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A CONCEPTUAL FRAMEWORK FOR SUSTAINABLE FREIGHT LAND TRANSPORT SIMULATION – PART 1

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Abstract
Freight transport is a fundamental activity for the economic growth of a country or region, and the transport sector is one of the main contributors to gross domestic product (GDP) measurements. The total tons to be transported per year and transport types must be taken into account by state organisations for infrastructure planning, routes, prices and taxes. Governments make investment decisions according to the size of the freight mobilised per year. Transportation companies should contemplate external and internal variables, for example, fuel prices, distances, environmental impact, among others. Sustainability has become a determining factor in transport companies' decision making. This paper presents a novel study about the factors that affect freight land transport from the sustainability perspective. Then it proposes a conceptual framework to act as a roadmad to build a simulation model of freight land transport by defining the key parameters in economic, social and environmental terms. 25 refs.
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Key Words: *Freight Land Transport, Sustainability, Circular Economy, System Dynamics*

Pages 401-411

IMPACTS OF MAINTENANCE POLICIES ON FRACTAL LAYOUT PERFORMANCE

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Abstract
Fractal cells were proposed to increase the flexibility of production systems and reduce production costs. Because all fractal cells comprise the same type of machine, they can manufacture any product type. Thus, product batches should not be moved on the factory floor. However, owing to natural wear and tear, machines must be stopped for maintenance, which requires machines from other cells, resulting in unnecessary travel. Therefore, this study aimed to investigate the impact of maintenance management policies on fractal physical arrangements using a simulation model. The results indicate that increasing the number of fractal cells can be advantageous for reducing product displacement and makespan. 20 refs.
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Key Words: *Computer Simulation, Fractal Layouts, Maintenance Policies, Product Makespan*

Pages 412-423

INTEGRATED MODEL OF RISK MANAGEMENT IN BUSINESS PROCESSES IN INDUSTRIAL SYSTEMS

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Abstract
Today's business systems are faced with an increased intensity of changes from the environment, growing complexity and increased competition, which affects the increase in the level of risk in all areas of management and execution of business processes. Therefore, Risk Management (RM) discipline and practice is increasingly applied in almost all types of business systems. RM is the systematic approach of identifying, estimating and reducing threats or uncertainties that may influence organizations. This article presents the proposed model for monitoring and managing business risks, including strategic and operational goals, organizational responsibility and management, business performance, internal audit and internal control, application of information systems and the success of business processes. The research was conducted on a sample of 387 respondents, employed in manufacturing and service companies. The research results show that organizations that accept the proposed model have a chance to successfully manage risks in their business processes. 33 refs.
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Key Words: *Risk Management, Business Process Management, Performance Management*

Pages 424-434

DIGITAL TWINS IN THE RETAIL INDUSTRY: A SYSTEMATIC LITERATURE REVIEW

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Abstract
Digital Twin (DT) is considered the most modern simulation method when it comes to tightly connect the real and virtual worlds to produce accurate simulation models of constant use to aid stakeholders in decision making. This method has been used more intensively in the manufacturing sector, but its use has spread to other sectors of great relevance in the economy, such as the retail industry. The contribution of this article to existing research is to present a Systematic Literature Review (SLR) addressing the state-of-the-art of the potential use of Digital Twins (DTs) to support decision making in the retail field. The main findings illustrate a considerable appearance of case studies applied directly in the sector, a strong investment in research focused on supply chains, an extensive use of simulation models and sensors, however, that mostly make use of secondary data and are not completely autonomous. Summary tables of the main benefits, opportunities and challenges in applying DTs in the retail sector are also presented. 35 refs.
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Key Words: *Digital Twin, Cyber-Physical System, Simulation, Retail*

Pages 435-446

AN OPTIMIZATION METHOD OF LARGE BUILDING SPACE BASED ON EVACUATION SIMULATION

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Abstract
To improve crowd evacuation efficiency in large building spaces during fires, a spatial layout optimization method using PyroSim and Pathfinder software was proposed. Disaster-causing factors that hinder safe evacuation – such as smoke spread, fire scene temperature, CO concentration, and visibility – were compared. The arrival time of danger in fire environments was analysed, the time required for crowd evacuation was calculated, structural characteristics of building space affecting evacuation efficiency were identified, and evacuation bottlenecks in large-scale buildings were revealed. Taking the super-large building of Silk Clothing City in Jiangsu Province, China as an example, a spatial layout optimization scheme focused on evacuation efficiency was proposed and its effectiveness was verified. Results show that before spatial layout optimization, the available safe evacuation time is 145 seconds, which is shorter than the required safe evacuation time of 197.8 seconds, indicating high safety risks during evacuation in a fire. After optimizing the layout of smoke exhaust equipment, the available safe evacuation time is increased to 205 seconds, substantially enhancing crowd evacuation safety. 23 refs.
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Key Words: *Fire in Large Buildings, Spatial Layout Optimization, Evacuation Efficiency*

Pages 447-458

DESIGN OF A PERIODIC STRUCTURE FOR COMPOSITE HELICOPTER ROTOR BLADE

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Abstract
This study investigates the design and optimization of a 3D periodic structure to minimize vibrations in helicopter rotor blade systems. The research focuses on nonlinear models for rotating beams using a hybrid formulation of finite element methods and variational asymptotic beam sectional analysis. The periodic structure attenuates vibration transmitted from the blades to the rotor shaft. Dimension optimization was performed using particle swarm and gradient search algorithms, showing a minimal average difference of 2.37 %. Performance simulations at 190 rpm revealed that a 5.4 % reduction in reaction forces in the X and Y directions and a 3.2 % reduction in Z direction forces of main rotor shaft occur in comparison with conventional damper system. As a result of the study, it was concluded that 3D periodic structures can form a suitable passive damping system and mass reduction solution for helicopter blades. 33 refs.
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Key Words: *3D Periodic Structure, Composite Helicopter Rotor Blade, Vibration Attenuation, Passive Vibration Damping, Particle Swarm Optimization*

Pages 459-470

SIMULATION INSPECTION TECHNOLOGY FOR SURFACE CHARACTERISTICS OF HIGH-QUALITY STRIPS

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Abstract
To address the challenge of high rejection rates due to surface quality defects that are hard to detect with the naked eye, a comprehensive model was developed for detecting such defects and implemented a full-fledged equipment and system for surface quality inspection. Specifically, a targeted comprehensive model was formulated to identify three types of plate and strip surface quality defects. Furthermore, the latest hardware equipment and an advanced unsupervised self-learning algorithm were integrated into the detection system to enhance the identification and classification of these surface quality defects. The results demonstrate an improvement in the comprehensive detection rate and classification accuracy of surface defects from 96 % and 91 % to 98 % and 95 %, respectively. Moreover, the qualified rate of finished products has increased from 94 % to 99 %, leading to improved accuracy in defect detection and a significant decrease in false alarm rates. These findings provide a solid foundation for significantly reducing material waste and enhancing the overall quality of the production process. 26 refs.
(Received in June 2024, accepted in August 2024. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Strip Rolling, Surface Quality, Defect Identification, Deep Learning*

Pages 471-482

ATTACHABLE IOT-BASED DIGITAL TWIN FRAMEWORK SPECIALIZED FOR SME PRODUCTION LINES

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Abstract
While large enterprises are actively preparing for digital transformation by leveraging technologies such as digital twins, smaller companies face challenges due to economic constraints and market uncertainties, leading to a relative lack of awareness and readiness. To address this situation, this study proposes a digital twin development framework tailored for small and medium-sized enterprises (SMEs). This framework utilizes attachable IoT devices for real-time collection of manufacturing data and leverages public server systems for data management. Moreover, it enables the refinement and optimization of digital twins by training machine learning models on collected data. Additionally, the framework includes the integration of simulation models and machine learning models for comprehensive digital twin modelling. Finally, the paper suggests a process for applying and validating this framework in real manufacturing companies, demonstrating the effects of digital twin implementation on productivity enhancement in the production lines of two SMEs. 31 refs.
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Key Words: *Digital Twin, IoT Device, Modelling and Simulation, Production Line, Small and Medium-Sized Enterprise*

Pages 483-494

SIMULATION OF THE EVACUATION STRATEGY FOR AN AIR–RAIL INTERMODAL HUB STATION

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Abstract
To clarify the evacuation bottleneck of air–rail intermodal hub stations and improve the efficiency of personnel evacuation, the smoke spread process and the visibility and temperature changes in the case of fire in an air–rail intermodal hub station in Zhengzhou, Henan, China, were simulated via PyroSim simulation software based on performance-based fire protection design technology. The available safe escape time was obtained, the whole process of safe personnel evacuation was simulated, the bottleneck position in the process of evacuation was revealed, and the time required for safe crowd evacuation in the fire environment was determined. Results show that with a smoke exhaust system, smoke spreads to both sides of the hub station in 270 s, the visibility on both sides is affected, and the safe evacuation conditions fail. When the smoke exhaust system does not function, the available safe escape time is 497 s, and the required safe escape time is 370.5 s. The obtained conclusions provide a decision reference for performance-based fire protection design of air–rail intermodal hub stations. 21 refs.
(Received in July 2024, accepted in August 2024. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Air–Rail Intermodal Hub Station, Fire Simulation, Emergency Evacuation*

Pages 495-506

SIMULATION MODELLING OF ELECTRIC VEHICLE CHARGING RECOMMENDATIONS BASED ON Q-LEARNING

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Abstract
The adoption of electric vehicles (EVs) represents a pivotal shift towards sustainable mobility, yet the challenge of efficient charging station recommendations persists, influencing user convenience and EV uptake. This study introduces a novel approach utilizing Q-learning for simulating EV charging station recommendations, aiming to optimize the matching process between EVs and charging infrastructure. By integrating Markov decision processes with Q-learning algorithms, we dynamically adapt recommendations to user behaviours and preferences, significantly enhancing recommendation accuracy and personalization. The methodology involves constructing a simulation environment to model EV charging behaviour, evaluating the performance of the Q-learning based recommendation system under various scenarios. Results demonstrate the effectiveness of this approach in identifying optimal charging strategies, thus contributing to improved user satisfaction and charging station utilization. The findings underscore the importance of innovative technological integration for addressing the complexities of sustainable urban mobility. 19 refs.
(Received in March 2024, accepted in May 2024. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Electric Vehicles, Q-Learning, Charging Station Recommendations, Simulation Modelling, Intelligent Transportation Systems, Sustainable Mobility*

Pages 507-518

FLEXIBLE JOB SHOP RESCHEDULING SCHEME SELECTION USING IMPROVED TOPSIS

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Abstract
Flexible job shops have difficulties in selecting rescheduling schemes under various disturbances. This paper proposes a rescheduling decision selection method that comprehensively considers production loss cost, completion time, machine load balancing rate, and additional machine energy consumption. First, the G1-improved entropy method and the improved TOPSIS method are combined to evaluate rescheduling schemes. Meanwhile, the proposed method combines subjective and objective factors to provide decision-makers with the optimal rescheduling scheme, leading to higher rationality, practicality, and effectiveness of the rescheduling process. Finally, a case study verifies the applicability of the proposed method in a typical flexible job shop scenario. 20 refs.
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Key Words: *G1-Improved Entropy Weight Method, Improved TOPSIS, Flexible Job Shop, Rescheduling Scheme Selection*

Pages 519-530

FINITE ELEMENT STUDY ON THE EFFECT OF FIBRILLAR MORPHOLOGY ON CORNEAL BIOMECHANICS

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Abstract
Understanding the relationship between fibril morphology and corneal biomechanics is crucial for predicting the ocular response to physiological and surgical loads. In this study, we developed a finite element model of the corneal strip to investigate the effect of fibril crimp parameters, area fraction and orientation on the nonlinear stress-strain behaviour. The fibrils were modelled as Ogden materials with a Gaussian distributed crimp degree, while the matrix was set linear elastic. Uniaxial tension simulations were performed to analyse the evolution of fibril deformation and stress with the applied load. The result showed good agreement with the experimental data reported in the literature and captured the three stages of corneal response. Increasing the fibril area fraction, and decreasing the crimp degree and angular deviation from the loading axis resulted in higher corneal stiffness. Interestingly, the stress-strain behaviour was insensitive to changes in crimp amplitude and period at a constant crimp degree. These findings provide novel insights into the corneal structure-function relationships and highlight the potential of multi-scale computational models for predicting ocular biomechanics. 35 refs.
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Key Words: *Fibril Morphology, Finite Element Model, Corneal Strip, Stress-Strain Behaviour, Uniaxial Tension*

Pages 531-542

EVOLUTIONARY ALGORITHM FOR DYNAMIC RESOURCE ALLOCATION AND ITS APPLICATIONS

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Abstract
In modern manufacturing, dynamic allocation of resources is key to enhancing production efficiency and competitiveness. With the advancement of intelligent manufacturing and Industry 4.0, the manufacturing environment has become increasingly complex and variable, making traditional static resource allocation methods insufficient for practical needs. This paper aims to explore multi-objective optimization methods for dynamic manufacturing resource allocation by constructing a multi-objective optimization model and proposing an improved NSGA-II algorithm to address this issue. The study demonstrates that the improved algorithm significantly enhances population diversity and global search capability, effectively coping with dynamic manufacturing environments to provide efficient and reliable resource allocation solutions. This research not only offers new insights into dynamic resource allocation but also serves as a valuable reference for related fields. 22 refs.
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Key Words: *Dynamic Manufacturing Resource Allocation, Multi-Objective Optimization, NSGA-II, Intelligent Manufacturing, Industry 4.0*

Pages 543-554

OPTIMIZATION STRATEGIES AND SIMULATION OF INTEGRATED MANAGEMENT IN SUPPLY CHAINS

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Abstract
With global economic integration and rapid IT advancements, enterprises face complex market environments and intense competition. Efficient management and coordination of supply chains and manufacturing are critical. This study explores optimization strategies for integrated supply chain and manufacturing management using system dynamics. Initially, it investigates the contractual collaboration model based on system dynamics, analysing dynamic behaviours and optimization strategies. Subsequently, a system dynamics simulation model of the integrated system is constructed. Simulation analysis reveals the interactive relationships and dynamic patterns within the system. While many studies focus on static analysis, they often overlook dynamic changes and complex interactions. This study enriches the theoretical framework and provides solutions for enhancing management efficiency and competitiveness in a volatile market. 17 refs.
(Received in May 2024, accepted in July 2024. This paper was with the authors 3 weeks for 2 revisions.)

Key Words: *Supply Chain Management, Manufacturing, Integrated Management, System Dynamics, Contractual Collaboration Model, Simulation Model*