule progress and project completion. Departments of Transportation (DOTs) are not an exception to this behavior. DOTs each have their own specification requirements. A comparison of the specification requirements, including definition, float ownership, software, differentiation of project levels/complexity, progress narratives, preliminary schedules, schedule updates, review and resubmit durations, and “as-built” schedule development, reveals areas of consistency and differences between states. Through this comparison researchers can support DOTs in developing specifications that support the DOT mission while not being burdensome to project management and the contracting industry. Preliminary findings indicate the requirements for proprietary scheduling software (e.g. P6) and the use of cost-loaded Critical Path Method (CPM) schedules for payment purposes are potential sources of conflict between the contracting community and DOT’s.
Yejee Paik; Baabak Ashuri	Examining Impact of COVID-19 on Unit Bid Price of Reclaimed Asphaltic Concrete Items regarding Georgia Highway Maintenance Project through Change Point Detection	The outbreak of COVID-19 in 2020 caused global panic with numerous consequent changes. The high fluctuation of construction bid costs illustrated the struggle to reflect such changes in the construction field. Although a new era of post-COVID is soon to arrive, cost inflation, labor shortage, and pent-up construction demands show that the construction industry is still suffering from the pandemic. This paper examines the impact of COVID on construction projects, specifically Georgia highway maintenance projects, by analyzing the unit bid price of the recycled asphaltic concrete pay items from Oman Systems. A spline regression was employed to examine the overall trend of the pay items, and residuals from the regression detrending are used as an input for Cumulative Sum (CUSUM) charting. A prominent mean shift in the price residuals was detected in 2021 with a lag of a year after the outbreak of the pandemic, indicating significant deviation in the price. This investigation is expected to provide insight into more accurate cost estimate of highway projects and more-informed investment decisions accounting for variability and uncertainty in the aftermath of COVID-19.
Jeyoung Woo, Ph.D.; Ghada M. Gad; Joshua A. Paredes; Uttarayan Bagchi	Metrics to Assess the Quality Performance of Capital Projects	Assessing the quality management (QM) performance of capital projects is challenging as construction projects are complex, unique, and fragmented. This paper aims to develop a comprehensive list of quality-related metrics used to assess QM performance on capital projects. To achieve this objective, a thorough literature review of existing quality metrics for the engineering/design, construction, and operations and maintenance (O&M) phases was conducted. The list of metrics was compiled from existing metrics being implemented in the industry. Information from the literature review was synthesized to provide a list of metrics with a drive for QM standardized metrics that could be used industry-wide. This paper's primary contribution is identifying and developing a quality metrics list that can be utilized to develop a standardized quality metric to evaluate the effectiveness of QM programs on capital projects.
Mohammad Movahedi; Seungwon Seo; Choongwan Koo; Juyeong Choi	Assessment of Estimation Methods for Demolition Waste Volume and Cost	For the past few decades, researchers have tried to make a sustainable built environment by maximizing recycling and reuse of construction and demolition (C&D) waste. In particular, demolition waste accounts for more than 90 percent of the total C&D waste generated in the U.S., thus signifying substantial potential for recycling and reuse. While there have been several models to estimate construction waste available for supporting its waste reduction planning, however, there has been a lack of estimation models for demolition waste. This research seeks to evaluate the feasibility and accuracy of four common estimation approaches for demolition waste (i.e., demolition waste volume and cost): a linear regression, an artificial neural network, and two advanced case-based reasoning approaches, which utilize several regression models on selected instances to improve the overall accuracy of predicted cost and volume of demolition waste. A database of 52 demolition projects, containing information on architectural characteristics, permit history, value, and contract requirements, is used to train models and facilitate evaluation. Different estimation methods are compared in terms of estimation accuracies while discussing the potential improvement of each method. This study will serve as the cornerstone to develop a more reliable demolition estimation model in the future.
Vuppala Srinija; Nikhil Bugalia, PhD	Evaluation of System Dynamics-based serious games for teaching Project Management concepts in Construction	The current study is a first-ever evaluation of the System Dynamics (SD) based serious game for its pedagogical impact on teaching Construction Project Management (CPM) concepts. An online game designed by the MIT Sloan School of Management is explored to identify three learning objectives consistent with the Project Management Body of Knowledge (PMBOK). A newly designed game session allowed the participants to control a project's hiring, management, and quality pressures and learn through the simulated impact. The game's effectiveness on learning outcomes was captured using Pre- and Post-game questionnaires implemented for 23 civil engineering undergraduate and graduate students in India. A statistically significant improvement of 44% in the post-game scores was obtained for the three learning objectives. About 83% of the participants agreed with the game's effectiveness in delivering the CPM concepts. The participants' feedback on sessions encourages further exploring the potential of SD's use in CPM teachings.

Authors	Article Title	Abstract
Zixian Zhu; Jiun-Yao Cheng; Idris Jeelani; Masoud Gheisari; Raja R. A. Issa	Virtual Onboarding: Construction Site Orientation for New Employees in a Virtual Environment	Construction site orientation, also known as induction or "onboarding", is an essential process for new, inexperienced, or transferred construction employees who work on sites to get familiar with various aspects of the jobsite such as site logistics, management teams, equipment, or safety precautions. Typically, this process is physically conducted on sites as a short tour by a management team member, sometimes accompanied by a written manual. However, traditional site orientations are often considered to have several shortages: deficiency of important information, time-consuming, unengaging, and unsafe for those unfamiliar with site conditions. As a potential solution to these issues, conducting a general site orientation in a virtual reality (VR) environment is more efficient and safer. This study designed and developed a virtual construction site as a digital replica of a large commercial construction project to provide a general virtual site orientation. A user-centered assessment was designed and carried out to evaluate participants' perceptions of the usability and effectiveness of the proposed virtual site orientation.
Olugbenro Ogunrinde	Scientometric Analysis of Literature for Emerging Technology Integrated into AEC Education Curriculum	Industrial transformation is experienced through the adoption and utilization of technologies. However, this is slow in the construction industry due to a lethargic approach toward innovation, which adversely affects project performance and productivity. The current study evaluates existing literature on the integration of emerging technology (ET) in architecture, engineering, and construction (AEC) industry and education curricula (EC). Also, applied a scientometric analysis to identify technologies integrated into AEC EC courses and institutions from 2010 to 2023. A qualitative content analysis was adopted in this study to scrutinize the selected articles. The study found BIM, VR, and AR as the top reoccurring ET incorporated in AEC EC but lack enough information on specific course integration. The research limitation is the use of only existing published literature. The study concludes by proposing a roadmap to help stakeholders assess technology integration into AEC EC, which could result in producing innovative and competitive professionals and likewise enhance AEC's project performance and productivity.
Paul J HICKEY, Ph.D. (expected 5/2023); Melissa L. ROCCO; Qingbin CUI	Listening to Leaders – How AEC Women Grow Their Career Pathways	Through semi-structured interviews with 20 women leaders, Vice President (VP) and above, from top Architecture, Engineering, and Construction (AEC) firms, researchers explored career path progression. This study sought to investigate root causes for women's AEC underrepresentation by gleaning insights from the experiences, successes, and challenges during their climb up the corporate ladder. Understanding the richness of individual journeys, researchers selected narrative inquiry to explore underlying themes and generate a career roadmap for early and mid-career women. NVIVO software facilitated qualitative analysis of the resultant compiled corpus of information, identifying common topics and industry best practices to promote diversity. Sharing successful initiatives with firms throughout the industry expands the long term focus from initial recruiting through long-term career nurturing for women. Study participants noted assembling a supportive personal network and identifying early career mentors as key success factors. Firms wishing to differentiate themselves and gain the proven benefits of diversity, highlighted by better business outcomes and greater innovation, should invest in diversity programs. Successful initiatives include creating a culture that nurtures women throughout their careers and tailoring more inclusive recruiting programs.
Jiun-Yao Cheng, MSc; Masoud Gheisari; Idris Jeelani	Enhancing AI Literacy of Undergraduate Students using Construction Safety Context	The integration of Artificial Intelligence (AI) has the potential to address various challenges in the construction industry, including cost overruns, safety concerns, labor shortages, and productivity issues. However, the construction industry has been slow to adopt AI solutions due to a lack of construction professionals with appropriate AI understanding. Currently, very few construction programs incorporate AI literacy into their undergraduate curricula. This study aims to address this gap by developing a 2-hour curriculum that teaches construction students AI literacy knowledge within the context of construction safety. The effectiveness of the curriculum was assessed through pre- and post-intervention questionnaires, which showed that the curriculum effectively enhanced construction students' AI literacy level. This research provides a valuable foundation for the future integration of AI literacy components into construction curricula, which is crucial for the construction industry to catch up with other industries in adopting AI solutions.
Adedeji Olushola Afolabi, Ph.D.; Oluwaseun Kasope Shaw	Examining E-learning Adoption in Construction Education in a Developing Country during the COVID-19 Pandemic	The COVID-19 pandemic led to the adoption of social distancing and the closing of public places. One of the public places affected was tertiary education settings where universities had to close. Without a physical school environment, some tertiary institutions resulted in e-learning. Therefore, this study examined e-learning adoption in construction education in a developing country during the COVID-19 pandemic. The study used a cross-sectional survey research design through an online questionnaire form. The study revealed the leading e-learning platforms used during this period. In conclusion, the study revealed the significant challenges and benefits of e-learning adoption in construction education during the COVID-19 pandemic. Beyond the COVID-19 pandemic, the study recommended more investment in e-learning infrastructure for both students and tutors.
Bassam Ramadan; Hala Nassereddine; Tim Taylor; Paul Goodrum	The Construction Worker's Social Experience: Age and Position	The construction industry does not have a great reputation for its workplace compared to other industries. A tolerant workplace has positive impacts on employee productivity. While existing research has analyzed the cultural and social experiences of construction workers across gender lines, no research has analyzed such experiences based on age or role. The purpose of this paper is to compare the construction workforce's attitudes to social and cultural issues across different age groups, and whether they have a supervisory role. In this study, we surveyed 2740 construction workers across the US using an online questionnaire. The survey participants were asked to rate statements adopted from the General Social Survey on how they feel on a Likert scale ranging from "Strongly Disagree" to "Strongly Agree" regarding five specific issues. Key findings show that younger workers and non-supervisors have a statistically significant worse experience compared to their colleagues.
Ricardo Eiris; Josiane Isingizwe; Masoud Gheisari	Exploring Intersectionality of Gender and Race: Immersive Storytelling Videos and Perceived Expertise among Diverse Construction Professionals	This study examines the perceived expertise of diverse construction professionals across gender and race in the construction industry. While expertise assessment is essential, contextual factors such as race and gender can influence the perceived expertise of individuals. An online study was conducted, employing an immersive storytelling tool in a between-subject experimental design with four different conditions. Construction-related discipline students were randomly assigned to experience an immersive story narrated by a Female African American, Female White American, Male African American, or Male White American construction expert. Results reveal no statistical differences, yet Female professionals received lower expertise ratings based on gender and race. Furthermore, students provided negative feedback predominantly for Female professionals. These findings underscore the importance of raising awareness among students regarding potential biases in evaluating diverse construction professionals.
Yuan Sun	A Virtual Site Visit on Four-legged Robots Applications in Construction	With the increasing deployment of robots in the construction industry, it is crucial for future professionals to not only be familiar with these robots but also understand their applications and associated safety challenges. However, the logistics and financial issues in bringing these robots to classes pose a challenge in including an effective robot-related curriculum in construction education. This study developed a virtual site visit that integrates Virtual Reality (VR) technology and immersive storytelling to expose students to a robot-dominant construction site. The virtual site visit enabled users to navigate a robot-dominant construction site and learn about four-legged robots, their applications, safety challenges, and countermeasures for working safely with robots. The results of the study demonstrate that virtual site visit offers unique opportunities for enhancing construction students' conceptual understanding of robots in diverse and unfamiliar scenarios without exposing them to undue risks or incurring substantial costs.

Authors	Article Title	Abstract
Erika Judith Rivera; Mohamed ElZomor	TRANSFORMING CONSTRUCTION ENGINEERING EDUCATION THROUGH INCLUSIVENESS TRAINING, AND MANAGING EXPECTATIONS .	The engineering, architecture, and construction professions have lost talents to other industries because Millennials and Generation Z tend to misapprehend the expectations related to inclusion and work-life balance (WLB) in the workplace. Construction careers are highly stressful, and demanding, with pressures such as achieving tight deadlines, aligning multiple stakeholders, managing disputes, etc. There is a disconnect between the perception/experience provided to students during their undergraduate degrees resulting in facing challenges, particularly coordinating between personal and professional lives. This study aims to address students' WLB expectations and career challenges related to inclusion by developing awareness about such unforeseen challenges. To achieve this goal, the study utilizes a twofold methodology: (a) surveying both industry professionals and construction management students, and b) proposing curriculum changes to better prepare graduates to succeed when entering the workforce. The study results indicated that inadequate work-life balance could result in project delays, higher project costs, and a devastating effect on the employees' mental and physical health. The findings of the study contribute to the body of knowledge by promoting work-life balance awareness through providing a pedagogical/workshop solution to foster inclusive recruitment and support retention.
Yang Ye; Pengxiang Xia; Tianyu Zhou; Jing Du, PhD	User Experience and Workload Evaluation in Robot-Assisted Virtual Reality Welding Training	Remote virtual training for tasks that involve intensive human motor participation is gaining popularity in the emerging education 4.0 era. However, the user experience and the underlying cognitive characteristics while facing the state-of-the-art training platform are less understood. This paper implements a robot-assisted virtual reality training system for welding training. The virtual reality system creates an immersive environment, and the robotic device provides the necessary physical interaction. A total of 28 participants who had no prior welding experience were recruited to learn welding skills. The participants were trained under the conventional training condition, visual guidance condition, and haptic guidance condition. Participants' pupillary response and subjective feedback were evaluated to investigate the user experience and the cognitive characteristics differences while being trained under different conditions. The results showed that participants felt easier when learning with conventional learning method, while pupillary response showed learning with visual and haptic feedback reduced the cognitive load. By showing the complexity of evaluating user experience, this study encourages training designers to evaluate the use of new technology with more dimensions.
Arnav Jain, M.Sc. in Construction Management; Shimeng Dai; Sinem Mollaoglu; Kenneth Frank; Meltem Duva; Annick Anctil; Kristen Cetin	Iterative Development of Dynamic Student Project Team Interventions	The development of teamwork skills in project management is becoming increasingly important as the future of work requires increasingly complex team organization and coordination. Professionals of highly technical backgrounds face challenges working in collaborative environments involving communication, management, conflict resolution, and challenging behaviors. To develop these complex skills, higher education curricula for construction engineering traditionally depends on courses outside of the discipline or extra-curricular activities. To help improve construction engineering students' collaborative skill development in and via project team assignments, this paper presents an iterative development process of dynamic project team interventions. The process to date utilized theory, empirical data, and expert reviews extending to partnering, organizational science, communication behaviours, human-computer interaction (HCI), and network science. The intervention module focuses on planning, management, coordination, conflict resolution, and communication aspects of project teamwork and includes a dynamic charter, a training module, and reminders driven by teams' use of the project charter. Insights into training and intervention modules for the future of work in higher education are discussed, and directions for future research are presented.
Hongtao Dang; John Gambatese; Sathy Rajendran; Mandi Kime	Training Development for DEI and Psychological Safety in Construction	The construction industry has a severe workforce shortage compounded with historical diversity, equity, and inclusion challenges. The Associated General Contractors (AGC) of Washington developed a culture to commit, attract, retain, and empower (CARE) construction workers in a diverse, equitable, and inclusive environment. Shortly, the AGC of America adopted the culture of CARE and began actively working to ensure construction workers feel valued, respected, and heard. At the same time, psychological safety emerged in conversations that construction workers should feel safe and be able to speak up with ideas, questions, concerns, or mistakes. As a result, many construction companies took a pledge and sought training for construction workers. This paper aims to present a training development for diversity, equity, inclusion (DEI), and psychological safety in construction. The authors collected data from multiple construction companies that were leaders in developing resources for DEI training. The authors analyzed scenarios collected from real-world construction projects, synthesized them in case studies, and prepared manuals for trainees and trainers. The developed manuals are publicly available for corporate trainers and university educators to train construction workers and students. The training positively impacts the DEI-built environment and workforce development.
Amit Ojha; Houtan Jebelli	REVITALIZING STUDENTS' PERCEPTION AND KNOWLEDGE OF CONSTRUCTION SAFETY: LEVERAGING VIRTUAL REALITY AS AN EXPERIENTIAL LEARNING TOOL FOR CONSTRUCTION ROBOTIC SAFETY EDUCATION	TTraditional lectures have difficulties instilling pragmatic skills in construction engineering students due to the inability to illuminate the complexities within the human-robot collaborative construction environment. While on-site can acclimatize construction students to reality and construct knowledge that can solve safety challenges, it is challenging to organize on-site training trips owing to the dangerous nature of construction workplaces. This research aimed to explore virtual reality (VR) as a tool to enhance students' perception and knowledge of construction robotic safety. For this purpose, the study developed a virtual training platform for providing construction engineering students with safety knowledge on interacting with simulated robots within the virtual environment of construction sites. A self-assessment approach was leveraged among 20 recruited students to demonstrate the efficacy of students' engagement and learning outcomes from the proposed learning approach over the traditional learning approach (slides). Results indicated a statistical difference in students' learning outcomes and engagement levels between the developed approach and the traditional approach. Findings demonstrated the implications of VR as an experiential tool to enhance the students' learning of robotic safety in construction.
Vineeth Dharmapalan; Khalid Osman	Diversity, Equity, and Inclusion in the Architecture, Engineering, and Construction Industry: A Subject Review	The body of literature exploring how diversity, equity, and inclusion (DEI) percolates in technical environments is growing. These studies adopt various goals and methodologies. However, limited systematic analyses exist regarding the status, development, and trends of DEI research in the Architecture-Engineering-Construction (AEC) industry. This paper presents a systematic literature review of recent DEI research trends in AEC by analyzing relevant publications. Both descriptive and content analyses were performed, considering the annual number of papers and the range of topics addressed. This review offers an enhanced understanding of the current state of DEI research, highlighting achievements, research gaps, and future research directions. This review is valuable for researchers aiming to address limitations and expand the scope of DEI research and for industry professionals seeking to implement DEI best practices.

Authors	Article Title	Abstract
Manideep Tummalapudi; Christofer Michael Harper, Ph.D.; Jon W Elliott	Technical Competencies for Transportation Construction Inspection Workforce Development	Construction inspection ensures the delivery of quality transportation infrastructure projects by demonstrating that the work put in place meets or exceeds the contract requirements. Performing quality construction work helps state departments of transportation (DOTs) realize the engineered lifespan of a transportation asset, which provides the best value for DOTs and the traveling public. However, difficulties in finding, hiring, recruiting, and developing well-trained and experienced construction inspectors are a growing risk to the quality of transportation construction projects. With new inspectors joining the construction workforce, proper training is needed to impart the technical competencies (knowledge, skills, and abilities) to perform inspection responsibilities accurately and efficiently. For training to be successful, it needs to provide learning in specific technical competencies. However, limited research has been conducted to determine the technical competencies an inspector needs to perform their job duties successfully. Therefore, this study investigates the technical knowledge, skills, and abilities needed to perform inspection responsibilities. Two surveys and two focus groups were conducted to collect information on inspection responsibilities and technical competencies. The results reveal the specific technical competencies that the transportation construction inspection workforce requires, and this information can be used to develop more effective training for inspectors.
Ali Golabchi; Yasser Mohammad; Aminah Robinson Fayek; Simaan AbouRizk	The University of Alberta's Construction Innovation Centre (CIC): Academia-Industry Collaboration for High-Impact Research	The Construction Innovation Centre (CIC) was established at the University of Alberta with the aim of providing breakthrough research, education, and training that would directly benefit the construction industry, leading to sustainable and economic development of our built environment –all while providing a competitive advantage for the Canadian construction sector. Bringing together over 30 inter-disciplinary faculty members and more than 50 industrial partners, professional associations, and government bodies, the CIC is accelerating and supporting innovation, productivity, and competitiveness in the construction industry through high-impact research. This paper shares the steps taken to establish the CIC including the development of its research roadmap, governing structure, services provided, and metrics to evaluate performance. By exploring the process of establishing the CIC as a collaborative construction research center, this paper provides insights into the opportunities, challenges, and directions for creating successful academia-industry collaborations. Such collaborations are crucial for developing impactful solutions that can address the challenges encountered by the construction industry through cultivating a collaborative environment for effective innovation and knowledge mobilization, successful dissemination of research findings, and productive training of highly qualified personnel.
S M Jamil Uddin, MSc; Mahzabin Tamanna; Anto Ovid; Abdullah Alsharef; Alex Albert	Workforce Challenges Posed by the COVID-19 Pandemic: YouTube as a Data Source	The COVID-19 pandemic is one of the biggest challenges the world has faced in recent decades. The pandemic has disrupted human life in significant ways. Similar to many other industries, the construction industry has faced numerous challenges due to the pandemic. Some of the challenges include project shutdowns, supply chain disruptions, health and safety challenges, project delays, and economic hardships. This study is focused on unveiling workforce-related challenges the industry experienced during the early stages of the COVID-19 pandemic. The investigation leveraged YouTube as the source of information given the presence of rich and relevant content. As a first step, YouTube's API was used to extract relevant videos using appropriate keywords. The analysis of the videos revealed a number of workforce-related challenges that the pandemic posed. These included job losses, lower wages, financial stress, and fringe benefit losses. Additionally, the videos highlighted the challenges of migrant workers from different regions including the US, Canada, Europe, Singapore, the Middle East and others. The videos also unveiled the struggle of minority workers such as Hispanic workers in the US. The findings of this study can be utilized by industry stakeholders and governments to overcome workforce-related challenges during similar emergencies in the future.
Claudia Valeria Calle Müller; Mohamed ElZomor; Erika Rivera	Training Underserved Communities in Construction Trades for Social Mobility and Job Equity	To promote social mobility and job equity in low-income communities, this research demonstrates a successful pedagogy that educates, trains, and certifies lower-income and underserved individuals, including unemployed, veterans, women, individuals aging out of foster care, and the homeless to join the construction industry thus filling the critical shortage of skilled craft workers in construction. The goals of this research are to: (a) identify gaps in construction trade knowledge of low-income individuals; (b) evaluate if individuals found better job opportunities after completing a construction trades program (CTP); and (c) identify pedagogy including course delivery and instructional technologies to effectively educate and train particularly the low-income workforce on basic construction knowledge and offer them the needed skills to find better job opportunities in this well- paid industry. To achieve these goals, this research surveyed 65 students, alumni, and faculty of a CTP that serves low-income and underserved communities. The results of this study showed that students of a CTP obtained better job opportunities and highlighted the importance of training low-income individuals in construction trades for social mobility. This study provides strategies for low-income communities to join the construction workforce, thus leading to a diverse workforce and filling in the construction workforce gap.
Rubaya Rahat, BSc; Mohamed ElZomor	Reinforcing The Connection Between Envision Rating System And Alternative Project Delivery Methods To Achieve Sustainable Infrastructures Through Construction Education	Educating construction management (CM) students to embrace infrastructure sustainability and utilize alternative project delivery methods (PDM) can facilitate addressing issues including project funding, stakeholder conflicts, as well as social, economic, and environmental implications. Therefore, this study introduces the CM students to how the Envision sustainability rating system can support the implementation of alternative PDMs in infrastructure projects through leveraging integrated design. Furthermore, the study reflects the participants' experience and perspective on using alternative PDMs to improve the sustainability performance of infrastructure projects. This study piloted a workshop along with pre and post-survey in a sustainable construction class under the CM program. The findings indicated that the workshop improved the students' competencies in delivering high-performance sustainable infrastructure (SI) projects. Moreover, the students shared positive feedback for incorporating alternative PDMs in SI projects. This study would be critical for implementing sustainable developments and enhancing the project management skills of the future construction workforce.
Michaela LaPatin; Nicola Ritsch; Daniel Armanios; Leif Albertson; Lynn Katz; Kasey M. Faust	Addressing Workforce Attrition, Retention, Absenteeism, and Recruitment in the Rural Alaska Water Sector	Rural water utilities often struggle to retain a reliable, skilled workforce. In the Yukon-Kuskokwim (YK) Delta of Alaska, this challenge is exacerbated by communities' remoteness, small populations, and limited economies. Workforce attrition leaves utilities understaffed and unable to provide sufficient water services to their community. In this study, we evaluate interviews with seven YK Delta water sector professionals, including environmental health officers, water plant operators, and water haulers. Through a hybrid qualitative content analysis and cognitive mapping, we seek to better understand the relationships between workforce attrition and interdependent system factors. For instance, we identify that overworking can lead to attrition, which can lead to service disruptions. Preliminary results indicate that a major concern for water sector professionals is the excessive hours of work, which leads to worker burnout, attrition, and absenteeism. We further identify that increased wages for water sector workers can improve retention and recruitment, likely leading to long-term improvements in water provision.

Authors	Article Title	Abstract
Daniel Mehrabi; David Grau; Sam Ariaratnam	Impact of an International Research Experience on Graduate Student Advancement	The importance of international collaborations and experiences is increasingly evident in the professional development of engineering graduates, preparing them for the global and interconnected nature of their disciplines. This study examines the role of international research experiences in enhancing the professional and intercultural development of engineering graduate students, focusing on participants in the International Research Experiences in Civil, Construction, and Environmental Engineering (IRECCEE) program. Using a mixed-methods approach, data collected from surveys and interviews are analyzed to assess the impact of the program on students' communication, networking, collaboration, independent research abilities, and intercultural competence. Preliminary findings indicate significant improvements in these competencies, highlighting the IRECCEE program as an effective platform for preparing students for successful academic and professional careers in a global context. The study further demonstrates the positive influence of international exposure on students' capacity to navigate diverse cultural and research environments. These insights underscore the importance of international research experiences in graduate education and provide guidance to improve the design and evaluation of such programs.
Rebecca Kassa	Assessing the Overall Personality of Construction Project Teams: A Weighted Combination of Individual Team Member Personality Traits	The importance of teamwork in the construction sector has been widely acknowledged. The success of a construction project requires coordinated interactions among team members working towards a common goal. To improve team dynamics and enhance project performance, it is essential to understand the impact of individual team member personalities on the group's behaviour. Social Cognitive Theory (CST) recognizes the influence of individual personal characteristics on a group's behaviour. However, there is a lack of research on overall team personality in the construction sector. This study, aiming to address this gap, developed and evaluated an overall construction project team personality from the weighted averages of individual team member personality traits. The weights were developed using a machine learning model, trained on data collected from 30 construction project teams completed within the past five years. These teams represented intercompany core team members, including but not limited to the owner, architect, engineer, contractor, and key subcontractors, and were not restricted by delivery methods, project size, scope, phase, or schedule. The results demonstrated that overall team personality provides a comprehensive summary of team characteristics, which is crucial for understanding motivation, drive, interrelation, and performance within a group, ultimately leading to successful project outcomes.
Emma Sophie Stine, Ph.D.; Amy Javernick-Will	The Evolving Career Aspirations of Socially Minded Engineering and Construction Students	Humanitarian Engineering (HE) programs are growing exponentially to meet the rising demand of engineering and construction students wanting to address equitable infrastructure service provision. This field is attracting students traditionally underrepresented in engineering and construction, including those of diverse backgrounds, identities, and passions. However, there is a dearth of research tracking students' evolving career aspirations through the influences of graduate school. This study conducts longitudinal interviews with seven students enrolled in seven graduate HE programs over two years. Through these interviews, students' career aspirations were collected and qualitatively coded, including desires around impact, daily tasks, work environment, location, and compensation. The study identified three expectation patterns of shifts in career interests over a graduate education. This ongoing analysis will address the shortage of research on the career pathways of socially-minded engineering and construction students. Results will be valuable for programs to support and meet the changing needs and aspirations in these fields.
David Gutierrez, MBA	Personal Values to Foster the Inclusion of Minority-Owned Subcontractor Firms in the Procurement of Construction Services: A Preliminary Study	This study explores whether priming universalism values in construction project owners for whom these values are central can increase the perceived importance of the inclusion of underrepresented firms when selecting a general contractor. This hypothesis was preliminarily tested in a sample of civil engineering and architecture students (n=42), which was divided into two groups. Those in the experimental condition received the universalism prime whereas those in the control condition did not. Then, both groups completed a general contractor selection task, basing their choices on typical decision factors, including the utilization of small, women- and minority-owned (SWaM) firms in the project proposals. While results did not provide support for the initial hypothesis, subsequent analyses showed that the prime significantly affected how conformity, tradition, and self-direction values related to the importance that participants assigned to the inclusion of SWaM firms in pre-qualification judgements. These findings suggest a strong influence coming from social norms in the workplace that future research should address.
Yuqing Hu; Xiaohong Xu; Jiannan Cai; Shuai Li	Building Diversity in the Construction Industry: Examining Hiring and Performance Evaluation Practices for Equipment Operators under the Trend of Technology Transformation	The construction industry has been male dominated for a long time and has struggled with diversity and inclusion in the workforce, especially for construction equipment operators with only 2.7% of women. Meanwhile, the construction industry is also currently facing the emergence of new technologies such as construction robots. This trend may offer new opportunities for increasing diversity and inclusion in the workforce, but it also poses the risk of exacerbating existing inequities without a well-designed transformation process of hiring and performance evaluation. This study aims to examine the current state of hiring and performance evaluation practices for equipment operators and identify the barriers and challenges to creating a more diverse and inclusive workforce, especially in the context of the incorporation of construction robots. Specifically, through content analysis of job posters and a series of interviews with industry professionals, this study identifies the reasons that prevent women from entering into this occupation, the existing barriers, and the potential impacts of emerging technology adoptions on workforce diversity. The findings of this study will provide valuable insights for the construction industry to build a more diverse and inclusive workforce in the technology transformation process.
Guillermo Mejia-Aguilar, Ph.D.; Luis Fernando Arévalo-Viveros; Adriana Rocío Lizcano-Dallos; Edith Johanna Mendoza-Higuera	Learning Mathematics in Engineering Education: A Comparative Analysis Between European, Latin American and North American Contexts	Mathematics is fundamental to engineering and deserves careful attention from academics and researchers to provide strategies for improving the knowledge and skills of future practitioners. Although strategies to improve mathematics education have been widely published, there are still some problems in Latin American contexts. A systematic review of 54 articles on pedagogical experiences, published between 2000 and 2020, compared European, North American, and Latin American studies. The results show that European and North American studies are based on explicit theoretical approaches, while many Latin American studies do not explicitly have a theoretical framework. European studies are based on cognitivism and North American studies on cognitive constructivism, but Latin American studies do not refer to any approaches in particular. Trends in the pedagogical knowledge about mathematics education in engineering differ between countries. Therefore, engineering education research in Latin American contexts must provide more insights to improve mathematics education in engineering based on explicit theoretical frames.
Yunping Liang	Introducing A Sustainability Module to Civil Engineering Decision-Making Curriculum: A Students-as-Partners Design Planning	The AEC industry is undergoing an active transition towards sustainability practices. It is of great importance to feature sustainability in current decision-making curriculum. This paper introduces a qualitative case study on course redesign, which takes a pedagogical planning process known as "students-as-partners" through action research. The redesign has two overarching goals: (1) introducing knowledge and skills required for aligning decision-makings with SDGs, within a module of a CE decision-making course; and (2) developing working partnerships that brings together varied perspectives on how to best integrate the contents. A team containing an instructor and two students, supported by a curriculum developer and three faculty peer mentors. A new module including active learning activities (i.e., experimental, participatory, and transformative learning), learning assessments (formative, summative), and a teaching evaluation were created. A semi-structured interview was performed to measure the impacts of the redesign project. The results show that the purposes of SaP are met. The students reported increased engagement and motivation for learning, and instructor is enabled to develop laser-focused course contents. Take-aways were summarized from the project as enablers for common challenges. As a new pedagogical practice, limitations were identified, such as the selection of student participants and challenges on logistic communications.

Authors	Article Title	Abstract
Woei-Chyi Chang; Sogand Hasanzadeh, Ph.D.; Behzad Esmaeili	A PIONEERING RESEARCH ON NEURODIVERSE ADHD WORKFORCE IN THE FUTURE CONSTRUCTION INDUSTRY	While incorporating novel technologies aims to facilitate the inclusion of the future construction industry, the empirical investigation of diverse workers' performance is necessary to better understand the strategies to broaden their participation. The literature has rarely focused on inclusivity in terms of involving workers with various disabilities in the construction sector. Thus, this study aims to pioneer the discussion on inclusivity in construction by focusing on workers with Attention-deficit/hyperactivity disorder (ADHD). A future bricklaying worker-AI collaborative task was developed to examine workers' attentional allocation, situational awareness (SA), and productivity in future works. The results indicated that ADHD workers exhibited a lower SA of dynamic objects by focusing on the primary task with no increase in productivity, leading to lower overall performance. This study provided insights into (i) understanding ADHD workers' performance on human-AI teaming of future jobsites, and (ii) proposing strategies to facilitate inclusivity in the future construction industry.
Anthony Olukayode YUSUF; Andres Nieto Leal; Abiola Akanmu; Homero Murzi; Alireza Shojaei; Philip Agee	Usability Evaluation of a Web-based Platform for Connecting Professional and Educational Communities: Instructors' Perspective	Equitable access to communities of practice for future workforce development has been challenging for construction education instructors. This has been identified as one of the triggers of deficiencies and disparities in the skills and competence of new construction engineering graduates and consequently, dissatisfaction of employers. To address this challenge, a web-based collaborative platform was designed and developed to integrate both communities. This study presents a usability evaluation of the web-based platform from instructor's perspective using quantitative and qualitative analyses. The results from semi-structured interview, ratings of system usability scale, and trust scale were used to infer users' acceptance of the platform. The results reveal high acceptance of the platform by end-users as a tool to connect with practitioners for workforce development collaborations. The results also show required improvements to enhance users' experience. The study provides a guide for the usability evaluation of similar matching platforms.
Yiru Hou; Soowon Chang, Ph.D.	Review of Metaverse Technologies to Broaden Accessibility in Civil and Construction Engineering Education	As the number of distance students increases, they are facing challenges such as isolation, limited access to resources, and the need for hands-on experiences. Metaverse-based education can be a solution to broaden accessibility to educational content. Therefore, this study provides a review of metaverse technologies and their potential to broaden accessibility in construction and civil engineering education. We explore the opportunities of utilizing advanced technologies, such as IoT, AI, and Blockchain, as supporting tools for an educational Metaverse to enhance effectiveness and efficiency in the learning environment. The potential of Metaverse-based education is also discussed to provide a more inclusive and accessible educational experience, leading to better learning outcomes and improved safety practices in the construction industry. This study concludes by highlighting the need for further research to explore the full potential of these technologies in the Metaverse context and to develop effective educational strategies and frameworks that can leverage their capabilities.
Silvia Tijo-Lopez, Ph.D.; Oscar Humberto Portilla-Carreño; Guillermo Mejia-Aguilar	Inclusion of BIM and Sustainability in Construction Education through Capstone Design Projects	The construction industry demands a new generation of professionals with the expertise to solve complex problems and manage new technological conditions. An approach that satisfies this need comprises integrating Industry 4.0 knowledge, Building Information Modeling (BIM), and sustainability principles in construction education due to their collective potential to address the evolving demands and challenges of the construction industry. Each component brings benefits contributing to more efficient, innovative, and environmentally responsible construction practices and improving interdisciplinary project planning and control in collaborative environments. As of 2021, undergraduate construction management courses at Universidad Industrial de Santander (Bucaramanga, Colombia) include Capstone Design Projects implementing BIM and sustainability. The Capstone Design Projects require students to collaborate in person and remotely and develop autonomous learning skills to adapt to current technological tools. Through those projects, the authors identified the challenges and possibilities of proposing an academic training strategy to meet the needs of the construction industry. This study discusses the challenges, advantages, and disadvantages of including BIM and sustainability requirements in construction education and academic formation. Furthermore, other academic programs in architecture, engineering, and construction (AEC) disciplines seeking to implement improvement actions in their teaching-learning scenarios can reference these findings.
Xi Wang, Ph.D.; Sogand Hasanzadeh	Understanding the Technology Adoption Challenges in Construction Industry through Experiential Learning Models	Innovation and technologies play a vital role in meeting the evolving demands of the construction industry. However, the construction industry still needs to increase technology adoption. One of the main barriers that has been discussed is the industry's readiness to adopt new technologies. To prepare the next generation of professionals, construction education needs to lead the trend by understanding current construction industry challenges and teaching how to develop technological development solutions to improve the constructability of projects. This study applies Kolb's experiential learning model to engage construction management students in hands-on experience and reflections related to technology adoption theories with industry professionals. In addition, this study aims to engage students to gain insight into their skills, interests, and values in technology adoption. The results contribute to identifying the areas that need realignments to the construction management curriculum and provide a pedagogical framework for construction technology adoption for academia and practice.
Deniz Besiktepe, Ph.D.; Rodolfo Valdes-Vasquez	Challenges in Supplier Diversity and Inclusions Programs in the U.S. Construction Industry	Almost four decades ago, federal and local governments began incorporating Small and Disadvantaged Business Enterprise (DBE) programs into their construction projects. However, the private sector in the U.S. construction industry does not have similar requirements, and the benefits and challenges of these programs are not well understood. This exploratory study aims to identify the challenges of supplier diversity and inclusion programs in the U.S. construction industry. Based on current literature and Twitter analysis, the study found that most DBE construction–related companies lack financial power, resources, and experience. Some may find it difficult to enter already-established relationships between prime contractors and existing DBEs. In addition, contract requirements and project delivery types can be restrictive for them, and the scope of work can be either felt extensive or limited based on their resources. This study also provides future research directions for successfully implementing supplier diversity and inclusion programs in the U.S.
Yuhan Jiang, Ph.D.; Jerry Nave; Benjamin Uwakweh; Andrea Spool-White	Using iPad and 3D Simulation Technologies for Enhanced Student Learning in CM 224 Surveying Lab at North Carolina A&T State University	North Carolina A&T State University (NCAT) is the largest Historically Black University (HBCU) in the United States. CM 224 Surveying Lab is a 1 credit laboratory course for sophomores in Architectural Engineering, Civil Engineering, Construction Management, and Geomatics. Laboratory sessions of distance measurement, differential and profile leveling, and traverse and topographic surveying using surveying instruments of auto level and total station. The authors were awarded a Scholarship of Teaching and Learning project to use the University provided iPad and free apps of surveying instrument simulators to enhance students' pre-class preparation and learning. This paper presents the pre-lab and post-lab survey findings from the pilot study of Spring 2023 with 19 students enrolled in CM224. The survey results showed that the developed course materials have the potential to help the underrepresented minority students to understand the surveying instruments of auto level and total station, and the field procedures of differential leveling, traverse surveying, and topographic surveying.

Authors	Article Title	Abstract
Deepak Sharma, PhD; Rakeshkumar Mahto; Mansi Rastogi	Artificial Intelligence and Simulated Virtual Models in Teaching Construction Courses	Artificial Intelligence (AI) and Simulated Virtual Models (SVMs) have influenced construction practices by making activities safer, error-free, efficient, cost-effective, high quality, connected, and transparent. With significant advancements, it is anticipated that new courses will be needed to familiarize students with applicable AI and SVMs. A course to introduce AI and SVMs was offered at a state university but the students requested a more visual and hands-on approach to establish connections between real-world engineering challenges and AI. A ride-on excavator toy was converted into a robot replicating real-world excavator operations of pick-up dirt and dumping at a specific location. In addition, a 3D simulation SVMs was developed for enhancing teaching learning. The use of the robot as a hands-on tool created significant interest in civil engineering and computer engineering students. The learning experience was captured through a structured questionnaire survey, and the analysis shows higher levels of student interest in learning AI applications for construction.
Moustafa Y. Elsayed; Juyeong Choi	A Small-Scale Simulation Approach to Educate the Next Generation of Engineers about Sustainability Challenges in Building Demolition	About 90% of demolition waste is recyclable and reusable based on its inert nature; however, recycling and reuse of those materials are limited. One major barrier is the lack of demolition engineers' knowledge about sustainable demolition practices. Material separation for recovery at demolition sites is much easier and more effective but more time-consuming than separation for recovery at material recovery facilities. As such, careful demolition planning by construction/demolition engineers is critical; however, most of the U.S. construction engineering curricula do not cover demolition operations, thus lacking learning opportunities about sustainable demolition practices. In an effort to develop the next generation of demolition engineers with the sustainability mindset, we designed small-scale demolition simulation activities using 1:14 scale demolition vehicles where students will be exposed to sustainability challenges (e.g., on-site separation vs. off-site separation) and learned their critical role as construction/demolition engineers. To mimic real-world demolition sites, different structural waste was used, and students would be tasked with operating excavators and trucks in separating and moving different types of materials for recovery within set time constraints. Through the hands-on experience, students could find potential challenges with sustainable operations and develop critical thinking skills to devise solutions and strategies to tackle them.
Abdulaziz Alotaibi; John Gambatese	IMPACTS OF WORK SETTING AND TASK COMPLEXITY ON MENTAL WORKLOAD AND SAFETY: AN EXPERIMENTAL STUDY	The construction industry is considered one of the world's most demanding, labor-intensive work sectors. Mental workload states of construction workers are known to affect their performance and safety. Previous studies examined construction workers' perceptions and impacts of mental workload on safety and hazard identification. However, there is a need to investigate whether specific task characteristics impact mental workload, and the corresponding impact of the level of mental workload on worker safety when performing tasks. This study is being conducted to evaluate the impacts of task characteristics on mental workload and safety. The study includes an experiment using self-evaluation, galvanic skin response sensors, and observations in a controlled environment to determine participant mental workload and safety impacts. The targeted subject population consists of adults who can perform the study trials. The study findings reveal that task performance differs when subjects are in a hazard-free room compared to when they are located on an elevated work platform, and performance is impacted by increased task complexity. The results can be used to assess the mental workload of workers to improve safety. The study contributes an understanding of how task characteristics impact mental workload experienced by workers and their safety while performing the work.
Ahmed Al-Bayati	Human and Workplace Factors Contributing to PPE Non-Compliance: A Critical Assessment	Construction workers face many occupational hazards, and Personal Protective Equipment (PPE) is essential in protecting them. Unfortunately, numerous studies have shown that a significant percentage of injured workers did not use or adequately use the required PPE during incidents. The aim of the study is to examine the human and workplace factors contributing to PPE non-compliance to manage these factors more efficiently. A survey was conducted between February and April 2022 to collect opinions from construction professionals. A total of 184 valid responses were obtained. The study found that workers' attitudes and capabilities were among the most frequently cited human factors, while a lack of leadership and safety training were among the most frequently cited workplace factors. This study emphasizes the importance of addressing these factors to improve PPE utilization and reduce fatal and non-fatal injuries among construction workers, making it an important aspect of construction safety management. Finally, the findings can be utilized to develop an investigation learning program. that identifies the underlying reasons behind PPE noncompliance.
Ziyu Jin, Ph.D.	Building and Construction Safety Design for Emergency Evacuation: A Review of Evacuation Environment and Current Technologies	A well-designed evacuation plan is essential for protecting human lives during emergencies. Traditionally, architects have relied on building codes to guide the design of the means of egress, including the layout of exits and maximum travel distance, to ensure the safety of building occupants. However, advancements in technologies such as Building Information Modeling (BIM), computer simulation and modeling, and the Internet of Things (IoT) have enabled more effective and improved design, planning and guidance for emergency evacuations. It is also important for constructors to consider the safety of workers during the construction phase in emergency situations. This paper aims to examine the current state-of-the-art research on design and planning for evacuation during the design, construction, and operation phases. By adopting a systematic approach, the paper summarizes the various approaches and technologies involved in building and construction safety design for emergency evacuations, identifies gaps, and highlights areas for future research.
Bahaa Chammout; Muaz Ahmed; Islam El-adaway	Exploring the Root Factors Impacting Work Zone Accidents: A Mixed-Methods Study	Work zones are vital for improving infrastructural utilities, yet pose significant dangers for workers and drivers who are often unfamiliar with these areas. Prior research examined various aspects of work zone accident causation; however, the interrelationships and critical combinations among the contributing factors have not been fully analyzed. This study aims to identify the underlying factors contributing to work zone accidents and evaluate the different combinations among them. To this purpose, accident factors were derived from a total of 133 research articles addressing work zone safety. Social Network Analysis (SNA) and clustering were used to comprehensively model the identified factors. Additionally, Association Rule Analysis (ARA) was implemented to determine the critical associations among the identified factors. Results revealed that work zone design parameters are the most analyzed in the literature, while temporal considerations, regulatory factors, and driver characteristics have been relatively understudied. Moreover, the analysis shows that several critical interdependent relationships among these factors, such as the combined influence of inclement weather and driver behavior on navigating work zones, have been comparatively understudied in the literature. Ultimately, this study contributes to the body of knowledge by providing a comprehensive understanding of work zone accident causation.
Ahmed Al-Bayati	Assessing Usability of the Construction Safety Culture and Climate Framework: A Crucial Method for Advancing Construction Safety	The construction industry has long struggled with safety performance, with many concerns surrounding the industry's ability to maintain high levels of safety. One effective approach to improve safety performance is through the use of construction safety culture and climate frameworks. However, the construction industry has faced several challenges in effectively utilizing these frameworks, including confusion due to the availability of multiple frameworks and the interchangeable use of definitions. To address these challenges, a distinct and practical framework for construction safety culture and climate has recently been proposed. The present study aimed to evaluate the perceived usability of this framework. To achieve this goal, an online survey was designed and administered, resulting in 77 valid responses. The analysis of the survey responses revealed that the participants generally perceived the framework's concepts positively. However, some aspects of the framework require improvement to enhance its usability further. The study's findings highlight the importance of adopting effective safety culture and climate frameworks in the construction industry and the need for ongoing evaluation and improvement to ensure their relevance and efficacy. As such, this research can contribute to improving the overall safety performance in the construction industry.

Authors	Article Title	Abstract
Adedeji Olushola Afolabi, Ph.D.; Oluwalobamise Deborah Orafidiya	DEVELOPMENT OF A WEB-BASED WEAR-FIT SYSTEM FOR CONSTRUCTION WORKERS' PPEs.	In most construction sites in Nigeria, compliance with wearing Personal Protective Equipment (PPE) is poor. Some construction workers have alluded to the degree of discomfort experienced while wearing PPEs on construction sites. Therefore, this study aimed to develop a web-based wear-fit system to involve construction workers in the process of PPE selection. The study used a cross-sectional survey research design which utilized an electronic questionnaire instrument in this survey. A total of 80 construction workers participated in this study. They were selected using a quota-purposive sampling technique. The data obtained were analyzed using frequencies, percentages, mean score tests, and analysis of variance (ANOVA) tests. The study revealed that construction workers experienced the most comfort in wearing Reflective Jackets, Lab coats, and Coverall or Aprons. In contrast, the slightest comfort was experienced using Hand gloves, Nose Masks, and Respirators. The study developed a web-based wear-fit system for construction workers' PPEs to aid comfort and compliance in wearing PPEs on construction sites. The study's contribution is mainly clamoring for the involvement of workers in the PPE selection process using electronic platforms such as the web-based wear-fit system.
Jayson Francois; Mohamed Khalafalla, Ph.D.; Doreen Kobelo	Preventing Drowsy Driving Accidents in Construction Industry Using Computer Vision and Convolutional Neural Networks	Construction machine operators are at risk of drowsy driving, which can lead to accidents and injuries on job sites. Job site injuries are a major concern in the construction industry, with operators of heavy machinery being particularly vulnerable. According to the U.S Bureau of Labor Statistics, in 2019, the fatal injury rate for workers in the construction industry was higher than the national average for all workers, and many of these fatal injuries were caused by heavy equipment. To address this issue, a method using computer vision and edge devices has been proposed to detect drowsy construction machine drivers using convolutional neural networks (CNNs). A dataset of images showing signs of drowsiness was constructed and used to train the CNN. After training, the neural network can score the testing images and predict if the subject in the image is drowsy or non-drowsy. This technology has the potential to greatly improve safety in the construction industry by alerting drowsy operators before an accident occurs, and thus reducing the risk of accidents and injuries on job sites. The implementation of this technology can help in reducing job site injuries and improve the overall safety of construction sites.
Ali Hassandokht Mashhadi, M.Sc; Abbas Rashidi; Nikola Marković	Probabilistic Versus Non-probabilistic Machine Learning Approaches for Estimating the Severity of Crashes in Construction Work zones	Roadway work zones often present hazardous conditions for drivers, pedestrians, and construction workers. Understanding the factors contributing to work zone crashes and their severity can assist the Department of Transportation (DOTs) in safety management and planning. Accordingly, this study investigated the effect of freeway work zones on the severity of crashes by employing machine learning algorithms. The model was developed using crash data and construction zone information from Utah between 2017 and 2021. This study compares the performance of probabilistic and non-probabilistic machine learning models in predicting work zone crash severity using the KABCO severity scale. All three models achieved promising accuracy levels, with Extreme Gradient Boosting (XGB) achieving the highest accuracy at 86%, followed by Gaussian Naïve Bayes (GNB) with an accuracy of 76% and Complement Naïve Bayes (CNB) with an accuracy of 74%. The findings of this study offer valuable insights for the safety management plans of DOTs.
Josiane Isingizwe; Ricardo Eiris; Ahmed Al-Bayati	Immersive Storytelling Safety Training to Enhance Trainee Engagement: Pilot Study for Fall Hazards in the Residential Construction Sector	Fall accidents remain the leading cause of fatalities in the United States. Training programs are often used to mitigate fall accidents, but they lack effectiveness in terms of engagement experienced by trainees. This pilot study developed an immersive storytelling safety training approach to increase trainee engagement during safety training focusing on residential industry fall hazards. A between-subject experimental design was used to comparatively evaluate trainee engagement across two conditions – (1) immersive storytelling and (2) immersive non-storytelling. Trainee behavioral, cognitive, and emotional engagement was measured using eye-tracking data and surveys. Twenty students from construction-related programs participated in this pilot study. While the results suggest some portions of the training that can benefit from the use of the storytelling technique, no significant statistical differences were observed across behavioral, cognitive, or emotional engagement. This study highlights how immersive storytelling safety training can be used as an alternative method for fall hazard safety training.
Kaushik Bhattacharjee, Ph.D. (Pursuing); Nikhil Bugalia	Do projects of different sizes face differences in safety-critical complexities? Empirical evidence from and implication for the construction sector of India	The existing literature emphasizes developing safety recommendations specific to small, medium, and large construction projects' unique needs. Research has also shown that enhanced complexities can negatively affect the safety performance of construction projects. However, whether projects of different sizes perceive complexities differently has not been examined empirically in the existing literature. To address the gap, the current study examines how differently sized construction projects perceive the technical, organizational, and environmental complexities while managing safety. An existing survey was adapted, and 180 responses were obtained from practitioners across small, medium, and large construction projects. The findings reveal that most complexities are perceived as critical throughout the industry, and the perception of technical, organizational, and environmental complexities differs within projects of different sizes. The study's findings significantly advance understanding of the safety-critical complexities confronting projects of varying sizes and aid in developing safety improvement recommendations tailored to their specific needs.
Tejal Mulay; Mohamed Khalafalla, Ph.D.; Shonda Bernadin	Acoustic Emotion Recognition for Improved Safety in the Construction Industry	In the construction industry, clear communication is vital for optimal teamwork and performance. Yet, diverse languages, accents, and continuous worksite noises often impede speech clarity, leading to misunderstandings and consequential errors. Addressing this challenge, the presented research introduces a speech emotion recognition algorithm tailored for construction. Unlike prior algorithms emphasizing language content, this approach centers on speech features, bridging a significant gap in construction-specific applications. The algorithm aims to identify four key emotions: anger, happiness, sadness, and neutrality, using six distinct acoustic features: pitch, intensity, frequency formants, jitter, shimmer, and zero crossing rate. Leveraging these features collectively enhances system accuracy. Designed in MATLAB, the decision-tree-based method calculates confidentiality intervals for each feature and is specifically developed for speaker-dependent emotion recognition. Remarkably, the algorithm secured an 86% accuracy rate in detecting anger, outperforming existing models. By recognizing and addressing the emotional states of workers, this method holds the promise to greatly enhance safety on construction sites, averting potential hazards.
Kehinde Abdulsalam Elelu, Ph.D; Tuyen Le; Chau Le	Multiple-Channel Audio Construction Equipment Dataset Preparation for Sound Detection and Localization to Prevent Collision Hazard	Construction workplaces often face unforeseen struck-by equipment hazards, leading to severe injuries and fatalities for workers. Detecting and localizing equipment sounds using multi-channel audio data has drawn interest in research. However, collecting such data for developing sound detection and localization machine learning models is challenging. Physical recordings on site required for deep learning are often infeasible due to the lack of proper sound attribute labels from heterogeneous construction sounds. This paper introduces a novel method for synthesizing overlapping and non-overlapping sound datasets in a three-dimensional space, utilizing Pyroomacoustics. The approach uses single sound data with attributes like start time, end time, azimuth, and elevation as microphone input to generate multi-channel audio output. The study successfully simulates 5025 distinct scenario audios for both datasets, utilizing seven single-sound audiotapes. The generated large dataset can train neural network models capable of localizing equipment collision hazards in construction sites.

Authors	Article Title	Abstract
Wei-Hsuen Lee; John Gambatese; Matthew Hallowell; Chukwuma Nnaji	Impact of Last-Minute Changes on Construction Safety	Construction activities depend highly on many conditions, such as human factors, weather, and materials. These conditions are dynamic and may involve many unexpected changes that impact current or subsequent activities. Unexpected changes that occur at the last minute when there is little time to respond to the change and pressure to complete the work, may lead to safety issues. However, there is no clear definition for a last-minute change and little information on how last-minute changes impact safety performance. This research presents a definition of last-minute change and utilizes an incident review rubric based on experts' recommendations and literature reviews to assess the relationship between last-minute changes and safety. The researchers analyzed 179 fatality incidents reported by the National Institute for Occupational Safety and Health (NIOSH) and associated states as part of the Fatality Assessment and Control Evaluation (FACE) Program. The analysis verified that many fatality incidents (29%) are related to last-minute changes. Moreover, the incidents can be categorized according to energy type and change characteristics to help understand the impact of last-minute changes on construction safety. The research results contribute knowledge to help construction teams understand the safety impacts of last-minute changes and prevent incidents caused by last-minute changes.
Peiyi Lyu; Siyuan Song; Raissa Seichi Marchiori; Xi Chen; Solomon Ajasa	Exploring the Influence of Extreme Weather on Construction Worker Safety	Extreme weather events related to climate change present injury risks to construction workers. The increased exposure to these extreme conditions leads to heightened physical and mental health challenges among these workers. This study aims to investigate the impact of extreme weather events on construction worker safety, utilizing historical accident data from Occupational Safety and Health Administration (OSHA) and extreme weather event data from National Weather Service (NWS) from 2015 to 2021. By employing a matched-pair analysis, the research explores the intricate relationship between extreme weather and construction worker injuries. The results show that extreme heat, flood, hail, and wildfire increase the risk of construction accidents. Under extreme weather scenarios, fall accidents and heat-related illnesses are more likely. Findings will help decision-makers understand the challenges faced by construction workers under extreme weather. Identifying the most dangerous weather event for construction workers can aid in task allocation and safety planning.
Raissa Seichi Marchiori; Siyuan Song; Solomon Ajasa; Peiyi Lyu; Xi Chen	ASSESSING USABILITY, FREQUENCY, AND EFFICIENCY OF FALL HAZARD PREVENTION DEVICES IN CONSTRUCTION: DEVELOPMENT OF A COMPREHENSIVE QUESTIONNAIRE FOR EVALUATION	Comparing to other industries, the construction sector has the most annual worker fatalities. One of the most dangerous jobs includes high-rise construction workers. There are many novel technological solutions to prevent and detect fall hazards, however, there is a lack of verifying which kinds of these technologies solutions has been used in the construction site. For this analysis, the first step consists of using the most recent literature review to assess a list of technology devices for fall protection. The second step consists of the development and distribution of a questionnaire that aims to assess the frequency of safety device usage and evaluate their effectiveness and usability through rating scales. The main findings indicate that the selected technological devices to mitigate fall hazards have not gained widespread adoption among general contractors. One of the primary factors contributing to this is the limited awareness and understanding of these devices.
Namgyun Kim; Changbum Ryan Ahn; JungHo Jeon	Detecting Activities Exposing Construction Workers to the Risk of Developing Carpal Tunnel Syndrome	Carpal Tunnel Syndrome (CTS) is a repetitive-motion injury that occurs when the median nerve is regularly compressed or squeezed. CTS causes pain, numbness, tingling, and weakness in the hand and wrist, which can affect workers' ability to safely perform their job tasks. The National Institute for Occupational Safety and Health (NIOSH) recognizes that construction workers are at high risk for developing CTS due to the repetitive motions, awkward working posture, and forceful exertions required in many tasks. Specifically, overhead working postures and sustained postures with the wrist bent are the major causal factors of CTS among construction workers. However, to date, there has been little discussion about assessing the risk of CTS among construction workers. To this end, this study explores an approach to detect activities exposing workers to the risk of developing CTS by assessing workers' hand movements. The inertial measurement unit sensors were attached to a participant's wrist. The convolutional neural network-based approach was adopted to classify workers' postures and activities. The result validates the feasibility of assessing the development of construction workers' CTS and provides a foundation for the implementation of ergonomic interventions to reduce the risk of CTS.
Solomon Ajasa; Siyuan Song; Xi Chen; Raissa Marchiori	THE APPLICATION OF BIM-BASED TECHNOLOGY TOWARD FALL HAZARD MITIGATION IN CONSTRUCTION	Falls remain the leading cause of occupational fatalities and accidents in the United States construction industry. Currently, the incorporation of Building Information Modelling (BIM) into construction practices has proven to be a valuable tool for eliminating general hazards on construction sites. This study investigated how the application of BIM technology has successfully contributed towards the mitigation of fall hazards at the construction and renovation phases of a construction project. Furthermore, the study explored how personalized monitoring has improved workplace safety while performing a task on the construction site. The study was conducted through a systematic review of past studies on the different general applications of BIM technology to construction safety engineering and design. The findings of this study highlighted the significant contribution of BIM application towards fall prevention measures during the construction and renovation phases. This study showed the tremendous potentials of BIM and developed an approach to integrate BIM with other technologies for real-time detection and prevention of fall hazards in the construction industry.
Evan C Stoddard, B.S. Civil Engineering; Siddharth Bhandari; Fred Sherratt	What Mental Health Stressors do Hispanic Construction Workers Actually Care About?	Increasing suicides amongst construction workers has put the spotlight firmly on understanding how the industry is contributing to the poor mental health of its employees. Studies have identified several work-related attributes that negatively impact the mental health of workers. However, much remains unknown on which of these work-related stressors are perceived by Hispanic workers as most relevant or impactful. Using self-report survey, the authors analyzed the responses of 91 Hispanic construction workers who were asked to rank their perceived importance of stressors commonly associated with the construction industry. The results were analyzed across Hispanic workers employed to work primarily in the field vs. those employed to work in desk jobs within the construction industry. The findings presented provide foundational knowledge that would support the determination, testing and creation of personalized interventions that organizations would need to consider improving the mental health of employees from different socio-economic backgrounds.
K. Joseph Shrestha, Ph.D.; Jeff Canon; Ahmed Adelaty; Krishna Kisi	COMMON BUILDING CONSTRUCTION CODE VIOLATIONS: CASE STUDY	Most cities, counties, and states in the U.S. adopt popular modal building codes such as the International Residential Code (IRC) and the International Building Code (IBC) for their jurisdictions with or without amendments. These codes provide a comprehensive set of requirements for residential and commercial construction. Inspectors from city, county, and state use these codes to ensure that the buildings being constructed in their jurisdictions meets the minimum standard to protect health, safety, and welfare of the occupants. If the construction is not up to the code, building inspection will fail, and the issues need to be fixed before continuing the construction. Such inspection failures can delay the project, increase the construction cost, and negatively impact the reputation of the builders. Such inspection failures can be reduced by identifying and understanding the most common building code violations from past projects. This study identifies the five to 12 most common building code violations for each of the five categories of inspections: a) framing, b) plumbing, c) electrical, d) gas, and e) mechanical. The findings can be shared with builders and homeowners to educate them about the common code violations which can reduce the number of building code violations in the future.

Authors	Article Title	Abstract
Arnaldo Bayona; Nathalie Moyen; Matthew Ryan Hallowell; Siddharth Bhandari	Exploring the hypothesized mechanisms by which serious injuries and fatalities impact business performance	Beyond the extreme human cost, serious injuries and fatalities (SIFs) also negatively impact the business performance of construction firms. The mechanisms operate through tangible factors (e.g., downtime, reduced productivity) and intangible factors (e.g., lower employee morale, loss of company reputation). To explore the significance and interactions of the factors influenced by SIFs, 15 safety professionals representing various industry sectors spanning from construction to technology, consulting, and insurance firms were surveyed. Specifically, they rated the extent to which each of 13 business factors impacted by SIFs in turn adversely influence one another. A network analysis depicts the relationship between these factors and identifies the most influential ones. Preliminary findings suggest that both tangible and intangible factors influence business performance, with intangible factors perceived as more salient after a SIF occurs. Company reputation and managerial bandwidth are the most prominent factors, while third-party prequalification, lawsuit probability, and productivity were ranked as less relevant. In contrast to contractors, owners perceive workers' mental health as a more important factor influencing the business bottom line when a SIF occurs. This study adds to the literature on how safety performance impacts firms' profitability by exploring the influence of each factor and their interactions with one another.
Shayan Shayesteh; Houtan Jebelli	EVALUATING THE FEASIBILITY OF PERSONALIZED HEALTH STATUS FEEDBACK TO ENHANCE WORKER SAFETY AND WELL-BEING AT CONSTRUCTION JOB SITES	Advancements in wearable sensor technology and AI provide an excellent opportunity to monitor the health status of construction workers on-site. However, there is still a lack of efficient means of promptly communicating this information to workers without violating their privacy. This study evaluates the feasibility of providing personal feedback to construction workers regarding their health status while carrying out routine tasks. The proposed mechanism employs machine learning models and a decision tree to provide workers with timely private feedback and corresponding recommendations or risk mitigation strategies. As such, an experiment was conducted to evaluate the performance of the proposed feedback system as well as users' perception of its usability. The findings revealed that the proposed feedback system could provide the workers with accurate and effective feedback regarding their health status, indicating the great potential to enhance worker safety and well-being at construction job sites.
Hongtao Dang; Sathy Rajendran; John Gambatese; Mandi Kime	Training Development of Infectious Diseases for Construction Workers	Construction workers may be at an elevated risk of contracting infectious diseases due to unsanitary conditions and constant exposure to health hazards on job sites. Poor sanitation is one of the major causes of the spreading of infectious diseases. Construction workers with poor or limited sanitary conditions may struggle with safe drinking water, hand washing, access to clean toilets, and properly handled and serviced food. Some examples of infectious diseases include the common cold, flu, tuberculosis, pneumonia, and human immunodeficiency virus/acquired immunodeficiency syndrome (HIV/AIDS). This paper develops several training scenarios on infectious diseases to keep construction workers safe and healthy in the construction industry. The authors collected documents and scenarios on four topics: potential exposures to infectious diseases, common causes and types of infectious diseases, precaution and prevention strategies, and control and protection plans. The authors analyzed scenarios collected from real-world construction projects and synthesized them in training manuals. The developed manuals are publicly available for corporate trainers and university educators to train construction workers and students. The research outcomes provide preliminary guidance and effective practices for training workers and preventing infectious diseases on construction job sites.
Qichang Dai; John Gambatese; Abdulaziz Alotaibi	RELATIONSHIP BETWEEN LEAN CONSTRUCTION PRACTICES AND CONSTRUCTION INDUSTRIALIZATION METHODS	Lean construction and construction industrialization have been the focus of the construction industry in recent decades. Lean construction has been shown to reduce waste and uncertainty, and construction industrialization has a positive effect on improving efficiency and safety. However, there is limited evidence in the industry that lean construction has sufficient potential in the context of evolving processes and methodologies. The present study identifies and quantifies the value, waste, and impact factors of lean construction practices and construction industrialization methods through a literature review, survey, and interviews. Interviews were used to validate the results of the literature review and survey. This study explores the relationship between lean construction and construction industrialization, and whether they reinforce each other to provide added benefit. The results of the study were used to assess 14 lean construction practices and four construction industrialization methods, along with their value and waste. The study findings reveal that the combination of the two methods can play a role in promoting each other in some instances. The contribution of this study to knowledge is an attempt to combine the application of lean construction practices and construction industrialization methods for better performance by demonstrating six aspects associated with construction projects.
Qinghao Zeng, Ph.D.; Botao Li; Pardis Pishdad-Bozorgi	ANALYZING THE RELATIONSHIP BETWEEN INDOOR ENVIRONMENTAL QUALITY AND OCCUPANTS' BEHAVIORS AND HEALTH FOR INDUSTRIAL BUILDINGS: A SYSTEMATIC LITERATURE REVIEW	Sustainable buildings are becoming increasingly desired. One of the specific aspects for evaluating sustainability is Indoor Environmental Quality (IEQ) which affects Occupants' Behaviors and Health (OBH) directly. While most of the research focus on high occupancy-buildings, this research is aiming at investigating and categorizing the IEQ factors that influence OBH of people working inside industrial buildings. This paper presents the state-of-the-art literature on IEQ factors and propose potential mitigating solutions to problems caused by unhealthy IEQ. Through a systematic literature review of bibliographical databases, and through quantitative analysis, this research identifies that the most influential features of IEQ on OBH. The most widely studied IEQ factors by researchers are "thermal conditions" and "indoor air quality", which directly affects clothing insulation and physical activity level of the occupants working in the industrial buildings. Potential solutions are highlighted based on the case studies from the literature. The contribution lies on describing the relationship between IEQ and OBH, as well as technological solutions for improving indoor environment.
Roya Raeisinafchi; Siddharth Bhandari; Logan Perry; Alex Albert	Construction Safety Training: Engaging Techniques and Technology Adoption Perspectives	Ensuring the effectiveness of safety training programs is essential for protecting construction workers and mitigating the occurrence of accidents, injuries, and fatalities on job sites. Despite ongoing efforts to improve the design and implementation of safety training programs, challenges persist, particularly in engaging trainees. This study aims to identify the techniques used by trainers to promote engagement within safety training programs. To this end, trainers from construction companies across the North America were surveyed. Thematic analysis of the responses from 195 participants revealed five key themes of engaging techniques: collaborative learning, experience-based learning, hands-on group activities, maintaining a comfortable and relaxed training environment, and effective communication techniques. Additionally, the analysis also indicated that trainers have a positive, albeit cautious attitude towards using new technologies to promote engagement from trainees. The findings of this study will aid in the development of more engaging and effective safety training programs.
Xi Hu; Rayan H. Assaad	Intelligent Inspection and Warning Robotic System for Onsite Construction Safety Monitoring Using Computer Vision and Unmanned Ground Vehicle	Worker safety is a critical factor to construction success and should be properly monitored and managed at jobsites. While many vision-based worker safety inspection/monitoring systems were developed by previous studies, they commonly suffer from low mobility of stationary cameras and the lack of taking real-time actions. To address these challenges, this paper proposes an intelligent inspection and warning robotic system using an unmanned ground vehicle (UGV). This robotic system (1) automatically and movably detects construction workers and personal protective equipment (PPE) using state-of-the-art YOLOv8 architecture deep learning-based computer vision model, and (2) dynamically warns/reminds workers of wearing the undetected required PPE. The developed system includes: (1) a robotic vehicle prototype to provide mobility, (2) a high-resolution camera to collect visual data, (3) a speaker for auditory warning/reminder information, and (4) a single board computer for real-time data processing. The proposed system was tested at a real construction site. Field test results showed that it can reliably detect construction workers and their PPE and then play voice messages to remind them to wear the required PPE. Ultimately, this paper contributes to the body of knowledge by developing an intelligent UGV-based system for improving onsite construction safety management.

Authors	Article Title	Abstract
JuHyeong Ryu, Ph.D.; Carl Haas; Eihab Abdel-Rahman	Postural Assessment Criteria for Manual Material Handling in Masonry Work	The construction industry is one of the industries with the highest rates of musculoskeletal disorders (MSDs). Masons are particularly susceptible to overexertion and back injuries due to the physical demands of their jobs and, thus, are more susceptible to MSDs. While previous research established that expert masons use different strategies to perform their work while experiencing reduced joint loads and increased productivity, it was unclear which movement strategies they used. This study analyzed the movements of novice, apprentice, and expert masons to characterize the postural characteristics of expert and in-expert techniques. Novice, apprentice, and expert masons' kinematics are analyzed for a standard concrete masonry unit wall-building activity and investigated the key markers of these techniques, such as trunk flexion and twisting. Masonry movement techniques refer to the kinematics and postures that the expert journeymen adopt while working. The results of this study describe the movement strategies experts use in comparison to inexpert groups (novices and apprentices).
Jie Li; Xiaowei Luo	Towards an EEG-based Approach for Detecting Falls from Height Hazards using Construction Workers' Physiological Signals	Falls from height (FFH) are the leading cause of fatalities in construction. Traditional methods for detecting FFH hazards have great limitations due to workers' desensitized risk perception or supervisors' subjective inspection. Electroencephalogram (EEG) provides an objective metric for overcoming the limits. Early hazard detection can be facilitated by measuring individual physiological states, exhibiting atypical patterns when workers face risks. Although previous work covered hazard detection using EEG, there is a scarcity of FFH-specific emphasis. How to determine appropriate EEG features for detecting FFH hazards was still not discussed. Therefore, this paper evaluated the validity of an EEG-based approach for detecting FFH hazards by establishing five supervised machine learning models. EEG data was collected from 20 front-line construction workers. Two EEG feature selection techniques were included and performances of five classifiers were compared. Support Vector Machine was found to have the best overall classification performance for FFH hazard detection when using the filter-based feature selection approach, with a high accuracy of 79.20%. Adopting the proposed approach has the potential to bring managerial benefits in proactive safety management. It sheds light on the development of an early warning system through real-time monitoring of physiological states of construction workers while working at height.
Moein Younesi; Youjin Jang; Kwonsik Song	Physiological Signal Analysis for Awkward Working Postures of Construction Workers using Wearable Biosensor	Awkward working postures are deviations of body parts from their neutral position. Construction workers who hold these postures for a long term are exposed to discomfort, reducing safety and productivity. While several studies have been conducted to assess the effect of awkward postures on human physical and musculoskeletal system like muscles and joints, little research has attempted to explore the impact of awkward posture selection on physiological system. This investigation is necessary for a broader comprehension of risky factors resulting from the awkward working postures of construction workers. Accordingly, this study aims to evaluate if and how physiological responses such as heart rate and skin temperature will be affected by awkward working postures. The study utilizes a non-invasive wearable wristband biosensor to measure and monitor participants' physiological signals during performing construction tasks in a simulated laboratory experiment. Signals in natural and awkward postures are then analyzed and further comparisons are discussed. The results show that postures have significant impacts on physiological patterns, specifically when sustained for a longer duration. The findings of this study are expected to be used for the recognition of awkward working postures and further for the safety management interventions of worker behavior.
Lynn Shehab; Elyar Pourrahimian; Farook Hamzeh	Bridging Construction Workers' Minds and Bodies: A Conceptual Approach	Cognitive and physiological abilities are essential in construction projects, which involve a complex and dynamic array of tasks and decisions. Cognitive abilities, such as problem-solving, decision-making, and critical thinking, are used to identify potential issues and develop innovative solutions, while physiological abilities, such as physical strength, endurance, and dexterity, are necessary for performing heavy and critical physical tasks. Both abilities are essential for communicating effectively within the team, adapting to unexpected changes, adjusting the plan as necessary, and implementing required changes. While several studies have explored cognitive and physiological abilities generally, this paper aims to conceptualize the relationship between cognition and physiology in construction to bridge construction workers' psychology and physiology through a conceptual approach. After defining cognitive and physiological abilities, links among them are drawn, and their value for different social and personal skills in construction, such as collaboration and improvisation, is explored.
Srijeet Halder; Saeid Alimoradi; Kereshmeh Afsari	A Computer Vision Approach To Assessing Work-Related Musculoskeletal Disorder (WMSD) Risk In Construction Workers	Work-related Musculoskeletal Disorders (WMSDs) are a group of painful disorders of muscles, tendons, and nerves caused due to improper work postures prevalent in construction workers. These disorders can cause temporary and/or permanent disabilities and seriously affect workers' livelihoods. Previous research has applied Machine Learning (ML) for the recognition of WMSD risk. However, previous research used inertial sensors strapped to the body to measure the angle of the body parts. These sensors are expensive and uncomfortable to wear while working. This research aims to eliminate the need for additional hardware through the use of computer vision. In this project, an ML pipeline was built to identify WMSD risk from workers' images. A pre-trained ML framework called Mediapipe Pose was used to generate features from the images. The relative positions of these landmarks were then used as the input for an Artificial Neural Network (ANN) to classify ergonomic and non-ergonomic postures using the supervised learning approach. After hyper-parameter tuning, 100% training and 99.96% validation accuracy were achieved. Finally, the trained model was tested on real-life videos of construction workers and found to perform satisfactorily.
S M Jamil Uddin, MSc; Nafisa Tabassum; Anto Ovid; Abdullah Alsharef; Alex Albert	Measuring Mental Fatigue in Construction: State of the Science and Future Opportunities	Mental fatigue in construction is a growing concern as it can negatively impact worker productivity, safety, and overall job performance. Factors such as long work hours, monotonous tasks, and high stress levels can contribute to mental fatigue. This can lead to decreased decision-making capabilities, increased errors, and a higher risk of accidents on the job site. To combat this challenge, studies have focused on measuring mental fatigue in construction using technologies such as EEG, Eye-tracking, and Virtual Reality among others. This study focuses on capturing the state of the science related to the utilization of technology to measure mental fatigue of construction workers. To achieve the objectives, relevant literature was searched on one of the largest scientific databases, Web of Science. Upon extracting the relevant research articles, the articles were investigated thoroughly to identify the technology adopted to measure mental fatigue, the targeted construction activity, and future opportunities to tackle mental fatigue in construction. The findings of this study will contribute to the body of existing knowledge by paving the pathway for future research on measuring and managing mental fatigue.
Mohamed Marzouk; Toka Taha; Ahmed Abdelaty	Assessing Safety Training in the Egyptian Construction Industry: A Comparative Analysis	The construction industry in Egypt is booming at unprecedented rates. The Egyptian government is spending a significant amount of its budget to expand the country's infrastructure systems and build new cities and business hubs. As a result, there is pressure to finish many government-funded projects in record time, which can come at the cost of workforce safety. Additionally, the safety measures adopted by construction companies in Egypt vary significantly according to organizational cultures and workers' behavior. This paper investigates the current safety training content in the Egyptian construction industry via content analysis. The paper focuses mainly on scaffolds and falling object hazards as it is one of Egypt's leading causes of accidents. Safety assessment tests were collected from a large-sized construction company and compared to the safety regulations of OSHA. Using content analysis to investigate the collected safety assessment tests, it was found that most of the questions addressed the various areas covered in OSHA. Thus, it was concluded that safety training programs are aligned with the safety regulations in OSHA. Additionally, the study identifies the gaps between OSHA and Egypt's current assessment to provide recommendations to improve the safety assessment tests to address all hazards concerning OSHA.

Authors	Article Title	Abstract
Gunwoo Yong; Meiyin Liu; SangHyun Lee	Automated Captioning for Ergonomic Problem and Solution Identification in Construction Using a Vision-Language Model and Caption Augmentation	Construction tasks impose high ergonomic risks, making it crucial to observe ergonomic problems (e.g., actions and postures associated with ergonomic risks) and provide solutions. As manually identifying problems and solutions is time-consuming and subjective, there has been extensive development toward automation through computer vision-based or sensor-based applications. Nevertheless, most existing studies have focused on assessing ergonomic risks, leaving tasks of recognizing problems and generating solutions to ergonomists. However, ergonomists are scarce in construction. Therefore, this study aims to automatically identify ergonomic problems and solutions from images by way of image captioning. To overcome limitations of traditional image captioning models, incapable of incorporating knowledge of ergonomics, this study applied a vision-language model (VLM) with caption augmentation leveraging text-based knowledge. The authors tested five work-scenarios and showed superior performance of the proposed VLM over the traditional model. This result showed the feasibility of the proposed approach in identifying ergonomic problems and solutions.
Yogesh Gautam; Houtan Jebelli	Autoencoder-based Motion Artifact Reduction in Photoplethysmography (PPG) Signals Acquired from Wearable Sensors During Construction Tasks	Construction workers often experience high levels of physical and mental stress due to the demanding nature of their work on construction sites. Real-time health monitoring can provide an effective means of detecting these stressors. Previous research in this field has demonstrated the potential of photoplethysmography (PPG), which represents cardiac activities, as a biomarker for assessing various stressors, including physical fatigue, mental stress, and heat stress. However, PPG acquisition during construction tasks is subject to several external noises, of which motion artifact is a major one. To address this, the study develops and examines an autoencoder network—a special type of artificial neural network—to remove PPG signals' motion artifacts during construction tasks, thereby enhancing the accuracy of health assessments. Artifact-free PPG signals are acquired through subjects in a stationary position which is used as the reference for training the autoencoder network. The network's performance is examined with PPG signals acquired from the same subjects performing multiple construction tasks. The developed autoencoder network can increase the signal-to-noise ratio (SNR) by up to 33% for the corrupted signals acquired in a construction setting. This research contributes to the extensive and resilient use of PPG signals in health monitoring for construction workers.
Pei-hsin Lin; Aritra Pal; Jacob J. Lin; Shang-Hsien Hsieh	Individual Component Detection of a Scaffolding Assembly for Vision-based Safety Check	Fall from heights accounts for 50% of the accidents on construction sites, and 20% are scaffolding-related. Therefore, ensuring the safety of scaffolding installation can significantly reduce accidents onsite. Scaffoldings are erected by assembling components such as footboards, standards, ledgers, and cross-bracings. A safety check must ensure all necessary components in a scaffolding unit are installed in the correct order. While vision-based scaffolding detection has become more accurate with the recent success of deep learning detection algorithms, the detection of individual scaffolding units and their components is still challenging due to the scaffolding component size and shape. The size and shape factors pose many difficulties for the vision algorithms to detect thin structures and components of similar looks. To address the difficulties, this study proposes a method to segment the scaffolding units and components from a point cloud using a deep learning-based 3D semantic segmentation model. After segmentation, a rule-based approach can be applied to check the missing components. The method has been implemented in a construction project, and the preliminary results confirm its applicability for drawing workers' attention to the missing scaffolding components, thereby improving the construction site's safety.
Nihar Gonsalves; Abiola Akanmu; Philip Agee; Alireza Shojaei; Xinghua Gao	Construction Workers' Behavioral Intention Towards a Passive Back-Support Exoskeleton: Application and Extension of UTAUT Model	Exoskeletons are promising solutions to address the prevalence of back injuries in the construction industry. However, scarce evidence is available regarding the acceptance of exoskeletons among construction workers. Using the Unified Theory of Acceptance and Use of Technology (UTAUT) model, this study explored construction workers' intention to use an exoskeleton. A field study was conducted wherein pipe and concrete workers performed construction tasks with a passive back-support exoskeleton. Data on workers' perceived usability, discomfort, exertion, safety, and social influence from using the exoskeleton were collected. Spearman's correlation analysis indicates a strong correlation between perceived ease of use, comfort, performance, safety and social influence, and workers' intention to use the exoskeleton. However, discomfort and exertion did not have an impact on workers' behavioral intentions. The findings of this study contribute to the UTAUT model and provide evidence on the drivers of workers' acceptance of passive exoskeletons in the construction industry.
Nihar Gonsalves; Abiola Akanmu; Alireza Shojaei; Philip Agee; Xinghua Gao	A Conceptual Framework for Implementing Passive Wearable Robots in the Construction Industry	Wearable robots have the potential to address the occurrence of work-related musculoskeletal disorders in the construction industry. However, sparse evidence is available on how to implement these technological interventions in construction organizations. Therefore, this study aims to develop an implementation strategy to aid the adoption of wearable robots in the construction sector. An online survey was conducted to identify the factors (i.e., facilitators and barriers) and stakeholders that could influence the adoption of wearable robots. Using the results of the survey, constructs from Normalization Process Theory, and literature review, an implementation strategy was developed. A four-step framework was formulated which includes Organizational decision on the implementation of exoskeleton; Operational strategy; Creating buy-in and training; and Deployment monitoring. The study proposes one of the first conceptual frameworks to guide construction companies in the implementation of wearable robots in the construction industry.
Sena Assaf; Kexin Liu; Zeyu Maou; Amira Saleh; Samaneh Momenifar; Ahmed Hammad	Evaluating Machine Learning and AHP Tools for the Pre-qualification of Construction Contractors based on Occupational Health and Safety Criteria	Workers in the construction industry remain exposed to different accidents and hazardous environments. Yet, occupational health and safety (OHS) factors are the least addressed in contractors' pre-qualification. As such, this paper presents two decision-making tools to evaluate contractors' performance based on OHS related criteria. Particularly, it presents the status of OHS-related orders in Alberta-Canada and the most prominent criteria to be integrated in pre-qualification. Based on the identified criteria, a machine learning-based clustering model and an AHP model were formulated to assist in the pre-qualification process. Data related to construction OHS performance was obtained from the Workers Compensation Board between 2016 and 2020 for more than 1,500 contractors with more than 7,000 OHS-related orders issued. Orders related to 1) falls, 2) hazards assessment, 3) safeguards, and 4) entrances, walkways, stairways, and ladders were the most common ones. Both of the developed approaches showed potential in supporting the contractor's pre-qualification process.
Novi Bramono; HW Lee	Benchmarking Healthy Building Requirements in Mitigating Airborne Transmission Diseases such as COVID-19: Identifying the Gaps between Current Codes and Building Rating Tools	The COVID-19 pandemic is evolving office building design and operation. Recent studies indicate that healthy building requirements, such as increased ventilation, higher air filtration, and temperature and humidity levels, could help mitigate the risk of airborne transmissions, such as COVID-19. As the risk of airborne diseases still exists, there is minimal information on the level current office building codes prevent or mitigate such risk. In response, this study aims to perform comparison of how building codes and rating tools recommend factors to mitigate airborne diseases. This study identified eight factors applicable to healthy buildings while mitigating the risk of airborne transmission allowing an effective comparison. The dataset included building codes for 15 states and cities and 4 rating tools, revealing several gaps in how codes and rating tools respond to airborne diseases. The study shows that, the benchmarked building codes lacked responsiveness to the risks of airborne diseases compared to building rating tools. The study results are expected to contribute to the effort of mitigating airborne transmission in office buildings, leading to healthier building design and operations in the future.

Authors	Article Title	Abstract
Abdullahi Alabi Ibrahim, Ph.D.	ASSESSING THE EFFECTIVENESS OF EXOSKELETONS IN REDUCING MUSCULOSKELETAL RISK IN CONSTRUCTION: A PILOT STUDY	The manual handling involved in construction work can put workers at risk for musculoskeletal disorders (MSDs) and other health issues related to hand and arm movements. While some studies have investigated the potential impact of new technologies like exoskeletons on MSDs, they have not specifically looked at their impact on the amount of movement and effort required to perform a task (known as Hand Activity Level (HAL)). The American Conference of Governmental Industrial Hygienists (ACGIH) has developed a framework for assessing HAL and determining a safe level for a task, known as the Threshold Limit Value (TLV). This study aimed to evaluate the effectiveness of an exoskeleton in reducing MSD risk in construction using the HAL-TLV framework. Ten participants participated in a simulated drilling task while wearing the exoskeleton, and the results indicated that it is possible to quantify the MSD risk reduction capability of an exoskeleton. This study helps us appreciate how the risk assessment tool works in construction. Practitioners and researchers can determine the true cost-benefit of using an exoskeleton as a safety intervention using the risk outcome from the risk assessment.
Kyeongsuk (Sean) Lee; Sogand Hasanzadeh, Ph.D.	Examine the Impact of Aging on Workers' Hazard Identification Ability in Dynamic Construction Environments	Given that the construction workforce is aging, managing their safety at job sites has become increasingly crucial for the construction industry. While the effect of aging on situational awareness has been extensively discussed in various fields, no study empirically examined the impact of aging on construction workers' hazard identification. Thus, this study utilized eye-tracking technologies to investigate the effects of aging on workers' hazard identification performance and attentional distribution abilities. The results indicated that aging negatively impacts workers' ability to broadly scan the 360° surroundings, as their cognitive processing becomes slower with aging. However, older workers showed better visual search strategies by fixating on hazardous areas in the scene, likely attributed to their crystallized intelligence that is information they have learned in the past and stored. As the proportion of older workers increases, it is crucial to prioritize their safety by addressing the impact of aging on their cognitive abilities and situational awareness and developing appropriate intervention strategies.
Shiva Pooladvand; Sogand Hasanzadeh, Ph.D.	Exploring the Schema of Attention and Search Strategy in Different Levels of Situation Awareness under Fall Hazards Conditions	Situation awareness is a cognitive process involving perception, comprehension, and prediction of the environment, and it is critical to accurately identify and manage hazards. Analyzing differences in physiological data can help determine an individual's situation awareness level and pinpoint the reasons for hazard identification failures. This study used eye movement data to quantify the differences in attention and search strategies at each level of situation awareness. The results showed that attention-related eye movement data, such as fixation duration, run count, and pupil diameter, increase in number or size as the level of situation awareness increases, while saccade count decreases. Moreover, individuals with higher situation awareness tend to use more systematic search strategies, enabling them to identify hazards more accurately and quickly. These findings provide insights into the differences between the various situation awareness levels and a foundation for developing customized training programs to enhance hazard identification skills.
Shiva Pooladvand; Sogand Hasanzadeh, Ph.D.	Effects of Heat Stress on Workers' Physical Fatigue and Attentiveness: Multimodal Roofing XR Simulation	Construction workers are at a high risk of experiencing heat-related illnesses as they mostly work outdoors, undertaking physically demanding activities. While several previous studies elaborated on the high likelihood of experiencing heat stroke on construction job sites, the effects of heat stress that might translate into an increased risk of injury due to exacerbating physical fatigue and reducing vigilance were not well studied. To tackle this gap, this study monitored subjects' objective and subjective fatigue metrics under various heat (No, Low, High) conditions within a simulated XR roofing task. Findings showed the negative effects of heat stress on increasing physical fatigue levels and reducing the efficiency of attentional distribution to identify hazards, increasing the likelihood of incident involvement. These findings call for designing practical interventions to minimize the risk of heat-related illnesses and fatalities.
Mostafa Namian, Ph.D.; Tianjiao Zhao; Michael Behm	Safety Nudge in Construction: Improving Safety Decision-Making Among Construction Workers	Construction is one of the most hazardous industries, characterized by high numbers of injuries and deaths. Despite employers implementing various safety programs to mitigate risks, these programs often entail high costs and inefficiencies. This article explores the utilization of safety nudges as a cost-effective and minimally disruptive solution to enhance safety performance in the construction industry. A survey was conducted among 108 industry participants to gather data on their attitudes and experiences regarding safety nudges. The core of the questionnaire consisted of four questions aimed at assessing perceptions and recommendations regarding the use of safety nudges. The results indicate that safety nudges hold promise as an approach for improving safety in construction, and many professionals believe in utilizing them in their safety routines. Construction companies should consider integrating safety nudges into their safety management strategies. Therefore, several practical safety nudges are presented in this article. Their implementation can enhance safety performance and reduce costs associated with traditional safety training programs. This study represents the first formal examination of construction safety nudges, providing inspiration for future research on this topic. Future research should focus on exploring different types of safety nudges and their effectiveness in diverse contexts and situations.
Behzad Esmaeili, Ph.D.,	Application of Paper-Based Wearable Electronics (PBWE) for Objective Assessment of Fatigue in Lower Back of Construction Workers	Wearable sensors proposed to measure fatigue in construction have shortcomings such as cumbersome size, high cost, flexibility, and high noise-to-amplitude ratio. Hence, this article demonstrates the use of inexpensive paper-based wearable electronics (PBWE) for predicting fatigue in the lower back of construction workers without compromising skin breathability or the natural motions of the wearer and with a low noise-to-amplitude ratio. Five (5) subjects were recruited to participate in a simulated manual lifting activity in the form of a repetitive lifting task while measuring their physiological conditions using paper-based wearable electronics, EMG, and off-the-shelf optical heart rate monitors. Analysis of variance (ANOVA) was employed for this study. The BORG scale was also used to assess the fatigue level of the participants subjectively. The noise-to-amplitude ratio of the paper-based wearable electronics (PBWE) was significantly lower than that of the EMG by about 4.5 times. The analysis produced p-values less than 0.05, implying a significant change in the fatigue level after carrying out the repetitive lifting task from the base value. The findings imply that paper-based wearable electronics are portable and reliable devices that can predict physical fatigue and have excellent potential to improve the safety of construction workers on a construction site.
Behzad Esmaeili, Ph.D.,	Situation Awareness Study in the Construction Industry: A Systematic Review	Safety is a critical issue in construction management, and one reason for accidents is the lack of situation awareness (SA) of workers. Although the concept of situation awareness has been widely studied in the construction industry, there are some inconsistencies among the findings regarding SA levels, measuring methods, and factors. Therefore, this paper aims to synthesize situation awareness research in the construction industry based on SA levels, measurements, as well as factors influencing SA. A systematic review method included database and search strings, screening and filtering, and coding and data analysis. In total 124 papers were identified and evaluated by the research team to determine themes and categories. For each category, Endsley's three-level theory is used as a baseline for SA levels; measurements of SA and SA components are developed for measurement classification; and factors including individual characteristics, processing, system design, and environment are decided. The findings can assist scholars in systematically understanding the current studies of SA in construction and shed light on future research areas.

Authors	Article Title	Abstract
Behzad Esmaeili, Ph.D.,	Determining the Effectiveness of Construction Safety Signs: An Eye-tracking Study	Warning signs are a critical defense against construction accidents; however, there's a lack of study on the effectiveness of construction signs. Therefore, this research examines the effectiveness of signs on construction sites by considering variables such as noticeability and comprehension. Noticeability relates to the signs' ability to attract attention, whereas comprehension refers to understanding them. In this study, comprehension is related to eye movement metric total fixation duration, while noticeability is related to visit count within an area of interest (AOI). The experiments utilized a stationary eye-tracking device to track nine participants' (Purdue University graduate students) attention and record reaction time. The results were analyzed using the Mann-Whitney test and found that the presence of text (p-value = 0.0) impacts comprehension speed and the use of pictograms in the signs (p-value = 0.049) impacts the noticeability. This research helps to identify and potentially improve less effective warning signs, contributing to decreased construction-related incidents.
Behzad Esmaeili, Ph.D.,	Support Vector Machine Analysis of Construction Workers' Automatic Behavior and Visual Attention	Automaticity is a core attribute of skill that is achieved as the attentional requirement gradually diminishes as proficiency increases with practice or repeated execution of a task. Hence, it is a phenomenon that affects workers' performance both positively (e.g., productivity) and negatively (e.g., accident involvement). Nevertheless, despite its significance, little is known about the effects of automaticity in the construction industry. To address this knowledge gap, this study used eye-tracking technology to examine the effects of automaticity on attention to productivity and safety-related areas of interest (AOIs) during repetitive construction activities. To achieve this research objective, 28 participants were recruited for a simulated roofing experiment. Based on the participants' attentional distributions, this study employed a support vector machine to distinguish and identify workers who are exhibiting automatic behaviors from those who are not. The findings of this study discovered that although automaticity can improve productivity, it can also cause workers in the construction industry to pay less attention to safety-related AOIs, which puts them at greater risk of safety hazards. Construction managers can use this study's model to predict automatic behaviors among workers to evaluate productivity and identify at-risk workers.
Mostafa Namian, Ph.D.; Daniel Godwin; Mohammadsoroush Tafazzoli; Ahmed Al-Bayati	The Impact of Education on Fatigue Among Construction Workers: A Longitudinal Study	Fatigue is a significant safety concern in the construction industry and can lead to fatal accidents if not properly addressed. This article examines the impact of education on the level of fatigue in the construction industry through a longitudinal study. The study utilized a literature review and survey data collected over a five-week period to explore the relationship between education level and occupational fatigue in the construction industry. Overall, 80 construction workers participated in this study. Workers' fatigue level was measured using a subjective scale called OFER (Occupational Fatigue Exhaustion/Recovery) Scale. The findings highlight that higher education levels are associated with lowered fatigue levels. Further analysis revealed that education has both direct and indirect impacts on fatigue levels among workers. Directly, education empowers individuals with knowledge, skills, and critical thinking abilities, enabling them to enhance their understanding of safety practices, risk assessment, and hazard mitigation. Indirectly, education provides better job opportunities with less demanding tasks, such as office-based work. The practical implications of the findings suggest the importance of personalized safety training programs tailored to individuals' educational backgrounds and job positions in the construction industry to effectively address fatigue, enhance safety practices, and mitigate the risk of accidents.
Akinwale SAMUEL Samuel Okunola, PhD; Abiola Akanmu	Detection of Cognitive Loads during Exoskeleton-Use for Construction Flooring Work	Active back-support exoskeletons are increasingly being perceived as potential solutions to the ergonomic risks of construction work. However, users of exoskeletons are susceptible to increased cognitive load could thwart the benefits of the device. Using self-reported cognitive load and electroencephalogram (EEG) data, this study investigated the detection of the cognitive load of users of an active back-support exoskeleton. EEG data and perceived ratings of cognitive load from participants performing flooring tasks are trained with several classifiers. The performance of the best classifier, Ensemble, improved using Synthetic Minority Oversampling Technique. This study contributes to existing knowledge by providing evidence of the extent to which cognitive load can be detected from the brain activity of exoskeleton users. The study also advances knowledge of the extent to which synthetic data could enhance the detection of cognitive load. Therefore, the study opens doors for improving exoskeleton designs to better support human cognition and performance.
Akinwale SAMUEL Samuel Okunola, PhD; Abiola Akanmu	Facilitators and Barriers to the Adoption of Active Back-Support Exoskeletons in the Construction Industry	The construction industry is known for the prevalence of musculoskeletal disorders, particularly back disorders, which are triggered by work involving abnormal postures. Active back-support exoskeletons are increasingly being perceived as ergonomic interventions to reduce the risks associated with construction work. This study examined the factors that would influence the adoption of active back-support exoskeletons in the construction industry. Using the Delphi approach, two-round surveys were conducted with key stakeholders such as safety professionals, supervisors, site superintendents, and construction professionals. The participants had the opportunity to experience the exoskeleton and provide feedback on the factors that could influence the adoption of the technology. The findings reveal the most important facilitators and barriers that should be considered to enhance the adoption of active back-support exoskeletons in the construction industry. The results could provide a practical guide for construction organizations to understand the requirements for implementing exoskeletons in their organizations. Manufacturers could use the design-related facilitators and barriers to adapt exoskeleton designs to construction work.
Mostafa Namian, Ph.D.; Chukwuma Nnaji; Sharareh Kermanshachi	Investigating the Impact of Smoking on Fatigue Level Among Construction Workers	Construction is a demanding and dangerous profession that requires a high level of physical and mental stamina. Despite the known health risks, many workers smoke as a means of coping with the fatigue associated with the job. This study aimed to investigate the relationship between smoking and fatigue among construction workers. Eighty workers participated in the study, with 43 non-smokers and 37 smokers. The fatigue levels of the participants were assessed using the Occupational Fatigue Exhaustion Recovery (OFER) scale, a subjective measure of fatigue. Results revealed that 46% of the surveyed workers were smokers, with 73% smoking tobacco and the remaining 27% using e-cigarettes or vapes. However, there was no significant difference in fatigue levels between smokers and non-smokers among construction workers. Although the mean fatigue scores did not differ significantly, it is important to highlight the potential risks faced by non-smokers due to second-hand smoke exposure in the construction industry. Non-smokers on construction sites are at a very high risk of being exposed to second-hand smoke, which can have detrimental effects on their health. Organizations should prioritize creating smoke-free environments, implementing smoking cessation programs, and raising awareness about the dangers of smoking to protect their employees' health and well-being.
Ibukun Awolusi, Ph.D.; Chukwuma Nnaji	Developing a Conceptual Model for Evaluating Construction Workers' Adaptation to the Use of Wearable Sensing Devices	Existing studies conducted across industries on the adoption and acceptance of safety technologies such as wearable sensing devices (WSDs) indicate that users still have some post-adoptive concerns about the use of these devices, and they tend to manage these concerns using different mechanisms. This unease is more pronounced in the construction industry reputed for being averse to the adoption of technology or innovation. Details about workers' post-WSD-adoption behavior and how to measure their coping mechanisms have received limited attention in construction research. This study proposes a conceptual model that can be deployed to examine the coping mechanism and infusion of WSDs for safety and health monitoring in construction. First, a review of the antecedents of the adoption and use of WSDs is conducted followed by an appraisal of existing theories and models that can be used to explain user coping behavior and adaptation. Subsequently, the feasibility and utility of the proposed conceptual model was evaluated by construction safety experts. This study provides foundational insights needed to generate new knowledge regarding the post-WSD-adoption behavior of construction workers. Such insights could influence strategies geared toward enhancing the successful use of WSDs for construction safety and health management.

Authors	Article Title	Abstract
Janet Mayowa Nwaogu; Albert P.C. Chan; Jackie Y. Yang	JOB CRAFTING AND JOB SCULPTING INTERVENTION FOR BALANCING WORK-LIFE AND IMPROVING MENTAL HEALTH AMONG CONSTRUCTION SUPERVISORS	Construction employees face work demands that strain their life and mental health. With the recent pandemic and increase in digitalization, different sectors are redesigning jobs to improve employee flexibility. However, the construction industry would require sector-appropriate techniques to meet project demands and improve employees' health. This study explores bottom-up job redesign techniques (i.e., job crafting and job sculpting) to identify techniques adopted that could improve work-life balance and mental health among supervisors. Using a qualitative methodology, 16 supervisors working in Hong Kong, Australia, Nigeria, and Ghana responded to semi-structured interview questions, including changes to their duties and deeply embedded interests they would like sculpted into their roles. The interview data were subjected to inductive content analysis. The result revealed that supervisors presently craft their jobs with six themes emerging but want more opportunities as it increases their perception of job control. The themes include modifying work schedules of subordinates and training subordinates. The respondents indicated that deeply embedded life interests designed into their roles should include research and development, fitness coaching, and training. This study developed a job crafting and sculpting design checklist for supervisors in construction organizations and highlighted the need to include employees in the job design process.
Hani Alzraiee; Harrison Fugate	Factors Preventing Construction Management from Adopting Wearable Sensing Devices in Construction Safety	Sensing technologies demonstrate promising potential in improving construction safety. The current research efforts focus on the sensing technologies development, yet these technologies are not implemented or are in the initial stages of adoption in the construction sector. This paper aims to understand the constructs that prevent decision-makers from adopting these technologies to enhance the safety of field labor. A modified Unified Theory of Acceptance and Use of Technology (UTAUT) was developed to study the barriers commonly found within technology adoption in the construction industry. The model addressed the perceived performance expectancy, perceived effort expectancy, openness to data utilization, social influence, data security, and facilitating conditions. A closed-ended questionnaire was used to collect the study data. The study found that an association was found between behavioral intent to implement a biometric wearable sensing device and perceived performance expectancy, openness to data utilization, and the social influence of the client.
Farshid Taherpour Sisakht, Studying Ph.D; Gabriel Dadi; Mahsan Keshavarz; Parisa Kheiri	Assessing the Potential of Machine Learning in Construction Safety: A Systematic Review	Many fatal and non-fatal occupational incidents have been reported in the construction industry globally. While many effective techniques have been developed in recent years to reduce the number of tragic accidents on the jobsite, there are still high rates of accidents. To improve management's decision-making processes, machine learning (ML) has drawn significant attention due to its ability to analyze large quantities of data to identify potential hazards on construction sites. Compared with traditional techniques, ML is able to handle large datasets and, through the use of different algorithms, can quickly analyze them to produce more accurate interpretations. Although machine learning has been identified as a useful statistical method for improving decision-making process, little systematic research has been carried out on the correlation between machine learning and construction safety. To address this gap, this study was developed to explore a systematic review of the effect of machine learning on safety of construction work sites. In examining and reviewing research two databases, it can be identified that ML techniques can be a powerful leverage for discovering useful knowledge from large datasets to perceive relationships, trends, and correlation. This study provides a contribution the research area of ML applications in enhancing construction safety.
Farshid Taherpour Sisakht, Studying Ph.D; Gabriel Dadi; Parisa Kheiri; Mahsan Keshavarz	Improving Hazard Recognition in the construction industry: A Systematic Review of a Building Information Modelling Approach	Many hazards fail to be recognized on construction projects because of the complex and dynamic nature of construction environments, resulting in life-threatening accidents and fatalities. Researchers and safety experts have attempted to identify potential safety hazards using emerging technologies. In particular, building information modelling (BIM) has attracted considerable attention due to its ability to increase cooperation between all stakeholders involved in a construction project in order to reduce safety issues. Given the importance of BIM in improving hazard recognition as the first step in the process of safety programs, there is a shortage of systematic reviews of this necessary safety factor. In response to this need, this paper explored the impact of BIM on hazard recognition skills. To fulfill this purpose, two databases were examined and related articles were reviewed. The findings of this research show that using BIM in the early stages of drawing provides a clear picture of the work site which can be used to identify potential hazards and help workers to perceive the associated safety risks. Therefore, the systematic review results provided a reference for safety management in the construction industry to reduce the number of workplace accidents using an established technology.
Vandana Chithra Padmanabhan, M.Tech	Quantifying the thermal comfort improvement in a redevelopment project in comparison to semi-permanent homes in a densely populated slum	Housing marginalized communities in resilient homes is an important aspect of building a climate-resilient population. In this study, the daily temperatures in a semi-permanent home in a densely populated slum have been compared to those in the homes in a consciously designed in-situ slum rehabilitation project built using vernacular technologies. On monitoring the indoor and outdoor temperatures over nine months under both conditions, results clearly indicated that the permanent homes are significantly cooler than the semi-permanent homes or slums by an average of 10-15% due to the higher thermal mass, insulation, and ventilation. The temperatures are also more stable, with lesser variation between seasons. The paper demonstrates that through minimal additional investments and good design prioritizing thermal comfort and ventilation, low-cost slum rehabilitation projects could lead to a healthier and more productive society. Such field investigation studies support robust modeling and design of rehabilitation homes.
Radwa Eissa; Islam El-adaway	Circular Economy Strategies for Decarbonization of the Built Environment Value Chain Scope 3 Emissions: A Network Analysis	With the anticipated growth in construction activities, minimizing value chain emissions, including those attributed to activities beyond an organization's direct control -aka 'Scope 3' emissions, and adopting circular economy (CE) practices have become critical to attaining the 2050 climate goals. Extant literature lacks a value-chain-comprehensive set of CE strategies on one hand, and an analysis of their actual project applications on the other. This research aims to build a holistic portfolio of CE actionable strategies that span across the entire built environment value chain, analyzing their extent of implementation and interlinkages within the literature versus actual projects. To this end, the authors conducted a systematic literature and practice review to extract and collate CE strategies and project case studies, and quantified the implementation frequency for each of the strategies and their interlinkages through a network analysis. Results revealed a broad yet fragmented implementation, with the most frequently implemented strategies including requiring sustainability ratings, passive design measures, and landfill diversion, whereas strategies targeting logistics and property market phases were rather scarce. Ultimately, the findings herein can serve as a foundation for a multifunctional database of value chain-specific strategies and case studies that can guide the industry on its track to decarbonization.
Gasser Ali; Islam El-adaway	DISTRIBUTED SOLAR GENERATION: DATA ANALYTICS OF THE EXISTING LITERATURE FOR GUIDING THE FUTURE PROSPECTS	Distributed Solar Generation (DSG) systems are small-scale units that are located at or near end-consumers such as residential rooftop Photo-Voltaic (PV) systems. DSG has driven a plethora of multidisciplinary research with various interrelated topics and perspectives. A broad understanding of research directions and potential gaps in knowledge can be elusive. Accordingly, the goal of this paper is to investigate the research trends related to DSG and explore research opportunities. This is achieved by performing a data-driven keyword search and network analysis on a large dataset of publications related to DSG to quantify topics related to DSG and the interconnectivity between them. The findings show that social equity in the context of DSG may be understudied as it has few publications contrasted with high citation impact and weak interconnectivity to other topics. In addition, the findings show a recent sharp growth in publications related to Machine Learning (ML) and Artificial Intelligence (AI) in the context of DSG. Ultimately, the findings in this paper should guide future multidisciplinary research in DSG.

Authors	Article Title	Abstract
Niousha Talebpour; Mohammad Ilbeigi	CITIZENS' SOCIOECONOMIC BACKGROUND AND THEIR ENERGY ACCESSIBILITY DURING EXTREME EVENTS	Climate change has led to an unprecedented increase in the frequency and intensity of heat waves around the world. Excessive heat can result in life-threatening situations for citizens, especially seniors, children, and people with chronic illnesses. Therefore, it is vital that all citizens, especially vulnerable populations, have access to air conditioning or other cooling mechanisms during heat waves. This emphasizes the criticality of electrical infrastructures to save lives during these extreme events. Previous studies indicated that the existing infrastructure systems are not equitably serving all citizens due to unjust urban development. The first step to fundamentally transform the existing processes is to better understand the problem through evidence-based and data-driven methods. Therefore, this study aims to understand inequity issues related to citizens' access to electricity during heat waves. More specifically, this study aims to empirically examine (1) whether there is a statistically significant association between citizens' socioeconomic status and their exposure to excessive heat and (2) if there is a statistically significant association between citizens' socioeconomic status and the reliability of their access to electricity during heat waves. The outcomes of this study set the stage for equitable urban development and just infrastructure systems.
Junyi Duan; Chengcheng Tao, Ph.D.	Improving Flood Resilience of Bridge Infrastructure Through Fluid, Structural and Risk Modeling	Flood in the Great Lakes area is one of the most common natural hazards, causing significant damage to infrastructure. In pursuit of sustainable and resilient communities against increasingly frequent inclement climate, protecting the lifeline safety of coastal infrastructure becomes imperative. In this paper, we propose a computational framework, which consists of computational fluid dynamics (CFD), finite element analysis (FEA), and Gaussian process regression (GPR) algorithm, to quantitively assess the responses and risks of bridge, the most vulnerable infrastructure subjected to floods. Based on the simulation results, an integrated tool to enhance the flood resilience of the bridge infrastructure is presented. The outcomes of the study pave the way for coastal communities to estimate the impacts and potential risks confronting the bridge infrastructure during flood hazards. The framework empowers stakeholders in the Great Lakes area to make optimal decisions, implement necessary protective measures, and enhance the overall resilience of the coastal infrastructure vulnerable to flood events.
Joy Gao; Xiaoyue Zhang; Chengcheng Tao, Ph.D.	Machine Learning-based Risk Analysis for Infrastructure Vulnerable to Flood Hazard	Flood hazards have affected millions of people through damage to infrastructure. Flood hazards in the Great Lake area in recent years have caused a large area of the infrastructure system in Indiana and Illinois paralyzed due to the high flood level on infrastructure damages. To assess the risk of flood for certain types of infrastructure, we develop a machine learning-based risk analysis model to generate predictions of risk scores based on several indicators from a public dataset. Different infrastructure types such as bridges, culverts, pump stations, and roads are considered. We predict risk scores to represent the flood risk from multiple components, such as exposure and criticality to flood hazards. The correlation is examined between certain indicators and risk scores to determine the critical variables used as input for the risk analysis model. The Gaussian process regression algorithm is applied to train and test the dataset. From the analysis results, we find the risk model's predictions are accurate compared to the original data points. Therefore, the machine learning-based risk model can be helpful to identify the degree to which infrastructure assets are at risk and provide recommendations for stakeholders and decision-makers on minimizing the effects of future flood events.
Aida Mollaei, PhD, MES; Guilherme Eliote; Beatriz Guerra; Sheida Shahi; Fernanda Leite; Carl Haas; Olaf Weber	A Transition Management Framework for implementing Circular Economy in the Construction Industry	Construction contributes to around half of global material consumption and solid waste generation. Transitioning to a circular economy is a potential solution to mitigate negative environmental externalities. Nonetheless, this transition is challenged by various technical and socio-economic factors. To identify a viable path for a circular economy transition, the overarching objective of this research was to build on transition theory and identify drivers, motivations, challenges, and efforts in shifting to a circular economy in the construction industry. For this purpose, semi-structured interviews were conducted with representatives from 13 construction companies in North America and Europe, including owners, contractors, and manufacturers, who are actively implementing circular economy principles. Interview findings were summarized, and a four-step transition management cycle framework for the transition to a circular economy in the construction sector was proposed. Findings are useful in managing the transition from a linear to a circular model in the construction sector.
Issam Srour; Antoinette Abou Jaoude	A METHODOLOGY TO DEVELOP MASTER PLANS FOR CONSTRUCTION AND DEMOLITION WASTE MANAGEMENT	In a linear economy, products such as construction materials are disposed of at the end of life of the built asset and are considered waste. The principles of a circular economy call for the reuse and recycling of products, thereby extending their lifespan. Construction and demolition waste (CDW) exceed a third of the total waste generated worldwide. Developed countries have created master plans to manage waste; however, these plans do not necessarily focus on CDW. Also, they fall behind in presenting a clear methodology for duplication in other parts of the world. This study proposes a master plan development framework targeted towards effective CDW management. The methods used consist of thematic and comparative analyses on data collected from literature, an analytic hierarchy process (AHP) expert supported analysis, followed by a case study application of the developed framework to the context of a developing country. Finally, a micro economic assessment is carried out.
Yohan Min; Hyun Woo Lee	Characteristics of early adopters and their followers of rooftop solar, electric vehicles, and heat pumps	To support electrification and decarbonization, building codes now mandate the inclusion of clean energy technologies in new commercial and residential constructions. However, there is a lack of comprehensive research on how "early adopters" and their "followers" differ in their adoption of various technologies at the city and community levels. By utilizing the Bass model, this study emphasizes the importance of recognizing community and city adoption patterns, understanding the social dynamics of diverse communities at different spatial scales, and considering early adopter traits to effectively promote technology adoption. The study reveals that higher adoption rates of electric vehicles (EVs) and heat pumps are linked to a greater presence of early adopters. Early EV adopters tend to have higher educational attainment and lower home values, while heat pump followers are associated with higher population density. Moreover, the study identifies an inverse correlation between early adopters and followers, as well as with market potential. This underscores the significance of striking a balance between encouraging innovation and imitation behaviors when crafting policies.
Ze Hua, M.S.; Elif Deniz Oguz Erkal	Exploring the Landscape: Environmental, Social, and Governance (ESG) in the Construction Industry	Corporate sustainability practices fueled by Environmental, Social, and Governance (ESG) reporting have been gaining popularity in corporate settings. Driven by environmentally conscious investors, communities, and other various stakeholders, critical investments are being made to set and achieve ambitious sustainability goals. The construction industry is not an exception to this trend. While ESG frameworks and standards suggest general roadmaps about ESG metrics and various disclosures, the implementation and reported topics vary widely amongst construction companies. Similarly, the research on the landscape and status of ESG in the construction industry has been limited and infrequent. This exploratory research paper seeks to take a step toward laying out the status of sustainability within the industry. Through semi-structured interviews with corporate leaders in large construction companies, common sustainability practices, challenges, and opportunities were identified. These interviews were also used to elucidate key disclosure topics, and best practices in the construction industry. This study will be beneficial to industry professionals to navigate the ESG landscape and benchmark against the exploratory baseline presented. Academics could develop this exploratory research further to suggest standardizations to ESG practices for industry-wide consistency, benchmarking, and improvement.

Authors	Article Title	Abstract
Paula Lopez Alvarez de Neyra, M.Sc.; Amelia Celoza	Deconstruction Information Model-Based Material Passports for promoting Circular Economy in the Architecture, Engineering, and Construction Industry through the use of Building Information Modeling: A literature review.	The Architecture, Engineering, and Construction (AEC) industry comprises 30% of the extraction of resources and 25% of the solid waste. Studies have indicated that the adoption of sustainable techniques to lessen this environmental impact is being inhibited by demolition waste, the lack of standards, and software homogenization. This relates to the linear way of using resources, and practices such as Circular Economy (CE) could be a key driver to achieving sustainability. This paper presents the Material Passports (MPs) tool for implementing CE in the AEC industry. MPs can provide information about how to assess materials at different lifecycle phases and their reuse at their end-of-life (EOL). Thus, this paper explores frameworks for Deconstruction Information Model (DIM)-based MPs within Building Information Modeling (BIM). DIM-based MPs provide information to enhance efficient demolition while recognizing valuable materials at the EOL. To achieve this goal, a literature review was conducted to understand how BIM could enable the use of MPs and what attributes should be addressed. This study aims to contribute to the implementation of CE in the AEC industry by developing tools that will allow us to understand how to benefit from materials by lowering the exploitation of resources for future construction.
Biao Kuang; Ziming Liu; Yangming Shi; Jianli Chen	Characteristics and Influencing Factors of HVAC Energy Consumption in the US Residential Buildings	Residential buildings account for over 20% of total energy consumption in the US, with heating, ventilation, and air conditioning (HVAC) consuming the most energy. However, there is little research that comprehensively explores how different influential factors affect energy consumption of space heating (SPH) and space cooling (SPC) separately. Therefore, based on RECS 2015, this study investigates the influencing factors of HVAC energy usage in single-family detached houses, considering SPH and SPC as separate categories. Random forest regression and multiple linear regression are employed to fit energy consumption, and their performance is compared. The results illustrate that nonlinear models fit HVAC energy usage better, with higher goodness of fit and fewer predictors. The determinants identified by both methods are similar, emphasizing housing size and climate over demographics, and vary by SPH and SPC. The order of influencing factors for SPH is climate > fuel type > housing size> number of windows; however, that for SPC is climate > housing size > equipment type > AC vintage. Finally, the study confirms that electrified SPH leads to less energy use. The findings contribute to understanding the differences in HVAC energy consumption and their influencing factors, facilitating the design of energy-efficiency programs.
Abigail Murray, Ph.D.	Disproportionate impacts of stormwater infrastructure failures on unhoused communities: A literature review	High-intensity storms expose pervasive deficiencies in aging stormwater management infrastructure, which poses a significant threat to the growing population of Americans living in unsheltered conditions. Unhoused communities are particularly vulnerable to flooding hazards, as their makeshift residences lack structural stability and property insurance protections, resulting in excessive damages and casualties. This literature review investigates how failures in stormwater infrastructure systems during high-intensity hazards disproportionately endanger unhoused individuals throughout the United States. Direct content analysis methods were used to converge on empirical consistencies in literature at the intersection of civil infrastructure systems, socially vulnerable communities, and resilience against natural hazards. Results identify limitations in the existing literature, as well as descriptive emergent themes to inform future research. This project aims to reevaluate current engineering best practices to more equitably protect unhoused communities from flooding hazards.
Gabriel Castelblanco; John Salazar; Jose Guevara	NETWORK STRUCTURES AND PROJECT COMPLEXITY IN ENVIRONMENTAL IMPACT ASSESSMENT OUTCOMES	Public-Private partnerships (PPPs) have been implemented as a suitable delivery method for infrastructure projects. Because of their size, those projects imply disrupting significantly the natural environment when creating complex built environments that fulfill human needs. In this context, PPPs require instruments to evaluate and mitigate environmental impacts through the infrastructure life cycle such as the Environmental Impact Assessment (EIA). In PPPs, the EIA is carried by concessionaires composed of Equity Providers (EPs), which are embedded in network structures. Despite the relevance of EPs and project complexity for the outcomes of the EIA, previous research in this field has mainly focused on understanding EIA processes rather than its outcomes and drivers for effectiveness. To overcome this limitation, this paper analyzes the influence of temporal network metrics (e.g., temporal degree centrality, temporal closeness centrality, and temporal betweenness centrality), defined by EPs relationships, and project complexity in delivering effective EIA. This research gathers information on 28 road PPPs in Colombia between 2014 and 2023. Findings show that actors' positioning computed through temporal metrics, especially temporal closeness centrality, influences the capacity of actors to carry EIA effectively.
Ehsan Mousavi, Ph.D.; Mohammad Saleh Nikoopayan Tak	History and Evolution of Ventilation in Cleanroom Environments: A Network Analysis Approach	Cleanroom environments demand specialized ventilation systems to uphold stringent air quality standards. This study aims to comprehensively investigate the research landscape of cleanroom ventilation and air distribution systems using a robust network analysis approach, complementing a systematic literature review. A systematic review identified relevant literature on cleanroom ventilation, forming the basis for a citation network comprising 133 papers. By employing three centrality measures (degree, betweenness, and closeness), the network analysis approach facilitates the identification of significant papers based on network characteristics. Content analysis of these influential works provided a deeper understanding of the research domain, revealing research gaps, trends, and promising opportunities for future investigations. The network analysis approach enriches our comprehension of cleanroom ventilation research by providing valuable insights into the structure and dynamics of the research community. Future researchers and practitioners can leverage these insights to make informed decisions in designing and implementing effective ventilation systems, ensuring optimal cleanroom performance. The study highlights the importance and usefulness of reference network analysis as a powerful supplement to review studies, offering a multifaceted view of the research landscape and advancing knowledge in the critical domain of cleanroom ventilation.
Sai Akhila Boddi Reddy, Ph.D.; Ingrid Arocho	Development of an Assessment Tool to Measure the Preparedness of Construction Firms for Upcoming Disasters	Construction firms play an important role in the recovery of communities after a disaster. In order to participate in the recovery of a community, it is important for construction firms to be prepared for disasters well in advance. It is also necessary for the construction firms to have capacity to withstand the disaster first before helping the community. There are several frameworks to assess resilience of communities but there is a lack of literature and tool to assess the performance of construction firms. This paper aims to fulfill the gap by focusing on the assessment of preparedness of construction firms. A set of previously identified readiness indicators is used to build an assessment tool. This tool consists of a series of questions to be answered by the personnel of construction firms to understand the level of preparedness. The results of this tool are given as a score ranging from 0 to 100 with 0 indicating that the construction firm is not prepared for the upcoming disasters and 100 indicating that the firm is well prepared. The results indicate the strength of the firms and the areas that has scope for improvement.
Suman Paneru, MS	An Exploratory Investigation of Social Vulnerability from the Building Resilience Perspective	Cities are becoming vulnerable due to climate change-induced disasters such as heat waves, flooding, landslides, and droughts. The severity and increased frequency of these extreme events have demanded a resilience plan in the major cities to combat climate change and extreme weather events, which requires a systematic community vulnerability assessment. However, the specific impact of extreme events such as high heat waves on community vulnerability has been difficult to measure due to the unpredictability of weather patterns and events. Further, compounding the effects of building and built environment characteristics, the social and behavioral characteristics of households can result in differing levels of vulnerability to extreme temperature events. Even though many studies have discussed the social vulnerability based on community demographics, the compounding effect has not been fully explored. When it comes to thermal resilience against extreme weather, socially vulnerable communities are more likely to be affected by extreme heat due to a lack of thermal resilient houses. In this research, Kolmogorov-Smirnov (KS-2 test) test was used to extend the relationship between building features data and the social vulnerability index of the city of Philadelphia.

Authors	Article Title	Abstract
Matthew Wiggins	Concurrent Modeling of Embodied Carbon and Construction Costs For Mass Timber Construction	Construction product manufacturing is a contributor to global climate change through its carbon emissions, known as embodied carbon (EC). Previous studies have found that utilizing a mass timber structural system can contribute to a reduction of EC. A barrier that prevents the use of mass timber is its higher cost than other available alternatives. Stakeholders that wish to reduce EC with the use of mass timber must justify the extra expense. A way to achieve this is to demonstrate the value of such a decision. Value is shown by quantifying how much EC is reduced and what the cost is. Current practices to provide this are cumbersome, which causes stakeholders to forgo the effort. The objective of this research is to develop a model which streamlines the process. To test the model, a case study compared the costs and EC of multiple structures. The study proved the model to be an efficient way of providing the value data. Additionally, the study found that alternatives utilizing mass timber resulted in a larger percentage reduction in EC than increase in cost. The model is expected to be an asset to stakeholders that wish to lower EC by selecting a mass timber structure.
Hang Ren; Lu Zhang; Travis Whetsell; N. Emel Ganapati; Parasar Gosain	An Analysis of the Axiological Antecedents of Inter-Organizational Collaboration in Resilience Planning using Exponential Random Graph Models	Building resilient communities requires effective collaboration among multisector stakeholders. However, stakeholders may hold different value priorities in implementing resilience strategies. Heterogenous collections of value priorities form distinct value systems. Differences rooted in value systems may cause conflicts that impede stakeholder collaboration. Despite extensive studies on stakeholder collaboration, there is a lack of systematic understanding on how the value systems of various stakeholders influence their collaboration. To bridge this gap, this study focused on examining the impact of stakeholders' value systems on their collaboration patterns through network and exponential random graph model (ERGM) analyses using data collected from a survey. Our results show that stakeholders' value systems have significant impacts on their collaboration patterns (i.e., presence or absence of collaboration, frequency of communication) in resilience planning. The findings of this study offer insight to enhance stakeholder collaboration in community resilience planning by considering stakeholder value systems.
Parasar Gosain; Lu Zhang	Integrating Stakeholder Value Dynamics with Resilience Evaluation for Housing	Enhancing housing resilience requires us to choose a path that can systematically assess the value of resilience to the housing stakeholders. However, there is a lack of method that assesses housing resilience value by considering stakeholders' perspectives. The lack of such a value assessment method has led many stakeholders to debate the benefits and effectiveness of resilience designs or strategies. To address this gap, this paper proposes a human-centered resilience evaluation framework that integrates stakeholder value systems and dynamics with resilience evaluation. Stakeholder value systems are ranked systems of things that are of importance to the stakeholders, and such systems may dynamically change in a disaster. The model mathematically incorporates (1) the degree that a resilience asset fulfills stakeholder values (i.e., resilience fulfillment degree), (2) stakeholder value systems and dynamics in a disaster, and (3) the integration and alignment between resilience fulfillment degree and stakeholder value systems. The use of the model was illustrated through an experimental case study that assesses the resilience value of three alternative housing projects in the context of a hurricane disaster. This framework offers a unique approach that integrates human perspectives with resilience assessment and facilitates human-centered resilience designs or strategies.
Sandeep Langar; Shreya Kaduskar	Resilient Materials and Technologies for A Single-Family Home: A Review	Resilient Materials and Technologies (RMTs) can absorb external stresses imposed during a natural disaster and enhance a building's resilience against natural disasters. Therefore, this study identifies RMTs available for implementation in a single-family home to be resilient against hurricanes and floods. The study also determined RMTs performance from the perspective of variables: multi-functionality, recyclability, smartness, and market maturity. The study used three-phased exploratory research involving establishing research parameters, data collection using the forward snowballing method, and then descriptive statistical analysis for the identified RMTs. The research identified 54 RMTs that could be adopted onto a single-family home's substructure (17 RMTs) and shell (49 RMTs). A significant majority of the RMTs were mapped onto the homes' shell assemblies. Further, most RMTs were identified as recyclable, and very few were as smart. Thereby indicating the need for smart RMTs that can transform in response to external stresses.
Xiyu Pan; Neda Mohammadi; John E. Taylor	River Flood Prediction based on Physics-informed Long Short-Term Memory Model	Flooding is one of the major natural disasters. Predicting river water levels and flooding is an effective way of enabling proactive flooding response measures. Although machine learning-based prediction models in prior studies have obtained a low error rate, they do not perform well during the rapid and significant water level rising (i.e., flooding). To provide a better flooding prediction tool, the present study first evaluates the commonly used Long Short-Term Memory model and points out the limitation of prior studies. Then, a novel model named Physics-informed (PI) LSTM is proposed. The PI-LSTM integrates hydrological knowledge into the neural network as well as extends the current physics-informed river water level prediction neural networks to a recurrent one. Compared with LSTM, PI-LSTM has a better performance in predicting rapid and significant water level rising. The study is expected to increase the accuracy of flooding prediction and provide better decision-making support to agencies responsible for flood forecasting and warning.
Muhammad Ali Moriyani; Chau Le; Tuyen Le	DEVELOPING A CONCEPTUAL LIFE-CYCLE FRAMEWORK FOR ADVANCING EQUITY IN LOCAL CAPITAL IMPROVEMENT PLANNING	The quality of life and societal outcomes, such as health, education, employment, and wealth, depend on infrastructure, but not all communities benefit equally from infrastructure developments. Some communities experience disadvantages like limited transportation access, unmet infrastructure needs, or outdated electrical distribution infrastructure. Public agencies at different levels have made efforts to advance equity, but approaches to equity-based policies vary within the United States and between agencies. Peer-to-peer learning is one of the most effective ways to identify promising strategies for achieving infrastructure fairness. However, little research has focused on how local agencies incorporate equity into their planning processes. This study conducted a content analysis of local capital improvement plans to propose a conceptual life-cycle framework for incorporating equity into the capital planning process. The framework covers various stages, from formulating a capital budget request to evaluating the project's effectiveness in improving equity if the request is accepted and implemented.
Ghiwa Assaf; Rayan H. Assaad	A Novel Approach for Classifying the Management Priority of Flooding Events using Clustering Algorithms and Geospatial Analysis	Due to the frequent occurrences and damages of flooding disasters, there has been an increasing interest in developing proper methods to help mitigate their consequences. Although previous research was directed to help in managing disasters, more data-driven methods are still needed. To this end, this paper developed a novel approach to enhance the decision-making process related to prioritizing the flooding mitigation, management, control, and/or recovery plans. First, data was collected for multiple flooding events and was cleansed to reach a total of 7,152 observations. Second, exploratory data analysis was conducted to examine and uncover trends and relationships in the data. Third, unsupervised machine learning was used to categorize the management priority of the disaster events using clustering analysis. Fourth, geospatial analysis was conducted on both the flood event level and on the county level. The results showed that flood disaster events could be categorized - based on their duration and frequency - into two management priority levels: low priority and high priority. The conducted research in this paper contributes to the body of knowledge by equipping agencies and disaster decision-makers with a decision-support system to prioritize short to long-term risk reduction and management interventions to better address flood disaster events.

Authors	Article Title	Abstract
Ghiwa Assaf; Rayan H. Assaad	Assessing The Vulnerability of Communities to Heat Waves: Developing a Heat Vulnerability Index	The construction of projects and buildings in urban areas leads to major transformation in the urban surfaces; where natural, pervious surfaces are transformed into rough, impermeable surfaces. This transformation leads to different environmental risks including the Urban Heat Island (UHI) effect. Not all urban areas are equally affected by the UHI effect, which makes some areas more vulnerable to extreme heat waves. Thus, this paper develops a heat vulnerability index based on demographic, land use/land cover (LULC), meteorological, and geographic factors to assess heat vulnerability of communities. First, data for multiple meteorological, demographic, geographic, and LULC factors was collected. Second, 4 vulnerability sub-indices were developed. Third, the heat vulnerability index was developed as a weighted average of the 4 sub-indices, where the Principal Component Analysis (PCA) method was implemented to calculate the weights of the factors as well as the sub-indices. The results reflected that LULC factors have the greatest impact on assessing heat vulnerability of communities. This research adds to the body of knowledge by helping authorities and decision-makers identify heat-vulnerable communities and ultimately developing immediate adaptation and mitigation plans for areas identified as highly vulnerable to heat-events to address future harm from high temperatures.
Mohsen Mohammadi; Rayan H. Assaad	Integrating Benefit-Cost Analysis and Monte Carlo Simulation to Prioritize Flood Mitigation Projects and Model Flood-Related Uncertainties	Historic and recent flood events show how susceptible communities are to floods. In the future, it is anticipated that areas prone to flooding will see a substantial increase in population density, which increases the damages of flooding events. In addition, climate change and rising sea levels may increase the frequency and severity of large-scale floods. This reflects that flood mitigation projects need to be properly planned and implemented. Hence, this paper aims to identify cost-effective flood mitigation measures for possible implementation in Essex County, New Jersey. First, the benefits were quantified for three potential flood mitigation measures/projects: elevation, wet floodproofing, and dry floodproofing under different scenarios. Second, the costs were estimated for the different alternative flood mitigating measures. Third, benefit-cost analysis and Monte Carlo simulation were conducted to select the most cost-effective measure(s). The results showed that while wet floodproofing and dry floodproofing might be more cost-effective than elevation, they do not provide the same protection level as elevation measures. This paper contributes to the body of knowledge by providing a framework that helps communities make informed decisions about their flood-related risks and money and prioritize projects to decrease flood losses by increasing the level of protection against flood hazards.
Mohsen Mohammadi; Rayan H. Assaad; Ghiwa Assaf	Modeling the Ripple Effects of Flooding Events: Determining Critical Dependencies Using Association Rule Analysis	The increase in frequency and intensity of flooding has become a global challenge. Increased population, rapid urbanization, and climate change all aggravate flood frequency and losses. Flooding events often lead to ripple effects which are a series of interconnected events that are triggered by flood hazards and aggravated by their recurrence. Ripple effects are often hard to predict and assess due to the high uncertainties inherent in their nature and causes. Hence, this paper aims to model the ripple effects of floods using data mining algorithms. First, data were collected for multiple flood events in the States of New York and New Jersey and their associated ripple events. Second, the data was cleansed and preprocessed. Third, association rule analysis was conducted to identify the critical dependencies or key combinations between the occurrence of flooding events and the associated ripple effects. The results illustrate that the following events are the most critical ripple effects resulting from flooding events: obstruction on the roadway, accidents, and single-line traffic alternating directions. The result of this study can provide helpful information for decision-makers to model infrastructure dependence and interdependence, which is an important consideration in the development of resilience-based performance standards to reduce flood-related losses.
Xi Hu; Rayan H. Assaad	Automatic Detection of Natural Hazard-Induced Power Grid Infrastructure Faults Using Computational Intelligence	Power/grid infrastructure systems are vulnerable to natural hazards. Many studies have focused on the use of sensing technologies to detect natural hazard-induced power grid faults. However, a massive sensor network to collect data for such studies is costly and may not capture complex grid conditions. Therefore, this paper develops an automated grid fault detection system. First, a smart microgrid was developed to simulate small grid operation, which can also dynamically sense the voltage and current for capturing the grid conditions. Second, three types of faults were introduced to the microgrid to represent the potential faults caused by natural hazards. Third, a one-day operation was simulated. Fourth, a dataset with 864,000 samples was collected, denoised, labeled, and used to develop three different ML classifiers. Model evaluation results showed that (1) the K-nearest neighbor was the optimal classifier to detect a partial shading fault with an accuracy of 99.19%, and (2) Decision tree was the most performant model for detecting three phase fault and tripping fault with accuracies of 100% and 99.90%, respectively. Ultimately, this paper contributes to the body of knowledge by integrating power grid simulation and machine learning for improving the resilience of power grids against natural hazards.
Yasser Jezzini; Rayan H. Assaad	Modeling Flood Vulnerabilities and Estimating Potential Economic and Social Losses: Assessing the Level of Community Flood Readiness and Preparedness in Newark, NJ	Flooding is a destructive natural hazard that causes significant economic and social impacts. Newark, a city located near the Passaic River in New Jersey (NJ), has a history of flooding and a high risk of future floods due to its location near rivers. However, there is limited research that was conducted to perform a comprehensive flood risk analysis in Newark. Hence this paper fills this gap. First, the study region and different flood hazard scenarios (10-, 25-, 50-, 100-, and 500-year return periods) were defined. Second, the flood depth grids were generated using H&H modeling. Third, the potential losses from flooding in terms of both economic and social impacts were estimated and quantified. The results provided insights into the most vulnerable areas to flooding in Newark. The findings also recommended potential mitigation measures that need to be implemented to reduce future economic and social damages and losses. This study adds to the body of knowledge by providing valuable insights for disaster management professionals and community leaders in developing effective flood risk management plans and making informed decisions on mitigation investments. Moreover, this study helps to increase the resilience of Newark to potential future flooding events.
Shafayet Ahmed; Vineeth Dharmapalan; Ziyu Jin	A Subject Review on the Use of Mass Timber in the US Construction Industry	There is a growing body of literature exploring the viability of mass timber as a building material. Research and development in the use of mass timber will expand now that the International Code Council has approved the construction of high-rise buildings using mass timber. While several studies on mass timber with differing goals and methods have been published, a systematic examination of the current status, development, trends and practical implementation associated with mass timber is limited. In the US construction market, a significant portion of industry practitioners are still reluctant to accept mass timber as a feasible load-bearing material. The purpose of this paper is to review and discuss the latest research trends and identify research gaps in the use of mass timber in the construction industry. The study conducts a systematic literature review using descriptive and content analysis of relevant publications in prominent journals from 2010 to 2022. This review study provides an improved understanding of the state-of-the-art research of mass timber and contributes to the existing body of knowledge by opening new directions for researchers. Practitioners can use the results of the study to make informed investment and implementation decisions.

Authors	Article Title	Abstract
In Bae Chung; Carlos H. Caldas	A Literature Review of Carbon Emission Monitoring Practices in Construction Projects	Climate change is a significant issue that may impact many aspects of our lives. The increase in global carbon emissions is one of the main reasons for such environmental consequences, and immediate action should be taken to manage the carbon footprint from human activities. Carbon releases from the construction sector contributes to a significant fraction of greenhouse gases being released into our atmosphere. Hence, various efforts have been made to manage the amount of carbon emissions in construction projects, such as developing standards, methods, and tools. While many earlier studies were associated with conventional analytical methods for estimating carbon discharges, recent studies have focused on monitoring the actual status of carbon emissions in a project, enabling project teams to take timely responses to minimize releases. This paper reviews carbon emission monitoring practices that can be applied in construction projects and provides a descriptive analysis. The review explains the type of technology adopted and indicates the project lifecycle stage that each application was designed to be used. The findings from this paper will provide an overview of the state-of-the-art practices for carbon emission monitoring and identify future directions for research.
Sorena Vosoughkhosravi; Amirhosein Jafari	Creating a Large-Scale National Residential Building Energy Dataset using a Two-Stage Machine Learning Approach	Buildings account for 40% of total energy demand in the US. Consequently, there is a pressing need for a dataset that provides comprehensive information on the energy consumption of household units in the US. The current practice on large-scale energy simulations may not reflect the actual energy consumption patterns. Additionally, the existing national building energy datasets, such as the RECS, have a limited number of datapoint and do not reflect the social aspects of the households. This study aimed to create a large-scale national residential building energy dataset using a two-stage machine learning approach, combining two national datasets of the RECS and the AHS. The outcome of this study is a large-scale and comprehensive national dataset that contains information about energy consumption in household units as well as their detailed building features. Three machine learning algorithms, including Artificial Neural Networks (ANN), Random Forest (RF), and Gradient Boosting Regression (GBR), were used to develop a data-integration framework. The results showed that RF had the best performance in predicting the end-use energy consumption. Additionally, the predicted energy consumption in the generated large-scale dataset had an accuracy of over 80%. These findings have significant implications for energy-efficient building design and operation.
Shiqi Ding, Ph.D. Student; Chengyu Tang; Da Li	Assessing Energy Performance and Thermal Satisfaction of Flexible Space Usage in Office Buildings	The tradeoffs between energy efficiency and thermal comfort in office buildings have been studied for decades. To date, researchers have proposed various strategies, such as occupant-based control strategies and personal comfort systems. Notably, operations of office buildings are embracing flexible work arrangements which allow occupant mobility, especially in the post-pandemic era. Research efforts on space recommendation strategies that match the needs of personal thermal preferences with different space conditions have been explored. However, existing literature lacks simultaneous quantification of energy consumption and thermal comfort at the whole building level when implementing flexible space usage. This paper quantitatively evaluates the influence of space match strategies on energy performance and thermal satisfaction in three typical office buildings of different sizes using the summer season. Our results demonstrate up to 22% cooling electricity savings and 15.7% increase in comfort probability across all simulated scenarios. These findings indicate that implementing space match strategies could improve building performance in both energy efficiency and thermal comfort to varying degrees.
Hamed Khaleghi; Aslihan Karatash	An Experimental Framework to Measure Dynamic Thermal Resilience of Wall Panels under Extreme Weather Conditions	As extreme weather events (e.g., heat/cold waves) are likely to become more frequent and more intense with climate change, it is vital to take action to mitigate their impact on the environment, society, and infrastructure. Therefore, identifying the thermal resilience of building envelopes under extreme weather conditions is important to adapt the buildings for long-term changes in climate. A majority of previous studies evaluated thermal performance of building envelopes under steady-state conditions. In contrast, this study introduces an experimental framework to evaluate the dynamic thermal performance of building envelopes (e.g., wall panels) under non-steady-state condition, by utilizing the measurement of their dynamic thermal properties. The analysis is carried out through the use of two key metrics, decrement factor (DF) and time lag (TL), which are employed to quantify the dynamic thermal resilience of building envelopes. This framework consists of five steps, namely weather data collection, experimental setup preparation, tuning phase, extreme weather simulation, and TL and DF calculation. The developed framework will aid in developing energy-efficient and resilient buildings to adapt to climate changes. Moreover, decision makers (e.g., designers, architects, manufacturers) will be able to better understand how building envelope design can impact energy efficiency and indoor thermal comfort.
Nathalie Thelemaque; Jessica Kaminsky	DESCRIBING TYPES OF AEC FIRMS WITH CLIMATE PLEDGES	In response to the industry's significant contribution to global greenhouse gas (GHG) emissions, many architecture, engineering and construction (AEC) companies have developed climate pledges. Climate pledges are commitments made by entities (e.g., companies and governments) to lower their contributions to climate change by reducing their GHG emissions. Approximately 30% of the top 100 design firms and 100 contractors ranked by revenue by Engineering News Record have made formal climate pledges. The researchers hypothesize that adopting corporate climate pledges may be associated with various corporate and geographic characteristics, including headquarter location, revenue, and ownership type. Thus, this study describes statistical associations between firm characteristics and climate pledges in the AEC industry, using a dataset that focuses on the top 100 contractors by revenue. This work finds that corporate factors are more likely than geographic factors to be associated with climate pledge adoption and contributes to the literature to guide strategies for climate action.
Claudia Valeria Calle Müller; Mohamed ElZomor	Origami Housing: A Post-Disaster Temporary Emergency Housing Solution	Over the last two decades, natural disasters have caused over $2.97 trillion in economic losses, 1.23 million deaths, and affected more than 4 billion people through injury, loss of housing, displacement, and/or requiring emergency aid. Data have shown that physical, social, and economic inequities play a significant role in the vulnerability of communities particularly post-disasters. Low-income communities have more than four times as many deaths per disaster, experience more severe and long-lasting infrastructure damage, and often receive delayed disaster recovery. Therefore, this causes prolonged and widespread homelessness as well as an inevitable temporary housing crisis. This research proposes an innovative short-term Origami temporary emergency housing solution, which offers an equitable, and affordable solution ensuring potential victims are offered quick shelter post-disasters. This study aims to address the challenges of post-disaster homelessness through: (a) understanding existing natural disasters housing solutions; (b) identifying post-disaster vulnerabilities pertaining to temporary housing needs; and (c) proposing Origami shelter solution and validating its feasibility and applicability through surveying engineering and architecture experts. The results of this study show the urgency for quick-assembly temporary emergency housing that allow victims to safely live and return to routine activities while infrastructure systems and homes are being repaired or rebuilt.

Authors	Article Title	Abstract
Soowon Chang, Ph.D.	Pattern Analysis of LEED v4 Rating System	Green building design and construction are important in mitigating the health and environmental effects of indoor air pollution and climate change. The Leadership in Energy and Environmental Design (LEED) rating system becomes essential for ensuring cost-effective, healthy, and environmentally friendly buildings. While the list of LEED certification elements can collectively contribute to sustainability in buildings, the comprehensive compliance of LEED-certified buildings with the entire list is still questionable. In this respect, this study investigates the key categories contributing to the highest LEED scorecard points and explores the relationship between different LEED rating parameters. This study compares LEED ratings of 40 buildings certified by LEED v4 with the highest point totals and analyzes their scorecards in various categories. The findings suggest how different LEED categories can be synergized with each other for an effective certification process. The patterns of current LEED certified buildings can be used to advance green building practices and can guide future research directions, ultimately contributing to sustainability in built environments.
Yijin Zhao; Bharadwaj R. K. Mantha; Da Li	Real-time Building and Comfort Data Collection Using Mobile Robots	Post-occupancy evaluation (POE) is crucial for assessing indoor environmental quality (IEQ) and identifying areas for improvements. Traditional methods such as paper-, web-, and polling-based surveys, face challenges of discontinuity, high costs, low response rates, and participation bias. To address these issues, a mobile robot platform with IEQ sensors and a touchscreen interface was developed to gather real-time feedback while monitoring built environments. A seven-day experiment in three testbed offices involving 34 participants showed that: 1) compared to the email survey, the robot remarkably increased the response rate from 12.5% to 90.18%, 2) participants found the robot useful with an average usability score of 72.8 (out of 100). Besides, among 23 valid exit survey responses, 78% preferred responding to surveys via the robot, and 87% expressed willingness to interact with it again. This study demonstrates the feasibility and usefulness of using mobile robots for continuous POE in real-world scenarios.
Rubaya Rahat, BSc; Mohamed ElZomor	Investigating Trends and Influential Factors for Sustainability Ratings In Envision-Certified Infrastructure Projects	Envision rating system is a globally used infrastructure sustainability rating system that assesses all types of infrastructure projects and fosters the necessary improvements to achieve sustainable performance. The Envision framework consists of 64 credits and based on the achieved points under these credits, infrastructure projects are awarded one of four levels: verified, silver, gold, and platinum, which in turn indicate how well the project addresses the sustainability indicators. This study explores the Envision-certified projects to date (2013-2023) and reviews the project trends, and project types as well as investigates possible correlations between the Envision award levels and various project factors including the project sector, type of infrastructure, project location/country and year of the award. The findings of this study provide an overview of current trends in the sustainable infrastructure industry, identify and motivate various project sector to pursue sustainability certification and provides direction for future research to exacerbate developing sustainable infrastructure.
Sunil Dhakal; Lu Zhang	Equity-Integrated Infrastructure Resilience Analysis: Case Studies of Florida Communities	To mitigate the impacts of climate change on infrastructure, there has been a growing trend towards adopting resilience strategies in infrastructure planning. However, research highlights historical discriminatory practices and biases in policies and investments, resulting in disproportionate disaster impacts on communities. To effectively evaluate infrastructure resilience, it is crucial to consider these disparities. To address this need, this study focuses on assessing infrastructure resilience while incorporating disaster inequality and disaster vulnerability using a proposed equity-integrated resilience evaluation model. The resilience of infrastructure in Florida counties with different characteristics (e.g., spatial, demographic, and socioeconomic statuses) were evaluated and compared. The findings reveal that (1) the more socially vulnerable counties experienced greater disaster inequality; (2) there is a higher percentage of disaster vulnerable counties in the rural group in high-intensity hurricanes, and (3) the infrastructure of the inland counties, collectively, has weaker resilience compared to coastal ones.
Mohamadali Morshedi; Arkaprabha Bhattacharyya; Makarand Hastak	EXPLORING SOCIO-DEMOGRAPHIC INEQUALITIES IN POST-DISASTER COMMUNITY WELL-BEING: CASE STUDY OF HURRICANE HARVEY	Natural hazards can disrupt various aspects of the community members' lives such as satisfaction with the solid waste management and debris removal system. These impacts can be disproportionate across communities with different socio-demographic backgrounds. This study is aimed at identifying such inequalities. To that end, a case study of the Houston area in Texas under post-Harvey situation is conducted. Satisfaction with waste and debris management services is taken as a sample metric for post-disaster well-being of community members. To quantify this metric, 311 phone call data, which pertains to municipal service requests, is used. The dataset comprises the topic, location, and the date of municipal service requests. The number of active service requests related to waste management is taken as the metric for the related community well-being domain. Socio-demographic disparities in post-disaster community well-being of the affected zipcodes are then explored. The results showed that zipcodes with lower income level, more single-parent families, and multi-unit houses were affected the most by Harvey. The study outcomes can inform policymakers in identifying the zipcodes that sustained disparate impacts caused by Hurricane Harvey. The proposed step-by-step method can be expanded to identify disparities with respect to other well-being domains, and for other locations.
Mohamadali Morshedi; Arkaprabha Bhattacharyya; Makarand Hastak	Prioritizing Capacity Building Strategies to Ensure Robustness and Faster Recovery of Cellular Networks from Hurricanes	This paper presents a regression-based approach for identifying the impact of county-level capacity building strategies on post-hurricane recovery pattern of cellular networks considering the impact of infrastructure interdependencies. The proposed approach models the recovery rate of the cellular network in a county, based on hurricane damage to cellular network, electricity grid, recovery of electricity grid, and the Baseline Resilience Index for Communities (BRIC). To demonstrate the applicability of the proposed approach, the recovery rate of the cellular network after hurricane Ida was regressed on the set of predictors using a Tweedie Regression. Historical data on the damage and recovery of the cellular network after hurricane Ida was collected from the U.S. Federal Communications Commission's reports. The recovery rate of the cellular network and the grid was calculated by fitting an exponential distribution to their recovery curves. The regression coefficients indicate statistically significant relationships between the recovery rate of the cellular network and the level of damage of the cellular network and grid, recovery rate of grid, and BRIC index. The coefficients could be used to estimate the effect of the capacity building strategies to maximize the rate of recovery of the hurricane damaged cellular network.
Lufan Wang; Md Ashiqur Rahman; Runhe Zhu, Ph.D.	Spatiotemporal Insights into Online Public Responses under Disasters in Developed and Underdeveloped Countries	Early-warnings and situational awareness during disasters are critical for protecting our built environments and communities. In recent years, the increasing prevalence of social media platforms has presented an unprecedented opportunity for gathering real-time information, facilitating rapid hazard detection, evacuation plan propagation, and damage assessment and recovery. However, underdeveloped countries have been inadequately explored compared with developed countries across different spatiotemporal scales. To address this knowledge gap, this study investigated online public responses before, during, and after two recent hurricanes, aiming to identify the different patterns between underdeveloped and developed countries at different stages of disasters. Twitter data of Hurricane Eta in Honduras and Nicaragua and Hurricane Ian in the U.S. was collected and analyzed using sentiment analysis and topic modeling. The findings revealed that individuals in Honduras and Nicaragua tended to express more negative attitudes and had more concerns about disaster damage than those in the U.S. Sentiment differences were also found between moderately and mostly affected regions in the U.S. Recommendations for future research directions and disaster response practices were proposed based on the findings.

Authors	Article Title	Abstract
Smitha JS, ME	A Life Cycle Analysis Based Framework to Analyze Various Circular Economy Strategies in Buildings	A shift to the circular economy is inevitable in the construction sector for sustainable development, as it promises solutions to two main problems of the industry - dealing with the waste generated and overcoming the shortage of raw materials. This study tries to identify circular practices in the construction industry, constraints to their wide acceptance, and recommendations to promote them. At the end-of-life of a building when it is demolished, a large amount of waste is generated and its handling is a major problem. In this study, life cycle analysis methodology is adopted to analyze various scenarios after useful life of a model building. The environmental impacts are calculated in terms of carbon emissions, taking into account two life cycles of building, considering options of deconstruction and demolition. Total carbon emissions are calculated for different scenarios and the results show a significant reduction in the impacts for circular strategies.
Toby Nelson; Cristina Poleacovschi; Kaoru Ikuma; Ivis Garcia; Chris Rehmann; Carl F Weems	Household Water Insecurity and Depression Symptoms Among Individuals Exposed to Hurricanes Maria and Fiona	Water insecurity is a condition that arises when individuals lack access to a sufficient, dependable, and safe supply of water to meet their fundamental needs for sanitation, hygiene, and drinking. In 2017, Hurricane Maria devastated Puerto Rico's water infrastructure, resulting in increased water insecurity, potentially contributing to mental health problems such as depression. This study examines the correlation between household water insecurity measured using the Household Water Insecurity Experiences (HWISE) scale and the depression levels measured using the Center for Epidemiological Studies-Depression (CES-D) scale of individuals residing in Puerto Rico. To achieve this goal, we conducted 154 surveys with respondents in Puerto Rico from May to July 2022. Preliminary findings from multiple linear regression analyses indicate a potential association between depressive symptoms among residents and water insecurity. The findings of this study highlight the importance of increasing access to clean piped water within residential homes. To achieve this, future research could explore potential options such as revising water distribution system requirements and enforcing federal water quality standards in Puerto Rico. By implementing these measures, policymakers and relevant authorities can work towards mitigating water insecurity and ensuring a safer and more reliable water supply for the population.
Sundeep Inti, Ph.D., P.E., LEED AP; Niharika Dayyala	Lightweight Cellular Concrete (LCC) for Stormwater Management in Parking Lots: A Design Optimization Approach	Lightweight cellular concrete (LCC) can substitute the thick aggregate layers within permeable parking (PP) lots. Nevertheless, LCC's lightweight may cause buoyancy forces that damage the PP lots. Increasing LCC density reduces buoyancy forces, adversely affecting PP lots' permeability and runoff storage capacity. Thus, this study assesses LCC feasibility in PPs and its influencing factors. First, the study conducted lab testing to develop various porous concrete and LCC materials with adequate strength while complementing permeability. Later, this study developed an optimization model that maximizes using LCC materials while avoiding buoyancy and meeting the required runoff storage capacity. Finally, this study demonstrated designing permeable parking lots for various rainfall intensities utilizing the lab developed LCC materials and optimization model. Results indicate that combining aggregate and LCC layers is beneficial, with LCC reducing the thickness of aggregate layers by 75-85%. The key factors affecting PP lots' hydraulic performance are the LCC density and void ratio.
Christopher Nicholas Bennett; Zia Ud Din, Ph.D.; Ahmed Senouci; Rosalind Anne Wyatt	Adoption of Circular Economy Practices in the Built Environment- A Survey of US Construction Industry Stakeholders	Millions of tons of construction and demolition waste are sent to landfill sites each year. The circular economy (CE) production and consumption model aims to reduce waste and extend the usage lives of products and infrastructures. Implementing CE in construction enhances sustainability by reducing resource use. In the past decade, barriers and drivers for CE implementation in construction have been identified. However, their applicability may vary in the United States due to cultural differences. There is currently a lack of studies examining the perception of specific barriers and drivers related to CE practices in the USA. This study assesses stakeholders' views on the barriers and drivers within the US construction industry. Data were collected through an online survey completed by 63 CE and sustainability, architecture, engineering, and construction stakeholders. Information was analyzed using the relative importance index and the Kruskal-Wallis test. The study findings highlight the top three barriers hindering CE implementation, which include a lack of experience, unfamiliarity with design and construction techniques, and insufficient performance information on reclaimed construction materials. While the top three drivers that promote CE implementation are environmental sustainability, image enhancement, and gaining a competitive advantage.
Amanda Quarshie; Cristina Poleacovschi; Kristen Cetin	An Assessment of the Social Determinants of Participation in Energy Efficiency Programs in Alaska Native Homes	Energy burden i.e. the percentage of household income spent on energy utilities including heat and electricity per year, remains a major concern for low-income households in the U.S. High energy burden is estimated as more than 6% of household income. Energy efficiency programs are major strategies used to address energy burden for low-income communities. Despite their potential to reduce energy cost, the adoption of energy efficiency programs remains low. Also, anecdotal evidence suggests that some energy efficiency measures are not being used by homeowners as expected. This study systematically reviews literature on the social determinants of the use of energy efficiency programs using national reports, journal articles and conference proceedings. Also, the paper applies a framework from the literature review to an Alaskan community using interview data (n=40). Preliminary findings from the literature review showed five major themes: communication of logistics, social behaviors, financial benefits, indoor environmental quality and pro-environmental attitudes. However, the qualitative study indicated that majority of people in Alaska communities have limited experience with energy efficiency programs. Poor communication of logistics was another key barrier to participation. Energy efficiency organizations should therefore improve advertising strategies and simplify application processes, if possible, to encourage participation in Alaska communities.
Michael Ammoury; Baris Salman	The Use of Advanced Solutions Towards COVID-19 Recovery at Airports in Eastern U.S.A.	The COVID-19 pandemic has urged airports to seek opportunities for innovation and to redefine a sustainable and resilient path to recovery. Yet, there is a lack of information on how airports of different sizes in the U.S. have used technology to recover from COVID-19. This paper addresses this shortcoming by exploring resilience management practices among airports of different sizes located in Eastern U.S.A. The results presented in this paper stem for a larger effort which featured interviews with consultants and solution providers along with a nationwide survey of airport authorities. Here, results obtained from 20 airports in Eastern U.S.A. are provided in depth. The results highlight preparedness and recovery opportunities among airports of different sizes and provide important categorical insights on the state of practice in terms of resilience management practices and the use of advanced technologies that can advance resilience. The overarching insights can benefit authorities by unearthing the challenges the industry faces and by providing them with guidance while adopting new resilience initiatives or solutions.
Brad Wells; Clifton Farnsworth; Andrew South; Evan Bingham; James Smith	EVALUATING THE IMPACTS OF HURRICANE MARIA ON RESIDENTIAL CONSTRUCTION IN PUERTO RICO	In 2017 Hurricanes Irma and Maria caused catastrophic damage in Puerto Rico. This study explored the effects these hurricanes had on residential construction practices during the first year of reconstruction. Semi-structured interviews were conducted with residential construction stakeholders impacted by reconstruction efforts. Residential structures built using current building codes experienced minimal storm damage. Conversely, significantly damaged residential structures were commonly built using informal construction practices, utilizing light wood framing methods. These homes were commonly not insured nor eligible for government assistance. Without assistance, the damaged structures were again being rebuilt using informal practices, thus setting the stage for further damage during future hurricane events. The cyclical nature of these informal construction practices is contrary to the nature of sustainable construction, in terms of resource consumption and social impacts. This research can be used to help prioritize reconstruction efforts and ultimately make changes to better prepare for other similar disasters.

Authors	Article Title	Abstract
Mohsen Goodarzi, Ph.D; Alireza Shayesteh	DOES LEED BD+C FOR NEW CONSTRUCTION PROVIDE A REALISTIC AND PRACTICAL SUSTAINABILITY EVALUATION SYSTEM?	As one of the most widely used green building certification systems, Leadership in Energy and Environmental Design (LEED) has significantly contributed to improving the sustainability of construction projects. However, it is still unknown if in this point-based system, the credits for evaluating sustainability are realistically and practically developed and weighted. To understand this, the performance of this system was investigated by assessing all the LEED BD+C: NC (v4) projects certified in the US. by the date of the study (n=797). The data was collected from the US. Green Building Council (USGBC) website's published data about LEED-certified projects. A model was developed based on the predefined relationships between credit categories and the overall LEED scores. After validating the model through confirmatory factor analysis (CFA), the influence of each credit category on the overall sustainability level was then evaluated through structural equation modeling (SEM). The expected and actual influence of these credit categories in determining the sustainability of projects were then compared. The results showed that the expected influence of the LEED NC credit categories is not consistent with the actual influences thus demonstrating the need for re-defining some of the credits and their corresponding weights.
Patricia Guillante; Kristen Cetin	Potential Factors Influencing Student Rental Housing Participation in Demand-Side Management Strategies	Buildings are responsible for the largest portion of energy consumption on U.S. electric grids. The wide participation of buildings in demand side management (DSM) can support decarbonization goals and increase reliability of electric power supply. The awareness and willingness of households to adjust internal loads, housing occupancy, and household energy consumption patterns all play an important role to support the potential for DSM. A particularly challenging type of housing to reach in DSM is rental housing. DSM presents an opportunity to support reducing the utility bills of renters through controls adjustments rather than requiring the landlord to invest in energy efficient technologies. This study aims to identify occupancy schedules and potential factors that may influence willingness to participate in DSM among renters, in particular college students. A survey-based method was conducted among 55 college students majoring in civil, environmental, and applied engineering and showed that, while the targeted population has low awareness about DSM strategies, they would be willing to participate in a DSM in the future. The factors that appear to drive willingness to participate in DSM for this population were related to the potential reduction of electricity costs and energy savings.
Asma A Sharafeddin, Ph.D.; Ingrid State Arocho	Potential Leading Sustainability Performance Indicators for Sustainable Low-Income Housing	Sustainability performance indicators (SPIs) are flexible tools developed based on specific frameworks to provide integrative strategies to assess sustainability. Indicators represent the pressing concerns and reflect the interests of project stakeholders. The residents' satisfaction level and the perspective of experts provide a solid base for identifying SPIs. Several frameworks and sets of indicators have been used. The triple bottom line +1 (TBL+1), which indicates social, environmental, economic, and governance aspects, was used here as an integrative framework to assess sustainability. This paper identifies and summarizes the significant potential leading sustainability performance indicators (PLSPIs) for low-income housing (LIH). A systemic literature review adapting three research design stages was used to identify and summarize the significant PLSPIs. Due to the length limitation, the paper presents two sets of PLSPIs, the PLSPIs related to social and environmental aspects. These sets include ten Social PLSPIs (SPLSPIs) and 14 environmental PLSPIs (EPLSPIs).
Don Miller; Yewande Sonayon Abraham, Ph.D.	COVID-19 IMPACTS ON CONSTRUCTION PROJECT EXECUTION: CASE STUDIES OF DATA CENTER PROJECTS	The world has been under the thumb of the global Coronavirus (COVID-19) pandemic since 2019 and is still recovering from its effects on society and industries. Data centers provide critical information technology supporting infrastructure for organizations and businesses. Although designated as essential construction that remained operational, data centers were not immune to the pandemic's adverse influences. This study identifies the unique challenges faced in the construction of data center projects through an in-depth qualitative case study analysis of five large data center projects built during the height of the pandemic. Insights were gained through interviews with fourteen project managers and clients overseeing these projects. Thematic analysis revealed an overall emphasis on health and safety. Supply chain disruptions, schedule delays, financial implications, reduced productivity, and contractual changes were also highlighted. Data centers are critical facilities and are in increasing demand as such should be adequately prepared to address future disruptions.
Elnaz Safapour	A Bibliometrics-Based Visualization Analysis of Sustainable Transportation Infrastructure Research	Sustainable transportation infrastructure has profound social, environmental, and economic benefits for both individuals and societies. Recent years have witnessed a growing interest in this domain, and multiple studies have been conducted over the past decade. However, the existing body of knowledge concerning the present status of research within the domain of sustainable transportation infrastructure is limited. This study intends to identify the most significant articles categorically, track the recent trends of publications, examine the most common keywords, highlight their interconnections, and determine the most influential authors in the field of sustainable transportation infrastructure. The visualization analysis method based on bibliometrics, including performance analysis and scientific mapping, was performed. The performance analysis method involved studying the reviewed publications based on their types, topics and exploring the year-wise trend of publications. The scientific mapping method involved the keyword co-occurrence analysis and citation analysis. The outcomes of this study provide a comprehensive and structured understanding of the existing research landscape, highlight influential articles, authors, and trends, and offer insights that can guide future research efforts, policy-making, and industry development within the realm of sustainable transportation infrastructure.
Enric Barkokebas; Regina Dias Barkokebas, Ph.D.; Mohamed Al-Hussein	Systematic Review of Material Selection for Building Envelopes Based on Multi-criterion Decision-making	This study conducts a systematic literature review to evaluate existent studies on the use of multi-criterion decision-making (MCDM) methods for selecting building envelope materials, and identifies the various criteria and weight distribution techniques employed in this process. The results and discussion section focuses on the environmental impact, cost, technical performance, and social impact criteria, as they were identified as the predominant criteria among the reviewed studies. The results demonstrate that environmental impact and cost criteria consistently carry higher weights in MCDM studies in comparison to the social impact criteria. It is also found that, while numerous MCDM methods have been employed in the building envelope material selection process, the use of a hybrid MCDM approach is found to be the most recommended course. Overall, the findings of this study assist construction specialists in understanding the current practices and limitations in material selection processes for building envelopes and provide insights for future research in this area.
Valeria Vecchio; Beda Barkokebas; Regina Dias Barkokebas, Ph.D.; Mohamed Al-Hussein	A Systematic and Bibliometric Review of Greenhouse Gas Emissions in the Construction Phase of Residential Buildings	The construction industry largely contributes to the increase of greenhouse gas (GHG) emissions, accounting for 37% of the total energy-related emissions worldwide. Research efforts have focused on alternatives to decrease GHG emissions levels in the operational phase of buildings, while limited studies focused on their construction phase. In this context, this research reviews the latest technologies and strategies to reduce GHG emissions during the construction phase by considering the application of different building materials, construction alternatives, and GHG emission predictive tools in the residential sector. The systematic review is organized based on the PRISMA 2020 guideline, and the results are analyzed using VOSviewer. The contribution of this study is the consolidation of state-of-the-art approaches to reduce GHG emissions during the construction phase of residential buildings, which can assist construction practitioners in taking effective measures to address and mitigate GHG emissions in this particular phase.

Authors	Article Title	Abstract
Maral Nazemi; Ahmad Alshami; Qian Zhang; Juyeong Choi	Reuse and recycling feasibility assessment for bridge components: a case study of a bridge investigation in Florida	Demolition waste is a significant issue in the world. Over the years, different methods for extending the lifespan of construction materials and reducing demolition waste through reuse and recycling has been investigated. Specifically, concrete bridges have significant potential for material recovery due to not only the substantial amount of materials used but also the possibility of their retaining nearly the same or similar properties across bridge lifecycles. Most bridges are demolished not due to their structural deficiency but because they are functionally obsolete. In the literature on circularity and waste management, however, bridges are rarely considered. This paper quantitatively assesses the reusability and recyclability of different components of a bridge in Florida. Moreover, the reuse and recycling costs for bridge components and their resulting material savings are calculated and compared with their non-sustainable demolition options to decide the most sustainable but still economically feasible options based on their benefit-cost ratios. This study specifically examines how parameters like component uniqueness, time, and transportation affect the feasibility of bridge components for reuse or recycling and suggests the most sustainable demolition plan.
S. Yasaman Ahmadi; Jennifer Lather	Comparing Differences of Community Resilience and Rurality in the USA for Counties Prone to Riverine Flooding	This paper explores the variations in community resilience factors between rural and urban counties across the United States, focusing on regions at relatively high risk of riverine flooding. Leveraging data from the FEMA National Risk Index, U.S. Census Bureau, and BRIC Community Resilience Index, the study explores the relationship between community resilience and the degree of rurality. The analysis identifies statistically significant differences between urban and rural counties and identifies the extent of Spearman's correlation between each factor and percent rural. Rural counties facing elevated riverine flood risks exhibit comparatively lower community resilience in social, economic, and infrastructure/housing. Conversely, urban counties have a lower resilience in community and environmental aspects. These are more pronounced than seen nationally; while the directions of the trends nationally are similar, the correlations differ in magnitude. Notably, these higher-risk rural counties have a greater need for infrastructure/housing resilience (ρ=-0.78) and have a greater level of community and environmental resilience than their higher-risk urban counterparts (ρ=0.47; ρ=0.52) as compared generally in the US (ρ=-0.49; ρ=0.30; ρ=0.34). This study contributes to resilience literature by identifying aspects of community resilience within high-risk riverine flood-prone areas that are unique compared with the general urban/rural dynamics in the United States.
Vaishnavi Jagalur Ramachandra; Naila Mahaveen; Siddharth Banerjee, Ph.D.; Pedram Ghannad	ARTIFICIAL INTELLIGENCE ENABLING SUSTAINABLE CONSTRUCTION: A SYSTEMATIC REVIEW	This review article focuses on the use of artificial intelligence (AI) in sustainable construction management. By employing keywords and filtering through the Scopus database, 95 relevant articles were analyzed using VOSviewer for quantitative analysis. The researchers also conducted a qualitative analysis to identify core research themes. The article provides an overview of the current state of AI development in the construction industry, with a focus on sustainable construction. It aims to inform industry professionals, academics, and policymakers about past research and future trends in using AI tools to enhance the synergy between the construction industry and sustainability. By presenting the findings of this study, the article contributes to the body of knowledge and assists stakeholders in making informed decisions regarding the integration of AI in sustainable construction management.
Behzad Rouhanizadeh	A GIS-Based Social Vulnerability Assessment of Communities in Coastal Areas, Exposed to Extreme Flood Events: A Case Study of New Orleans Urban Area	According to statistics, the majority of Louisiana's urban coastal area is low-income, out of which a significant percentage is susceptible to issues dealing with hazards and the relevant consequences. On the other hand, the increasing number of hazards along the Mexican Gulf coast, has become a severe concern for governors. In this study, social vulnerability to extreme floods for New Orleans urban area is evaluated. through four phases. The indicators of social vulnerability are identified and using a statistical analysis process the most important indicators are determined. Also, Social vulnerability Index (SVI) is estimated and mapped, and the flood risk maps are generated. Finally, by merging the SVI map and the flood map, the social vulnerability exposure map is generated. The results revealed that four key factors that account for 78.60% of the variation in the overall dataset include Age (31.3%), Urbanization (21.5%), Employment Status (13.7%), and Education Level (12.1%). The output of this research can help stakeholders and decision-makers lessen impact of extreme flooding on the social life of vulnerable communities living in coastal areas.
Mohamed AbdelRaheem; Heba Gaber	Framework of the Assessment of the Financial Feasibility of Utilizing Piezoelectric Harvesters into Roadways	Traditional energy production has inadvertently led to climate change and energy scarcities. In response, renewable energy has emerged and is continuously expanding to meet our demand for clean, sustainable, and renewable power. One promising avenue is the utilization of piezoelectric harvesters to extract energy from roadways. However, the initial embedding costs of these harvesters can be high. Therefore, conducting an economic analysis is crucial to determine the viability of investing in this new renewable energy source. This study aims to assess the economic feasibility of implementing this technology through the application of life cycle cost analysis (LCCA) and comprehensive economic evaluations. By examining a real-life hypothetical scenario, the study demonstrates that this system will incur higher costs over the study period. However, sensitivity analysis reveals that modifying certain factors, such as reducing the prototype cost to below $6, would result in a positive net saving.
Marcus Nartey; Cristina Poleacovschi	Factors Leading to Tap Water Mistrust in Served Alaska Native Communities – A Case Study of a Village in the Norton Sound Region	Water insecurity, a global issue, particularly impacts Alaska Native communities due to poverty and social disadvantages. Historically poor water access and infrastructure affect over 30 Alaska Native communities. Despite some having piped water access, mistrust of tap water prevails, leading to reliance on potentially unsafe alternatives like river and rainwater. To bridge the gap in understanding tap water mistrust among Alaska Natives, we conducted interviews with a Norton Sound Health Region community. Findings reveal tap water quality perceptions, knowledge of pipe issues, health concerns, and supply disruptions drive mistrust. This research emphasizes the link between mistrust and infrastructural problems, aiding policymakers in prioritizing resources for water infrastructure development and maintenance.
Haniye Safarpour; Deborah Carroll; Lauryn Spearing	Spatial and Demographic Trends in Lead Levels: The Case of Chicago's Water System	Contaminants, such as lead, in water systems pose significant public health risks. Despite growing public awareness, the presence of lead service lines remains a concern in water systems. Consequently, there is a need to ascertain spatial and demographic trends in lead contamination to identify regional areas to monitor and to inform outreach campaigns. Leveraging lead water quality data collected in Chicago, we use Poisson regression analysis to identify the zip code level demographic drivers of high lead levels. Our model showed that the percentage of Black residents and the percentage of buildings built before 1980 were significantly associated with the percentage of samples with more than 15 ppb of lead, the EPA standard. Such trends shed light on underlying issues that may contribute to lead contamination, such as historic inequities in the built environment. These findings will assist decision-makers in prioritizing capital projects and educational campaigns, ultimately improving water services.
Ashtarout Ammar, Ph.D.; Gabriel Dadi; Hala Nassereddine	State Departments of Transportation Efforts Toward Optimizing The Management of Ancillary Asset Data: State of Practice and Future Recommendations	The evolving concept of smart infrastructures is redefining operational performance toward optimizing the performance of infrastructure systems by leveraging the asset value instead of expanding the existing systems. This can be achieved by leveraging the value of asset data, which is vital for efficient infrastructure management practices. However, state Departments of Transportation (DOTs) face several challenges in managing transportation asset data throughout the asset lifecycle. As such, this paper investigated the current practices in implementing Asset Management Systems (AMS) to manage ancillary transportation asset data, the Maintenance Management Systems (MMS) integration with the overall maintenance framework, and the nature of the adopted systems. Furthermore, this study explored the status of adopting AMS to manage the data for 25 ancillary asset classes. A web-based survey was developed and distributed. The results are encouraging and illustrate an increasing interest of state DOTs in implementing AMS to manage ancillary transportation asset data.

Authors	Article Title	Abstract
Ashtarout Ammar, Ph.D.; Makram Bou Hatoum; Hala Nassereddine; Gabriel Dadi	Introducing CHAMFiT: A Decision-Making Tool for Optimizing the Use of Wireless and Sensing Technologies in Highway Projects	Although technologies benefit the horizontal construction sector, investing in them doesn't guarantee that state Departments of Transportation (DOTs) can reap the technologies' fullest potential. Thus, it is important to provide DOTs with proper guidance to match the capabilities of the technology to the requirements of the DOTs' tasks. As such, this study presents a tool to evaluate the fitness of transportation technologies for construction highway and asset management tasks (CHAMFiT). This tool focuses on wireless and sensing technologies, including radio frequency identification, e-ticketing, ground penetrating radar, unmanned aerial systems, light detection and ranging, geographic information system, and global positioning system. Drawing on previous research, surveys, interviews, and a workshop, CHAMFiT maps common activities performed by state DOTs during construction and asset management phases to the characteristics of the investigated wireless and sensing technologies. The developed tool will help state DOTs make insightful decisions to implement wireless and sensing technologies successfully.
Junyi Duan; Chengcheng Tao, Ph.D.; Ying Huang	Finite Element Analysis of Structural Lining Materials for Pipeline Rehabilitation	Pipeline infrastructure is to essential to the economy of society and the life quality of the residents in US. Aging issue such as time, corrosion, cracks, or damages induced by earth movements might occur in the pipelines, resulting in a leak or explosion and causing potential losses of lives and properties. As an affordable and flexible trenchless alternative, epoxy resin is a widely used structural lining material for preventing pipeline leakage and increasing the service of pipelines. To investigate the effect of epoxy resin liner on underground pipeline maintenance and rehabilitation, we conduct a three-dimensional (3D) finite element analysis (FEA) to simulate the mechanical properties of structural liner for pipeline rehabilitation. Abaqus CAE software is applied as a computational tool to model the pipeline, structural liner, and surrounding formation. A parametric study is performed to present the effect of various factors, such as liner thickness and the addition of carbon nanotubes (CNTs), on the mechanical performances of the pipe and epoxy resin liner. The simulation results reveal the correlation between different parameters and rehabilitation effects. The FEA results can provide optimal solutions for the structural lining material design and guide the trenchless construction and maintenance procedures for pipeline infrastructures.
Jieyi Bao, M.D.; Xiaoqiang Hu; Yi Jiang; Shuo Li; Tommy Nantung	CREATION OF TRUCK WEIGHT ROAD GROUPS FOR PAVEMENT DESIGN	Weigh-in-Motion (WIM) and Automatic Traffic Recorder (ATR) devices, particularly the former, serve as indispensable sources of traffic data for Mechanistic-Empirical (ME) pavement design. However, the sparsely distributed WIM and ATR devices are unable to cover the entire roadway network in Indiana. The current Truck Weight Road Groups (TWRG) were developed using WIM traffic data of 20 years ago to reflect regional traffic conditions in Indiana. Because of the outdated traffic data, the existing TWRG classes fail to accurately reflect the actual traffic conditions, especially in the cases of extremely low and high truck traffic volumes. This study was performed to derive new TWRG classes using the newly collected WIM traffic data to provide accurate traffic information for pavement design. Consequently, employing the new TWRG values can significantly improve the quality of pavement design, resulting in considerable cost reduction of highway projects.
Amal Bakchan, Ph.D.; Kevin D. White	Identifying Socio-technical Challenges to Decentralized Wastewater Infrastructure Management in the Rural Alabama Black Belt	The Black Belt region of rural Alabama has struggled from a lack of access to managed wastewater infrastructure, resulting in the presence of raw wastewater on the ground and significant risks to public and environmental health. In addition to soil conditions that cause hydraulic failure in conventional septic systems, the wastewater crisis in the Black Belt is further exacerbated by several constraints, such as high poverty and low-population density. It is imperative to holistically understand the nature of challenges underlying the Black Belt's wastewater crisis, bringing in-depth insights into the complexity of the operating environment. To do so, this study identifies wastewater challenges, spanning technical, financial, social, institutional, and environmental dimensions. We applied hybrid deductive-inductive qualitative content analysis on eight semi-structured interviews with 11 stakeholders involved in the wastewater sector in Alabama to better understand wastewater issues and barriers to improvements. Results show that inflexible funding processes—such as requirements for communities to match funds and have technical capacity to manage them—strain Black Belt communities' competitiveness to secure wastewater infrastructure funding. Findings highlight the need to audit funding systems to consider rural, underserved communities' financial constraints, thereby ensuring more equitable allocations and potentially improving wastewater access in these communities.
Pooya Darghiasi; Mohsen Shahandashti	Enhancing Winter Maintenance Decision Making through Deep Learning-Based Road Surface Temperature Estimation	State and local highway agencies spend substantial budgets repairing infrastructure damages caused by snow and ice every year. These infrastructure damages (e.g., pavement corrosion and road potholes) can be prevented by establishing effective winter maintenance strategies which require monitoring road surface temperatures (RST). Information about actual and estimated road surface temperatures is typically obtained from road weather information systems (RWIS). However, RWIS do not exist in many locations, making it challenging to obtain information about RST in locations where RWIS are not available. This study aims to evaluate the applicability of deep learning models in estimating the road surface temperature based on the National Weather Service's weather forecast data which are provided in 2.5 km grid-cell spacing over the continental United States. The deep learning models were developed using actual RST and associated weather forecast data collected from North Texas roadways for two winter seasons. The performance of the developed model was measured based on different accuracy metrics including root mean square error, mean absolute error, and R-squared. The results indicate the deep learning model estimates road surface temperature with a root mean square error of 1.7 °C, mean absolute error of 1.35 °C, and r-square of 0.92, respectively.
Ahmed Al-Bayati; Louis Panzer; Ricardo Eiris	Third-Party Damages to Underground Utility: The Critical Need for Root Cause Analysis	Third-party damages to the subsurface infrastructure are a persistent issue that negatively impacts the integrity of the underground infrastructure and its vital services. Hundreds of thousands of third-party damages occur every year in the United States. These damages are more likely to reoccur when ignoring the value of learning from them. Therefore, this study investigates 16,937 damage reports that occurred in North Carolina in 2020 and were reported to North Carolina 811. The findings suggest that undesirable excavator practices contribute the most to third-party damages, followed by locator practices, general industry practices, and utility owner practices. In addition, the finding shows that most of the reported causes represent the direct causes of damages, not the root causes. Identifying the root causes is critical for a sustainable approach to significantly reducing damages to underground utilities. Overall, this study identifies the current direct causes of damages and weaknesses that hinder the industry from acquiring the needed knowledge to prevent damages to subsurface utilities.
Faisal Quibria Chowdhury; Yoojung Yoon	Case Study: Effect of the Condition Data of Automated Pavement Surveys on Pavement Performance Indicators	State Departments of Transportation (DOTs) have been transitioning from manual to automated pavement condition surveys with the advantages such as safe and speedy data collection and consistency and repeatability in data collected. The manual and automated data collection methods have inherently different capabilities for measuring pavement distress. When state DOTs use pavement performance indicators developed based on manually collected data and have already introduced an automated data collection process, the different capabilities can be problematic by either overestimating or underestimating actual pavement conditions. This study investigated the effect of the condition data of automated pavement surveys on a manual-based pavement performance indicator through a case study. The case study was a structural cracking index used for the West Virginia Division of Highways. This study investigated the effect of automated pavement condition surveys on manual-based pavement performance indicators. The study found that automated surveys can lead to changes in distress data compared to manual inspections, suggesting non-random change patterns. These changes can lead to significant budget losses for state agencies. The study also demonstrated the applicability of the approach used for a case study for other state agencies to evaluate their current pavement performance indexes.

Authors	Article Title	Abstract
Mina Zamanian; Mohsen Shahandashti	Empirical Study of the Correlation Between Geoelectrical and Soil-Index Properties of Clayey Soils	Insufficient subsurface information and soil mischaracterization contribute to significant delays and cost overruns in up to 50% of all infrastructure projects. Adequate and accurate determination of soil-index properties such as plasticity index and fine/clay fraction which affect the shear strength of clayey soils help assess infrastructure stability, especially in locations with extreme wetting-drying cycles such as North Texas. Due to the inherent limitations of geotechnical site investigation methods, extensive research has been conducted to establish relationships between various soil-index and geoelectrical properties of clayey soils. However, little to no efforts have been made to quantify the effects of plasticity index, fine fraction, and clay fraction on the electrical resistivities. This paper investigates the relationship between these variables using correlation and linear regression analyses. Other influencing variables such as water content and dry unit weight were also used in the analyses. Conventional laboratory electrical resistivity tests and physical property tests were performed on 56 soil samples taken from some locations across Texas, US (842 observations). The results show statistically significant relationships between clay and fine fractions, plasticity index, and electrical resistivity. The results also show that electrical resistivities are more influenced by the plasticity index than the fine and clay fractions.
Shiva Arabi; David Grau	Automated Underground Water Leakage Detection with Machine Learning Analysis of Satellite Imagery	Increasing water shortages, droughts, and global warming demand methods to rapidly detect underground water leaks. Conventional techniques are costly, time-consuming, and error-prone. However, remote sensing techniques can offer innovative solutions. Previous studies mostly used optical sensors. However, optical data has limitations, including noise interference, limited to null subsurface penetration, and weather dependency. Therefore, the study in this paper aims at exploring the combination of radar satellite data and machine learning to automatically identify underground water leakages. Radar data offers sensitivity to soil moisture below the surface. Moreover, image texture features were leveraged from dual-polarized radar data to enhance prediction. Gray-level co-occurrence matrix texture features were combined with backscattering coefficients to create a feature space that could better train the random forest. Results indicate the ability to automatically detect 69% of underground leaks with subsurface moisture alone, which increases to 81% with the addition of texture image analysis.
Frederick Chung; Minsoo Baek; Yejee Paik; Baabak Ashuri	Empirical Analysis of Pavement Condition Transition Probabilities	Due to needs of maintaining pavements located in statewide, the “one size fits all” approach for estimating pavement conditions no longer works as pavement deterioration depends on roadways characteristics. Understanding how pavement deterioration probabilities vary based on diverse factors is critical to improve accuracy of pavement condition estimations. The objectives of this paper are to build empirical Markov Chain pavement deterioration models and analyze how transition probabilities of pavement condition differ depending on multiple factors. The data of the Georgia Department of Transportation pavement inspection records from 2017 to 2021 is used to develop Markov Chain models and evaluate pavement condition transition probabilities. The major finding of this research is that pavement condition transition probabilities significantly vary depending on highway system types, traffic volume, and annual average temperature. It is anticipated that findings from this research will help highway agencies to improve accuracy of long-term forecasting of pavement performance.
Felipe Araya, Ph.D.; Nivaldo Calabran	EXPLORATION OF HEALTHCARE INFRASTRUCTURE INTERDEPENDENCIES DUE TO NATURAL DISASTERS	Infrastructure systems are known to be interdependent. Interdependencies among infrastructure systems are often revealed during disruptive events, such as natural disasters. Healthcare infrastructure plays a fundamental role in society after the occurrence of disasters facilitating the response and recovery of communities. This study aims to explore the role of interdependencies in the management of healthcare infrastructure in response to natural disasters such as earthquakes. The authors carried out 15 semi structured interviews during 2022 and 2023 with stakeholders involved in managing healthcare infrastructure in Chile that were qualitatively analyzed. Our results show that protocols exist to manage healthcare infrastructure during disasters; although the interdependencies between healthcare infrastructure and other urban infrastructure systems (e.g., water infrastructure) are recognized, existing protocols have given limited attention to them. Our results provide healthcare infrastructure agencies with insights to respond to future natural disasters understanding the importance of interdependencies with multiple infrastructure systems.
Mahdi Ghafoori; Moatassem Abdallah, PhD; Mehmet Ozbek	Modeling and Predicting Deterioration of Concrete Bridge Elements Using Machine Learning	The objective of this paper is to predict Health Index (HI) of concrete bridge elements using machine learning methods based on National Bridge Inventory (NBI) and the National Bridge Elements (NBE) databases. To this end, entropy based mutual information analysis is applied to evaluate the influence of different deterioration factors, such as daily traffic, location, and age on bridge elements deterioration. Moreover, several machine learning models are developed to identify the best method to predict bridge elements’ HI. Based on predictive performance metrics results, random forest method had the best performance in terms of mean absolute error, root mean square error, mean absolute percentage error, and coefficient of determination metrics for all the elements. The primary contributions that this research adds to the body of knowledge are: (1) application of entropy based mutual information to evaluate linear and nonlinear impact of different factors on bridge elements deterioration; and (2) development of new machine learning models to predict deterioration of bridges with various characteristics including age, daily traffic, and location. The models developed and presented herein are expected to support decision makers in identifying optimal time of interventions to minimize maintenance costs while maximizing bridge performance.
Jeremiah Adebiyi; Jim Anspach; Roy Sturgill; Philip Meis	Evaluating Utility Data Reliability: A Comparison of One Call and Subsurface Utility Engineering (SUE) Records	This study investigates the accuracy of as-built utility mapping through a comparison of utility records derived from traditional One Call systems and Subsurface Utility Engineering (SUE) investigations conducted as defined by the ASCE 38-22 standards. Focusing on a case study in South Dakota, a 'linear foot' metric was developed to quantify discrepancies and assess missing utility records. The findings revealed significant disparities in utility linear footage between the two methods, with SUE investigations consistently identifying a larger extent of utilities. This underscores the necessity of incorporating SUE practices early in the project development stages to ensure accurate utility data. Hence, this study emphasizes the potential of SUE investigations in enhancing the efficiency and risk management of construction projects.
Jae Heo; Soowon Chang, Ph.D.	Systematic Review of Social Equity for Installing Public Electric Vehicle Charging Stations (EVCS)	The site selection of public electric vehicle charging stations (EVCS) will have a long-lasting impact on people’s access to and use of EV, and thus long-term social equity. Since it is hardly possible to reinstall a public EVCS once it is built, site selections for EVCS should consider a fair share of benefits. In this respect, this research explores the evaluation criteria of social equity for guiding public EVCS installations through a comprehensive systematic review. This study will provide a comprehensive social aspect which synthesizes evaluation indicators and socioeconomic and demographic variables regarding EVCS installations towards fair infrastructure investment. The proposed complete social equity criteria can be utilized to investigate the patterns of community and social features so that socially acceptable, preferable, and equitable sites for EVCS can be suggested. This study will advance the body of knowledge on planning, design, and installation decisions of equitable public infrastructure.

Authors	Article Title	Abstract
Lila Madariaga; Clifton Farnsworth; Andrew South	Deciding Infrastructure Reconstruction Priorities After Disasters: A Literature Review	Disaster reconstruction is costly and given limited resources prioritization of the most critical infrastructure elements is necessary. This paper summarizes a literature review exploring how post-disaster reconstruction is performed on a macro-level, meaning the integrated nature of multiple infrastructure systems. This research specifically focused on determining how decision analysis is carried out in real-time application and how those decisions may be influenced by the growing body-of-knowledge on reconstruction decision making analysis and optimization techniques. The literature reports many different processes that have been developed for prioritizing infrastructure reconstruction, including a number of academic models designed to aid prioritization efforts. For their part, governments and managers of infrastructure systems are making prioritization decisions as disasters strike, but it is unknown whether or not real-world decision-making routinely incorporates these academic prioritization strategies. These results will help inform further research in developing macro-level interdisciplinary decision-making models for effectively prioritizing infrastructure reconstruction.
John Montagu; Simone Curtis; Constance Crozier; Cristina Torres-Machi; Kyri Baker	Trends in Equitable Electric Vehicle Adoption and Impacts on Pavement Condition and Electric Power Infrastructure	Increased EV adoption leads to reduced revenue from gasoline sales taxes used for road maintenance, while placing additional strain on power infrastructure designed for predominately smaller loads. This paper analyzes the adoption of electric vehicles (EVs) and infrastructure health in the Colorado Front Range and San Francisco Bay Area. The study analyzes demographic factors affecting EV adoption and assesses potential adverse impacts on pavement and power infrastructure quality. As expected from the literature, we find income to be the strongest predictor for EV adoption. However, we find noticeable differences in other trends between these two areas that demonstrate the importance of a regional approach for modelling the impact of EV adoption on infrastructure. Regarding the impact of EVs on power and transport infrastructure, it is unlikely that EV adoption has reached a high enough level to significantly affect infrastructure in either areas. The results suggest, however, that in the Bay Area, people living in counties with high EV adoption and high levels of income, are more likely to experience power outages. Overall, this study provides insights into the broader impacts increased EV adoption may have on pavement and power infrastructure.
Anh D Chau, Ph.D.; Long D Nguyen	Development of an Integrated Web-based Application for Pavement Design and Life Cycle Cost Analysis	The selection between rigid and flexible pavements is a critical decision in infrastructure development. Though studies have highlighted the potential benefits of rigid pavements, practical applications and substantial evidence to aid governmental decision-making remain scarce. Furthermore, there is a discernible disconnect between the design and life cycle analysis processes in current practices. Addressing these challenges, this paper introduces PaveDecision.com, an online application that combines both rigid and flexible pavement design and life cycle cost analysis in a single platform. With its user-friendly interface and capacity to process a multitude of input variables, this platform serves as a versatile tool for professionals and educators alike. Its computational accuracy has been confirmed through tests aligning with manual calculations in design standards. Ultimately, this research illuminates the potential of consolidated platforms like PaveDecision.com in enhancing pavement design processes, facilitating cost-effective decisions, and advancing sustainable infrastructure development.
Kyudong Kim; Helena R. Tiedmann; Kasey M. Faust	Construction Industry Changes Induced by the COVID-19 Pandemic: Impacts on Work Productivity	The COVID-19 pandemic permanently changed the construction industry. Remote meetings are more commonplace, and technological advancements and implementation accelerated. Although previous studies have identified the types and characteristics of such pandemic-induced changes, little is documented about how each change affected work performance. Here, we investigate construction industry changes and associated impacts. In November 2022, a list of changes was distributed to construction industry professionals working for the US- or South Korea- based companies using an online survey (n= 245). The survey asked respondents to identify which changes they underwent during the pandemic and whether their perceived productivity consequentially increased or decreased. The analysis revealed that the implementation of several workforce- and technology-related changes, such as document/design review platforms, improved productivity. On the other hand, the implementation of mitigation strategies for supply chain interruptions had a negative effect. The results empirically demonstrate that pandemic-driven changes impacted the performance of construction organizations.
Mohamad Abdul Nabi; Bahaa Chammout; Islam El-adaway; Rayan Assaad; Ghiwa Assaf	Investigating Price Fluctuation Transmission Among Construction Materials	Generally, fluctuation in one material's price can cause a series of chain reactions in the supply chain system, known as price fluctuation transmission, as all materials are interconnected and interrelated. None of the previous studies have investigated price fluctuation transmission among all construction materials. This paper aims to fill this gap in knowledge. The authors collected Producer Price Index (PPI) data for 16 construction materials, modeled the relationship between each pair of materials using Vector Autoregression technique, and validated the causality using Granger Causality test. Network analysis was performed to identify the price fluctuation transmission capacity, susceptibility, and intermediatory capacity for each material. The results showed that the materials with the highest price transmission capacities include: (1) “Fabricated structural metal products”, (2) “Construction sand, gravel, and crushed stone”, and (3) “Plastic construction products”. Ultimately, it is concluded that significant changes in the price of these materials can be an indication of price escalations in the supply chain and other construction materials. This paper provides industry practitioners with an unprecedented framework that highlights materials that can act as early warning signs for overall price fluctuations in the construction industry.
Muaz Ahmed; Islam El-adaway	EXPLORING THE INFLUENCES ON CONSTRUCTION BIDDING DECISIONS: INSIGHTS FROM LITERATURE AND INDUSTRY EXPERTS	Decision-making in construction bidding is one of the complicated processes. In determining related decisions, contractors weigh various bidding factors to assess the expected benefits of a construction project. Various studies have identified factors that impact construction bidding-related decisions. However, there is a lack of research that examines the alignment between industry and literature as related to the perception of the importance of bidding factors on bidding decisions. This paper fills this area of research need. First, the authors performed a content analysis of 124 construction bidding-related journal papers, and accordingly, 43 bidding factors were identified and mapped with analyzed journal papers. Second, the authors developed a survey to gauge the perception of industry experts about the influence of the identified bidding factors and collected 82 responses. Thereafter, a statistical analysis was conducted to investigate the alignment between literature and industry. The results indicated that some bidding factors have been understudied in literature compared their perceived industry importance such as risk of fluctuation in labor, equipment, or material price, contractor's risk attitude, and value of liquidated damages. Ultimately, this study adds to the body of knowledge by identifying any misalignment between the industry needs and research efforts on construction bidding.
Tamima Elbashbishy; Islam El-adaway	Assessing the Impact of Skilled Labor Shortages on Project Cost Performance	Over the past decade, there has been a notable increase in skilled labor shortages within the construction industry. This shortage has numerous negative consequences on construction projects, such as delays in completion, compromised quality, and higher costs. Therefore, the goal of this paper is to examine the extent of skilled labor shortages observed throughout the industry and their impact on the cost performance of construction projects. To achieve this goal, the authors identified ten key construction trades that heavily rely on skilled labor. Subsequently, an industry survey was conducted to measure the extent of skilled labor shortages, as well as the effect of these shortages on project costs. The survey responses were subjected to statistical analysis, including the use of Two Sample Z-Test and Pearson's Correlation Coefficient Test, to investigate two aspects: (1) the level of skilled labor shortages and their cost impacts for each identified trade, and (2) the correlation between skilled labor shortages and the cost performance of construction projects. Results show that MEP trades have the highest skilled labor shortages, followed by civil works trades. Further, MEP trades also have the greatest impact on cost performance among the identified labor-intensive trades.

Authors	Article Title	Abstract
Islam El-adaway; Jeffrey Russell; Ramy Khalef; Fareed Salih; Gasser Ali	Identifying and Exploring Construction PM Evolutions and Research Directions	Project management (PM) is the process of organization, allocation, and control of resources to achieve a specific goal. Previously, PM focused on planning and executing projects according to predetermined objectives, but it has evolved to include the use of technology to aid in managing and delivering projects. However, no research has provided a comprehensive analysis of this PM evolution. To fill this gap, this data-driven study conducted a scientometric analysis, using PM-related research papers, to identify the PM evolution along the holistic lifecycle of its knowledgebase. The findings of this study identify four distinct PM phases: PM 1.0, PM 2.0, PM 3.0, and PM 4.0. Each PM evolution's trend was found to be built on the preceding one, with even earlier generations of PM still impactful today. Trend analysis also suggests that there will be an increased focus on big data to further advance the field of PM with effective technological implementation. This suggests that PM 5.0 may be around the corner supporting previous PM principles to then balance environmental, ethical, and social concerns. Ultimately, this study will be beneficial to PM stakeholders by providing a holistic understanding of the main principles in PM and potential future research paths.
Deniz Besiktepe, Ph.D.; Osman Turkyilmaz	Exploring Decision-Making Methods in Lean Construction Tool Selection	Lean Construction (LC) practices comprise a set of tools providing optimal value generation with reduced waste and costs while promoting stakeholder collaboration. The selection of these tools is a complex process considering various organizational and strategic goals with the number of available LC tools. Companies implementing LC principles need practical applications to select the most optimal and value-generating tools that align with their goals. With that, this study explores the utilization of decision-making methods in LC tool selection. The study determined limited studies utilizing decision-making methods in LC tool selection and further reviewed Lean manufacturing tool selection efforts. The study revealed the lack of systematic approaches in LC tool selection within several LC tools. Moreover, future research directions were suggested, such as understanding the value of LC tools for different project types and investigating decision-making methods in other industries for lean tool selection with their applicability in the construction industry.
Hyun Jeong Koo, Ph.D.; David Kelly	Investigating Perception Variances among Project Participants concerning the Challenges of Renovating Historic Buildings	The common goal of historic building renovation and restoration projects is to accommodate current needs while preserving the cultural and aesthetic heritage of buildings. However, the challenges encountered when renovating historic buildings are different from new construction projects. To provide better insights, the authors conducted a survey of industry practitioners to identify the frequency and severity of common challenges. Comparison of results by the respondents' functional role shows a significant difference in assessing the severity of challenges, but no difference in assessing the frequency. Notably, construction team members tend to perceive the challenges as more frequent and severe than design professionals do. This study contributes to the body of knowledge in the risk management research domain as well as the historic renovation construction domain. Also, this study allows industry practitioners to better understand this type of construction project and manage plans by considering differences in their roles.
Amrit Shahi; Jin Ouk Choi, Ph.D.; Young Hoon Kwak	New and Emerging Modularization Business Drivers in Industrial Projects	The prevalence of modular construction has sparked interest in understanding the industry's new and emerging business drivers for modularization to seek maximum modularization benefits in capital projects. Previous studies on modularization business drivers have primarily focused on the building sector, with few addressing industrial projects. Additionally, these studies have been criticized for failing to address emerging issues such as sustainability and Environmental, Social, and Governance (ESG) initiatives. To address these research gaps, this study identifies new and emerging business drivers for modularization in capital projects, mainly heavy industrial projects. A comprehensive analysis of existing business models/tools in the industry, followed by a literature review and brainstorming sessions with subject matter experts from the Construction Industry Institute Research Team 396, was conducted to gather all the potential business drivers for modularization. As a result, a total of ninety-seven potential business drivers were identified. The subject matter experts assessed these drivers through a survey, indicating that sustainability, construction-related emissions and waste, ESG initiatives, transportation-related emissions and congestion, and standardization (repetitive design) are the new and emerging business drivers. This study offers valuable insights for practitioners seeking to analyze the potential of modularization ventures.
Amrit Shahi; Jin Ouk Choi, Ph.D.	Identifying Key Modularization Decision Factors in Industrial Projects	Modularization, a strategy of transferring some or all site-based work to external locations, has the potential to improve project competitiveness with cost and schedule advantages. While much previous research on modularization has primarily focused on the building sectors, many heavy industrial projects have yet to fully realize the benefits of modularization due to poor and late decisions. To address this issue, this research identifies the critical decision factors for implementing modularization in industrial projects. Utilizing the expertise of the Construction Industry Institute Research Team- 396, the researchers identified the decision factors for modularization based on their importance in the industrial sector after thoroughly examining existing business cases/decision models from world-leading global companies and literature. A survey questionnaire was prepared and distributed to the subject matter experts, asking them to rank the importance of decision factors. The result indicated that the top ten key decision factors for modularization in industrial projects were site location, site attributes, site access, labor costs, cost savings, owner's ability, logistical constraints, maximum module size, labor availability, and site infrastructure. The study guides the practitioners seeking to maximize the benefits of modularization in heavy industrial projects.
Shafayet Ahmed; Ziyu Jin	Methodology to measure the efficiency of scientific decision-making frameworks to select the preferred building material	Decision-making in the Architecture, Engineering, and Construction (AEC) industry is challenging due to stakeholders with divergent expertise. Oftentimes, the process of decision-making does not follow a systematic approach. Several scientific decision-making methods have been implemented to streamline the decision-making process in the AEC industry. However, previous studies have shown that not all frameworks are well-structured, equally efficient, and applicable to all scenarios. This study attempts to develop a methodology to combine and assess the efficiency of the two common multi-criteria decision-making frameworks, Choosing by Advantages (CBA) and Fuzzy Analytical Hierarchy Process (FAHP). The study focuses on addressing the early material selection problem in the industry. The proposed methodology compares concrete, steel, and mass timber building materials in the US from an early decision-making perspective. The findings of the study will have significant contributions to construction practices in terms of making rational and informed decisions regarding building material selection.
Sreelakshmi S, Ph.D.; Ashwin Mahalingam	WHAT DOES BIM ADOPTION MEAN TO CONSTRUCTION FIRMS? – A CASE FROM INDIAN CONSTRUCTION INDUSTRY	Building Information Modeling (BIM) is a powerful tool that can greatly enhance the efficiency and effectiveness of construction projects. However, despite its many benefits, the adoption of BIM in India has been slow. Construction organizations are typically project-based, and the decision to use BIM can vary depending on factors such as the contractual arrangement, project requirements, and the capabilities of vendors and subcontractors. Considering these, we identify the different pathways of BIM adoption from an Indian perspective. This study intends to understand how BIM adoption varies from one firm to another from an institutional theory perspective. This is achieved by using an in-depth qualitative case study approach. The results of the study indicate that firms display adoption differently, guided by institutionalized logic. Competence logic and completion logic were some of the institutional logics we observed that influenced adoption. Overall, this research highlights the approaches taken by different construction firms in India towards 'BIM adoption' based on the institutional logics that the firms follow and contributes to the institutional theory literature by understanding the interplay between the different logics.

Authors	Article Title	Abstract
Asitha Rathnayake; Danny Murguia; Campbell Middleton	Measurement of Construction Productivity: State of the Practice in the UK	Productivity indicates how efficiently resources are utilized to deliver outputs. Studies show that the UK's construction productivity lags behind similar European countries and the USA. This paper aims to uncover the underlying reasons by examining the industry's approach to measuring productivity. Our findings stem from semi-structured interviews with 29 industry practitioners and the observations of productivity measurement technologies on three projects. Production rate (output per unit of time) emerges as the most common productivity metric in projects, assessed on a daily, weekly, and monthly basis for decision-making. We also identified several issues in this area. Firstly, the industry tends to prioritize activity outputs over their interdependencies, influenced by earned value management thinking. Secondly, labor productivity (output per worker-hour) is not measured often due to reduced incentives and contractors passing productivity risks onto subcontractors. Lastly, inconsistencies in metrics and data collection limitations hinder the development of company-wide performance measurement frameworks.
Piyush Pradhananga; Mohamed ElZomor	Bridging the Gap to Success: Developing Accelerated Bridge Construction (ABC) Success Index Tool for Pre-Project Planning	Pre-project planning encompasses all the tasks from project initiation to the beginning of detailed design. Planning efforts at this stage have a significant effect on project success than efforts undertaken after project kickoff. Given that some contractors are new to the Accelerated Bridge Construction (ABC) method, providing knowledge of ABC success indicators during the initial phase will significantly impact ABC project success. The research aims to: (1) identify the success indicators through systematic literature review; (2) conduct a survey of ABC stakeholders with focus on successful ABC projects to validate and define the weighted success criteria; and (3) develop an ABC success index matrix. The study identified 16 ABC success indicators which should be taken into consideration during the pre-project planning stages of the ABC project. The study findings will support, educate, and direct ABC contractors to realize/value the significance of pre-project planning and encourages better organizational management.
Anthony E. Sparkling, Ph.D.; Kyubyung Kang	State-of-Practice in Electrical Contracting and Infrastructure Opportunities in the United States	The United States (US) committed over $1.2 trillion to help strengthen the nation's infrastructure systems and networks. Nearly $450 billion of these funds are being invested in energy and electrification projects. Electrical contractors (ECs) are poised for exponential growth in areas such as energy, power, and electric vehicle (EV) charging infrastructure, yet research is limited on strategies to engage in the expanding infrastructure market. The goal of the study is to investigate future opportunities for electrical contractors from the Infrastructure Investment and Jobs Act (IIJA). This study reaches several conclusions using factors such as region, project size, and industry/market. Nearly $197.5 billion has been awarded across all 50 states and accounts for 15,691 projects. The analysis of the IIJA funded projects revealed that broadband, clean energy and power, and EVs are directly relatable to ECs. The funding approved for these projects is approximately 8% of the total funding. There are 10,740 projects smaller than $2 million which makes up nearly 68% of the total number of projects that were funded in the spending bill. The South is experiencing a surge in large-scale battery projects. Meanwhile, the west coast is leading the charge in both renewable energy and EV infrastructure projects.
Makram Bou Hatoum, Ph.D.; Hala Nassereddine; Mahmoud El Jazzar	Achieving Agile and Transformative Change Efforts in Capital Project Organizations	Successful capital project organizations need to have a high degree of agility to anticipate and initiate change efforts with a transformative impact on strategy, structure, people, and culture. One question arises that contributes to organizational science: What makes an organization's response to change agile and its impact transformative? This study proposes a self-assessment "Change Response-Impact (CRI) Matrix" that allows decision-makers to map their change efforts across two variables: "change response" and "change impact". Through a survey distributed to the capital projects industry, data was collected on 60 change practices to identify the most critical and most challenging practices of each quadrant of the matrix. This paper focuses on exploring the change practices of the upper-right quadrant of the matrix, i.e., for organizations with a high degree of agility and going through a transformative impact. Findings of this study can guide practitioners and researchers as they navigate successful organizational change efforts.
Sepehr Khorshid; Siyuan Song; Peiyi Lyu; Raissa Seichi Marchiori	From Heat to Cold: Examining the Preparedness of Construction Projects During Unprecedented Winter Storms in the South	Construction workers face increased health and safety risks due to harsh weather conditions, resulting in delays and additional costs for construction projects. Climate change has made weather events more unpredictable, leading to unprecedented winter storms in regions not accustomed to severe cold weather. As a result, construction projects in the southern regions of the United States may encounter unusual weather challenges, with inadequate safety procedures and maintenance for workers and machinery. A literature review was conducted to explore measures taken in cold regions to mitigate the effects of winter storms on construction projects and workers. In addition, a web-based survey was developed using an evidence-based survey design approach to assess the level of preparedness of construction sectors in the South for unprecedented extreme winter events. This survey design provides a valuable tool to evaluate their readiness for such events and identify potential gaps in their preparedness.
Muhammad Amir Hamza Khan; Elnaz Asadian; Robert Leicht	Identifying Elements for Lean Construction Implementation in Trade Contractor Organizations	Lean practices and initiatives can substantially benefit the construction industry but the implementation level by trade contractors is lagging. This is partially due to a lack of awareness of potential methods that can be employed by trade contractors, as well as a lack of tools to assist them in realizing their current level of lean implementation. The effectiveness of lean implementation in trade contractors cannot be improved without understanding the current state of its adoption. Several maturity models have been developed to assess lean adoption for organizations and general contractors, however none has been created for the trade contractor community. Trade contractors execute most of the production tasks on construction projects thus they should benefit the most from lean adoption. This paper identifies 15 elements for lean construction implementation by trade contractors using literature review of existing lean construction maturity models and lean construction project implementation.
Rana Khallaf; Kareem Othman; Jose Guevara; Gabriel Castelblanco, Ph.D.	A SYSTEM DYNAMICS MODEL FOR A NATIONAL PPP PROGRAM: THE EGYPTIAN PROJECT PORTFOLIO	Public-private partnerships (PPPs) have become a prevalent delivery method for large global projects. Previous research has examined individual Egyptian PPP projects; however, there is missing program perspective level analysis, which is crucial to gain deeper insights into the program's overall outcomes. This paper proposes a System Dynamics model for a national PPP portfolio focusing on Egypt to address this gap. It aims to provide a tool for practitioners and policymakers to study the entire PPP system and the factors affecting it. Four causal loops show how policymakers and investors must balance economic growth with social acceptability to develop effective infrastructure strategies. The findings demonstrated an excessive reliance on the Egyptian PPP program in the energy sector and unsolicited proposals. Hence, policies focused on strengthening public capacities to procure PPP projects may be needed to counteract this tendency and enhance competition. The Egyptian PPP program can also benefit by prioritizing investment in critical infrastructure projects, particularly in sectors historically underfunded in the PPP program, such as ICT, which is critical for fostering the benefits of Industry 4.0. This paper analyzes the national PPP program dynamics and offers PPP decision-makers valuable approaches to improve project portfolio outcomes.
Esraa Y. Hyarat; Laura Montalban-Domingo; Tatiana García Segura; Amalia Sanz-Benlloch; Eugenio Pellicer, Ph.D.	CRITICAL SUCCESS FACTORS TO LEAN CONSTRUCTION IMPLEMENTATION: A SYSTEMATIC LITERATURE REVIEW	Since 1990, Lean Construction (LC) has drawn many participants in the construction industry due to its innovative features that have been demonstrated in the industrial sector, resulting in a flurry of adoption and implementation. As is typical with new techniques, some factors facilitate and encourage their adoption. This study aims to discover and explain the overall critical factors for LC implementation, regardless of company size, specialization, or nation, from a theoretical perspective. Additionally, recommend future study directions on this topic. A systematic literature review was conducted to identify the Critical Factors (CFs) for LC implementation from previously published research. The CFs were identified and categorized into six major types: managerial, operational and technical, cultural and human, educational and knowledge related, financial and contractual, and governmental. The dependability and correctness of the data acquired in earlier investigations are critical to the accuracy and consistency of this study.

Authors	Article Title	Abstract
Fahad K. Alqahtani, PhD; Eid K. Alagha; Ahmed Gouda Mohamed	Critical Success Factors of Public-Private Partnership for Urban Infrastructure Projects in Saudi Arabia	The public–private partnership (PPP) is a paradigm employed to upsurge the broad spectrum of financial perks of infrastructure deliverables. It is perceptibly becoming comprehensively acclaimed as the remedy to the significant bottleneck in PPP-urban infrastructure projects' (UIP) service delivery in the Kingdom of Saudi Arabia (KSA). The empirical initiatives have scarcely examined the cross-sectoral dimensions of crucial success determinants in KSA's PPP-UIP. Hence, this paper seeks to investigate to investigate a set of critical success factors (CSFs), portraying an approach to augmenting the prospect of successful PPP-UIP in KSA. Twenty-eight probable CSFs are revealed after examining a large corpus of literature, which are whittled downto 15 CSFs, banking on UIP managers' convictions, and conducting focus groups. In this context, a structured questionnaire matrix was devised premised on the hierarchical model constituted following a thorough literature review. The current study subsequently utilized the Analytic Hierarchy Process (AHP) methodology to examine beneficial characteristics in the KSA's UIP. Findings obtained in this paper equip decision-makers with an insightful perspective, slanted towards constructing further productive approaches for implementing PPP-UIP in KSA successfully.
Sanjeev Adhikari; Pavankumar Meadati; Druthi Katragadda	Identify applications of AR in the Construction Industry	Augmented Reality (AR) technology will promote worker efficiency through visualization and simulation, reduce health and safety concerns, and improve management in the construction industry. AR-enabled information improves student comprehension in regular classroom settings and prepares students to be technologically enriched professionals in the construction sector. Since the use of AR in the construction industry is still in the early stages, the amount of knowledge of AR hardware and software devices is to be explored. This research aims to assess the present state of development using a literature review. The study helps to provide an in-depth understanding of potential applications in the construction industry. It also analyses the uses and difficulties of AR for teaching and training in the Architecture, Engineering, and Construction (AEC) sector and measures its effectiveness in doing so. This review also serves as a resource for academics, educational institutions, and schools, boosting awareness of AR in AEC training and education.
Ali bayesteh; Ming Lu	Short-Term Planning of Municipal Drainage Infrastructure Maintenance Operations: Problem Statement and Optimization Formulation	Multiple infrastructure projects are scattered over a broad urban area and are usually executed simultaneously. Scheduling these multi-concurrent projects, and allocating shared scarce resources to them, while accounting for their restricted deadlines and preconstruction activities (e.g., locating underground utilities, site readiness) is daunting. It demands thoughtful approaches to effectively allocate resources while ensuring that projects are completed within the specified time frame. In collaboration with a municipal drainage services provider, this paper aims to improve the short-term planning of this kind of project, as such in municipal infrastructure maintenance operations. The problem is formulated into a mathematical model to represent the objective and its relevant constraints analytically. The model is prototyped and tested in Excel and validated by conducting case studies based on data collected from the real world. We found that the developed model outperforms the partner company's current practice in providing optimum solutions and significantly faster response time.
Mahya Sam; Bryan Franz	Evaluating vulnerability to uncertainty in human-robot collaboration: A case study in drywall finishing	Construction projects are exposed to high levels of logistical uncertainty like material shortages, power outages, and unpredictable weather events. Proactive planning around these uncertainties is complicated by the many resource interactions and interdependencies needed for the completion of most construction tasks. Exposure to uncertainty and a high sensitivity to that uncertainty makes project schedules more vulnerable to delay. The application of human-robot collaboration (HRC) in construction tasks has the potential to reduce uncertainty related to labor, but may increase vulnerability in other unexpected ways. This paper explores how HRC in a subset of construction tasks, specifically in drywall finishing, affects project vulnerability to simulated disruptions. Data from jobsite observations and worker interviews are used to develop a meta-network model of the drywall finishing process, which is integrated a semi-automated robot named “Canvas” in an HRC application. The results identify the circumstances under which HRC in drywall finishing makes the project more or less vulnerable to uncertainty. The findings of the research will aid project managers by enabling more resilient planning of HRC applications and provide guidance to robotic manufacturers improving the integration of their systems on construction projects.
Cristian Camilo Osorio, Ph.D (Current); Cristhian Camilo Amariles López; Rodrigo Herrera; Eugenio Pellicer	BIM IMPLEMENTATION IN SMALL & MEDIUM-SIZED COMPANIES IN THE COLOMBIAN CONSTRUCTION SECTOR	The construction sector has been characterized by having lower productivity than other industries. Construction has been encouraged to improve project performance and promote improvements in the life cycle. BIM is a project management methodology based on virtual construction and collaborative work that allows better integration in the life cycle project. The main objective of this research is to demonstrate, through a survey, the BIM implementation level in the Colombian construction industry. It was concluded that implementing BIM methodology in Colombia is incipient without a full implementation in the industry. Many enterprises continue to use traditional methods; however, the benefits in companies where it has been implemented are evident. Additionally, statistically significant differences were found in variables like BIM maturity and knowledge, among groups, such as type of enterprise, and organizational levels. Collaborative strategies could be developed to reduce barriers such as lack of knowledge, extra costs, and fear of change.
Shani Alexandra Montes Victorio, Master of Science; Roy E. Sturgill	Review of Effective Practices for Managing Utility Coordination Stakeholders in Highway Projects	The increased proliferation of utility infrastructure within the public right-of-way has become a growing challenge. Today's highway projects typically require interaction with many utility owners because of the increasingly complex utility infrastructure. Researchers have investigated different practices for effective utility coordination, including better communication and timely involvement of all stakeholders. Unfortunately, insufficient communication and coordination between utility stakeholders remain highly cited problems. Practitioners strongly believe that applying basic project management to utility issues can help alleviate those problems. Under the project management heading, stakeholder management is considered one of the most important tools and issues to project success. This fact, coupled with the persisting inefficiencies regarding communication and coordination among utility stakeholders, has created the need for a comprehensive review of stakeholder management literature in the utility coordination domain. This study aims to address this gap by analyzing the study interest of scholars in this field. Researchers conducted a systematic literature review that gathered relevant information from journal and conference papers and research reports. This information was categorized into the three well-known stakeholder theory approaches – descriptive, instrumental, and normative. The results revealed directions for future research regarding stakeholder management in utility coordination on highway projects.
SeogJae Choi, MSE	Identifying the Job Characteristics Affecting Construction Firm Employee Turnover Intention	Researchers have proved that employees who have the intention to quit the organization, called turnover intention, have decreased productivity and may not fulfill their duties properly. The turnover intention has a negative relationship with the quality of core job characteristics of the organization. As the construction industry has distinctive characteristics compared to other industries, the job characteristics that influence turnover intention need to be explored separately. This study identifies job characteristics of the construction industry that can affect turnover intention. Through the literature review, autonomy, task identity, required skill variety, task significance, justification in assigning work location, and job security are identified as core job characteristics. Based on that, this study suggests a survey evaluating the organization’s level of these job characteristics and turnover intention. The results showed that skill variety and justification in assigning work location are significant predictors of turnover intention. This study contributes to the understanding of the relationship between the independent variables, including the quality of job characteristics and demographics, and the dependent variable, turnover intention. Also, the suggested survey will be conducive for human resource practitioners who want to proactively identify and address employees with a high possibility of turnover.

Authors	Article Title	Abstract
Elyar Pourrahimian, M.Sc; Diana Salhab; Lynn Shehab; Simaan AbouRizk; Farook Hamzeh	Application of Chaos Theory in Project Management	Chaos theory, a mathematical discipline, delves into the behavior of dynamic systems highly susceptible to initial conditions, often called the butterfly effect. In project management, chaos theory becomes a tool for comprehending and predicting intricate systems, exemplified by large-scale engineering projects. Its application involves identifying and mitigating risks, improving decision-making, and enhancing overall project performance. By harnessing chaos theory, project managers attain profound insights into project dynamics, leading to more adept strategies for control and optimization. Consequently, the incorporation of chaos theory revolutionizes the management and refinement of complex systems. Nevertheless, scholarly exploration of chaos theory's role in project management remains limited. This article aims to analyze the integration of chaos theory in project management and its specific benefits in the context of substantial engineering endeavors. It encompasses fundamental chaos theory principles, implementation techniques in project management, instances of successful real-world engineering projects, and prospects for future research in this domain.
Oscar Humberto Portilla Carreño, MsC; Guillermo Mejía Aguilar; David Grau	EARLY DEFINITION MATRIX OF LOW-COST HOUSING PROJECTS FOR DEVELOPING COUNTRIES	The construction industry plays an essential role in developing countries. Effective development of construction projects leads to improved well-being and progress for society. Despite their importance, construction projects still face diverse and unpredictable challenges that threaten their performance, such as managing the increasing complexity of their requirements. Poor scope definition in the early stages of a project is one of the leading causes of failure and underperformance. This study aimed to develop a management tool to assess the early scope definition of low-cost housing projects tailored for developing countries, including sustainability and building information management criteria. To achieve this aim, this article carried a methodology out based on the collection of information from the construction management literature and validated by a panel of experts using the Delphi method. The study defined a requirements matrix made up of three main sections, eight categories, and thirty-nine requirements. The management matrix included sustainable standards for efficient energy, water management and information management using BIM from the early stages of the project. Thus, the results of this study provide project managers with a set of criteria to meet the new and complex requirements of sustainability and BIM in developing countries.
Felipe Araya, Ph.D.; Katia Ogalde; Leonardo Sierra	A Critical Review of Impacts from the COVID-19 Pandemic in Construction Projects: What Have We Learned?	The COVID-19 pandemic was a large disruptor for construction projects, disrupting the global supply chain, limiting workforce availability, and creating contractual challenges. However, the pandemic can also be seen as an opportunity to improve for the construction industry. This study aims to review existing literature and identify negative and positive impacts in the construction sector due to the COVID-19, and qualitatively analyze interviews with Chilean experts who worked through the pandemic to compare the negative and positive impacts identified from the literature with those discussed by experts. Our results show that more negative impacts are reported compared with positive impacts, which emphasizes the disruptive nature of the pandemic in the construction industry. However, when discussing positive impacts, experts were more optimistic and reported benefits, such as implementation of new technologies and digitalization of construction. This work may assist construction companies in defining new strategies for the post pandemic construction sector.
Avinash Aruon; Tripp Shealy	Are we on the same wavelength: Exploring inter-brain synchrony of engineering student teams when designing and building	The collective performance of construction project teams results from individuals sharing ideas and actions, and this collaboration shapes their values toward common goals. Inter-brain synchrony (IBS) is a potential explanation for team performance, which is coordinated brain activation across individuals. IBS is observed in other disciplines but not adequately studied in engineering and construction project teams. The purpose of the research presented in this paper was to establish the existence of IBS in engineering project teams during design and build activities. The study included 16 undergraduate fourth-year civil engineering students who were paired to form eight dyads. Each team was given the same three tasks varying in time and budget constraints. Team members wore a brain imaging device that measured the change in oxygenated blood in their prefrontal cortex. IBS was observed among all the teams but more prominent in some teams over others. Specific regions of the prefrontal cortex also expressed more IBS than others. The connection between IBS and team cooperation and performance varied. Further exploration is needed to better understand the role of IBS in team dynamics and performance.
Linda Atieno Odhiambo, MSc	FIT-FOR-PURPOSE HANDBOOK DEVELOPMENT FOR THE UPSTREAM, MIDSTREAM, AND MINING (UMM) SECTORS	Projects in the Upstream, Midstream and Mining (UMM) sectors present unique complexity. The Construction Industry Institute's (CII) Research Team 398 aimed at developing the criteria that define project complexity in the UMM sector in an attempt to offer guidance to manage project complexity. The eventual goal is to create a fit-for-purpose handbook for the UMM sector that will highlight specific tools from the CII database that can be leveraged to enhance project performance. This project is divided into phases; the first phase is to develop a complexity matrix for the UMM sector CII companies with more mature project management organizations. The academic team used convenience sampling and conducted interviews with owners and contractors for this purpose. The methodology also included reviewing literature from research into complexity, the characteristics of the UMM sector and incorporating the findings of the RT 305 and the PTAG complexity matrix to further understand complexity. The result was a complexity matrix that includes factors relevant to all the three sectors. The current and subsequent phases are a source of useful tools for project teams to understand and manage complexity.
Abdullah Alsharef, Ph.D.; Anto Ovid; S M Jamil Uddin; Alex Albert	Biggest Challenges Facing the Construction Industry	The construction industry is one of the main pillars of the economy. It plays a vital role in the country's economy by generating employment, upgrading current infrastructures, and boosting overall economic activities. In the United States, the economic contribution of the construction sector to the gross domestic product is nearly 4%. Nevertheless, the construction industry has not reached the desirable levels of overall performance in terms of delivering projects on time and within budget while maintaining high levels of safety, quality, and sustainability. Consequently, it is critical to pinpoint the industry's challenges to provide practical solutions. In this study, 25 experienced construction professionals were interviewed to understand better the emerging and persistent challenges of the construction Industry. The study findings suggest that the most significant and pressing challenges facing the construction Industry are: (1) the shortage of skilled labor, (2) supply chain disruptions along with material and labor cost volatility especially after the Covid-19 pandemic, and (3) the slow integration, high cost, and maturity of new emerging technologies (e.g., 3D printing, virtual and augmented reality). The study findings will help Industry leaders, governmental agencies, and construction researchers develop solutions that would improve the overall performance of the construction Industry.
Meltem Duva; Sinem Mollaoglu; Dong Zhao; Kenneth A. Frank	Evaluating the Impact of Micro-Level Changes on Macro-Level Network Structures in AEC Project Teams	Most Architecture, Engineering, and Construction (AEC) projects experienced disruptions, changes, or cancellations due to the COVID-19 pandemic. To compensate for the adversarial effects of this unexpected situation, some project owners stopped and restarted their projects after evaluating their scope and timeline, which caused changes in role assignments and communication structures. However, there is a knowledge gap regarding how communication network structures changed at the macro level with the involvement of new individuals at the micro level for the projects paused and restarted. Thus, this study examines the changes in the individuals occupying key roles and the impact of their egocentric networks on the project networks considering performance values. The research team collected archival, e-mail exchange, and survey data from an AEC project during the construction phase and conducted social network analysis. The study findings demonstrated that network topologies and collaboration patterns were different before and after the involvement of new project members. Especially, the new project manager acting as a network bridge prevented the formation of subgroup structure and contributed to the existence of the core-periphery structure. The results add to the body of knowledge by providing empirical observation on the macro-level effects of micro-level changes in AEC teams.

Authors	Article Title	Abstract
Abdullah Alsharef, Ph.D.; S M Jamil Uddin; Siddharth Banerjee; Anto Ovid; Alex Albert	Information Sources and Lessons Learned by Construction Organizations during the early Months of the COVID-19 Pandemic in the U.S.	The COVID-19 pandemic has been the most severe global health emergency in recent history. The pandemic has affected the construction industry like other industries, especially during the early months. Several studies have assessed the pandemic's impacts and examined several mitigation strategies. However, no study has discussed the information sources that construction organizations relied on to obtain information about COVID-19 and the early lessons learned. This study compiled the information sources that construction organizations relied upon while operating during the early months of the pandemic by conducting interviews with construction professionals. The study also collected the early lessons learned from operating during the pandemic. Interview findings suggest that the most frequently used sources were (1) the Centers for Disease Control and Prevention (CDC), and (2) local city and county websites. As for early lessons learned, the findings from the interviews revealed that there is a need for an industry standard to work during similar events and the need to stockpile adequate material and place early orders. The current study's findings would help industry leaders and decision-makers better understand how the construction industry reacted to the COVID-19 pandemic to establish the best practices to remain operative, productive, and safe during future pandemics.
Miaosi Dong, M.D.; Pingbo Tang; Burcu Akinci; Ruoxin Xiong	Stabilizing Manufacturing Lines of Customized Building Mechanical Components Under Uncertain Machinery Deteriorations	In customized building mechanical component production, frequent quality issues and maintenance caused by unexpected machine failures interrupt production, leading to waste and delays. Integrating predictive maintenance strategies into manufacturing operations is necessary to solve this problem. However, under the uncertainties of machinery deterioration and productivity, existing literature lacks a quantifiable index for precise evaluation of joint maintenance and production schedules. A significant challenge is the scarcity of production and maintenance data to infer these deterioration models accurately. As a result, current methods struggle to balance production goals with machine maintenance, often leading to sub-optimal performance and more downtime. This paper presents a maintenance and production scheduling framework that integrates data extraction and process mining to infer manufacturing line deterioration models. This framework generates stable maintenance coordination plans, considering uncertain products' production schedules and machinery deterioration rates. It establishes predictive maintenance using the models estimated from limited data. Production and maintenance activities can be thus scheduled to stabilize productivity and quality. The authors validated this framework using data from a ventilation duct manufacturing line. The results show that it can use limited data to produce reliable deterioration models that support stable maintenance and production scheduling.
HASAN GOKBERK BAYHAN; Sinem Mollaoglu; Kenneth Frank	Line of Privity's Effect on Project Performance: A Case Study	The construction industry relies on temporary alliances for project completion, emphasizing effective coordination and communication. Line of privity (LoP) is a key concept in construction projects, representing the contractual relationship between parties and playing a vital role in inter-team coordination. This study investigates the impact of LoP on team communication and productivity within a transaction cost framework, using mixed methods with social network analysis. The main hypothesis posits that contractual and organizational ties, measured by LoP and distance, enhance project team productivity through improved communication. Data were collected from a healthcare project using mixed methods throughout project delivery. Analysis reveals the importance of direct communication, although excessive focus may hinder performance due to fewer parties involved or information overload. Increased Organizational Distance negatively affects completion rates, while frequent long-distance communication promotes understanding and coordination among distributed teams. A direct correlation between the ratio of LoP communications and project performance was observed. This paper provides insights for construction project management, emphasizing the significance of direct communication, effective management of Organizational Distance, fostering long-distance communication for distributed teams, and understanding the impact of LoP communications on project performance. These findings contribute to efficient coordination, reduced idle time, and minimized rework.
HASAN GOKBERK BAYHAN; Sinem Mollaoglu; Kenneth Frank	Team Collaborations During Time of Disruptions: Transaction Costs and Social Network Perspective with Hierarchical Linear Modeling	This study explored changes in communication patterns within construction project teams during times of disruption (i.e., the COVID-19 pandemic), focusing on transaction costs associated with communication and coordination through individual-level project team interactions. Nodes within the communication networks were classified based on their roles (Owner, General Contractor, Designer) and were further categorized into three tiers according to their significance, decision-making authority, and involvement in the project. By utilizing social network analysis (SNA) and hierarchical linear modeling (HLM), the study discerned considerable shifts in network dynamics. Designers and Owners in Tier 2 showed a decline in network centrality and importance, as evidenced by reduced eigenvector centrality and increased inverse of closeness centrality. Conversely, the Owner and General Contractor in Tier 1 either maintained or slightly enhanced their network importance. Local transitivity, indicating the propensity for nodes to form clusters, fluctuated across roles and tiers. The pandemic typically decreased the authority score, implying diminished perceived credibility of nodes. The elevated communication load on Tier 1, mainly including project managers, exerted pressure on their capacity limits. The disruptive period and the potential impacts of COVID-19 marked an irrevocable shift in global communication, not just in the construction industry, necessitating role and tier-specific strategies.
Xinran Hu, Ph. D.; Yunfeng Chen	BIM's Impact on Project Management Performance	Prior studies on the impact of Building information modeling (BIM) on project management performance (PMP) have mainly focused on different business types or projects. However, few quantitative studies have explored the impact of BIM adoption on PMP across employees' experience, company' BIM percentage, and countries. To address this gap, a survey was carried out on 229 BIM-related practitioners to collect their perceptions of BIM's impact on PMP for real-world projects. The survey results indicated that BIM contributed the most to early problem detection and the use of coordination tools, but less to safety management. Significant differences were observed between respondents with less and more than five years of experience, and companies with less and more than 30% BIM percentages. No significant differences were found, except for safety management, between countries including and excluding the US. This study contributes to the understanding of BIM's impact on PMP at multiple levels.
Wedad Baker Abu Adi, Ph.D.; Jennifer Shane	A Comprehensive Review of Integration Management Components in Construction Management	The increasing complexity of construction projects necessitates an effective project management system. In construction management, integration management is a crucial and valuable system encompassing all project aspects, processes, and stakeholders. It ensures effective communication and coordination throughout the project lifecycle from initiation to completion. Integration management comprises six main components: project charter development, knowledge integration, process integration, team integration, supply chain integration, and integration of changes. Although previous research has addressed one or two of these components, they have yet to address all of them, their significance, factors, and barriers in the construction industry. This paper reviews previous research to comprehensively understand all integration management components. The review aims to determine the barriers that impact integrated management implementation and define the critical factors that enable effective integration across different processes. This review is the first step in highlighting the importance of integrating, managing, and controlling all project processes, activities, and elements. It will serve as the foundation for future research in managing construction projects, strengthening critical success factors, and eliminating barriers to better understanding integration management for construction projects.

Authors	Article Title	Abstract
Tarek Salama, Ph.D.; Hisham Said	Agility Assessment Tool for Modular and Offsite Construction (MOC) Organizations	Offsite fabrication has been proposed as a critical component of the effort to industrialize the construction industry and close its performance gap with the manufacturing industry due to its positive impact on project schedule, cost, safety, and quality. Agile manufacturing is considered a successful way for manufacturing and assembling products. However, tools of lean manufacturing and lean construction are the main applied tools in the industry and academic research for modular and offsite construction. Manufacturing firms recognized the importance of responding quickly to market demands in a cost-effective way. However, it is difficult to determine if an organization is agile or not and its level of application for agility principles. This paper proposes an agility assessment framework for modular and offsite construction based on existing literature for agile manufacturing. This simplified assessment tool integrates the agility enablers (AE) and capabilities (AC), into a single group of competencies to describe the MOC external (enablers) and internal (capabilities). Validation of proposed framework was conducted using Delphi technique by interviewing eight executive experts from the MOC industry. It is concluded that acquiring agile certification by MOC professionals benefits the industry.
Parshva Patel; Roy Sturgill	An Assessment of As-Built Accuracy Using Ground-Based Photogrammetry Compared to Traditional GPS Survey	Public infrastructure, like electric and telecommunication utilities, are increasingly moving underground to avoid above ground congestion in urban areas and for protection of their facilities. Locating underground utilities remains a challenge in the United States, and accurate as-built records are crucial for urban development and utility management. Emerging Geospatial, three-dimensional (3D) and as-built utility survey technologies are essential for producing reliable and accurate geospatially referenced subsurface utility data. However, the practice for collecting utility as-built data using 3D modelling technologies is one of the least used approaches among the United State DOTs. Therefore, this study aimed to compare the positional accuracy of digital as-built data of underground utility captured through ground-based photogrammetry with traditional real-time kinetic (RTK) corrected GPS survey points with elevations calculated by survey level. The results demonstrated geospatially accurate 3D scan and the notable accuracy achieved by device orientation demonstrates ground-based photogrammetry's value for utility as-built data collection.