Pages 371-382

ADAPTIVE DISCRETE-EVENT SIMULATION FOR RELIABLE PRODUCTIVITY PREDICTION

Son, Y. H.; Lee, E. S. & Son, J. Y.
E-Mail: yhson@etri.re.kr

Abstract
Accurate productivity prediction is difficult in manufacturing work centres with high variability from human-machine interaction. Conventional discrete-event simulation (DES) relies on static master data, limiting its ability to reflect operational changes under dynamic conditions. This study proposes an adaptive DES framework that updates simulation parameters using monitoring-derived process metrics without modifying simulation logic. An information model and event-driven procedure transform heterogeneous manufacturing data into structured simulation inputs. The framework is validated in a vibration welding case involving human-machine collaboration, where electric current signals extract time-dependent production and waiting metrics. Results from ten production days show 99.12 % prediction accuracy compared with 91.12 % for static approaches, demonstrating that monitoring-based adaptation significantly improves reliability in high-variability environments. 8 refs.
(Received in March 2026, accepted in April 2026. This paper was with the authors 3 weeks for 2 revisions.)

Key Words: *Discrete-Event Simulation, Productivity Prediction, Adaptive Simulation, Human-Machine Interaction*

Pages 383-393

SUSTAINABLE MANUFACTURING DIGITAL SHADOWS: INTEGRATING VR, AI, REAL-TIME DATA

Nascimento, J. P.; De Araujo, A.; Ferreira, Y.; Palmeira, E.; Winkler, I. & Pimentel, C.
E-Mail: joaopsilva@aluno.ufrb.edu.br

Abstract
Industry 5.0 prioritizes sustainable, human-centred production, but practical frameworks integrating digital twins, artificial intelligence, and virtual reality (VR) remain scarce. This study develops an operational toolbox acting as an advanced digital shadow, featuring a real-time pipeline via MQTT, Telegraf, InfluxDB, FlexSim, an InceptionTime model for energy forecasting, and VR. Lacking automated physical interventions, it relies on a decision-mediated feedback loop: simulated sensor data is cloud-streamed, AI-analysed, and 3D-visualized, empowering human decision-makers to manually implement changes. The proof-of-concept achieved ~2 seconds end-to-end latency, validated short-horizon energy forecasts (*MAE*/*RMSE* reported), and demonstrated VR's feasibility for spatial bottleneck comprehension. This integrated architecture provides a replicable blueprint for near-real-time immersive systems, supporting industrial awareness and sustainability-oriented decision-making (SDG 12). 32 refs.
(Received in March 2026, accepted in June 2026. This paper was with the authors 2 months for 3 revisions.)

Key Words: *Industry 5.0, Data architecture, Digital Shadow, Virtual Reality, Sustainable Development Goals 12*

Pages 394-405

REVERSE ANALYSIS ON THE STOCHASTIC CAPABILITIES OF OPEN-SOURCE SIMULATION SOLUTIONS

Borges, D.; Dias, L. M. S.; Machado, R. J. & Henriques, M. F. N.
E-Mail: denisa.borges@ccg.pt

Abstract
The growing complexity of production systems, combined with the licencing costs of commercial simulation solutions and the need for greater interoperability, has driven increasing interest in open-source discrete event simulation (DES) solutions.

However, their stochastic capabilities remain largely unvalidated. This study evaluates the ability of open-source DES solutions to reproduce predefined statistical distributions. A conceptual model was implemented across five open-source solutions and one commercial solution benchmark, with a specific statistical distribution assigned to each process building block. Simulation outputs were analysed using SciPy, Fitdistrplus, and Arena's Input Analyzer.

Results reveal significant variation in adherence between predefined and proposed distributions. SimPy demonstrated the greatest consistency, highlighting the importance of statistical validation in simulation modelling and suggesting that open-source solutions represent a viable alternative to commercial simulation solutions. 21 refs.
(Received in March 2026, accepted in June 2026. This paper was with the authors 2 weeks for 3 revisions.)

Key Words: *Open-Source Simulation Solutions, Stochastic Distributions, Discrete-Event Simulation, Analytical Solutions, Statistical Validation Study*

Pages 406-417

DESCRUM: AN AGILE FRAMEWORK FOR DISCRETE-EVENT SIMULATION WITH QUANTITATIVE VALIDATION

Foncault-Moreno, L.; Pereira, T. N. F. & Montevechi, J. A. B.
E-Mail: ingfoncault@gmail.com

Abstract
Discrete-Event Simulation (DES) projects are inherently complex, requiring technical rigour in model development and effective coordination between multidisciplinary teams. Although agile approaches have expanded beyond software contexts, their integration with DES remains conceptually fragmented and understructured in the literature. This study investigates the application of DEScrum, a hybrid framework designed to align the macro-stages of the classical DES life cycle with Scrum iterative cycles. The research adopted an Action Research approach in a structured academic setting, organised into three development stages. Quantitative evaluation was conducted using two indicators independent of Scrum prescriptions: the Planning Compliance Rate, reflecting process stability, and the Deliverable Quality Index, based on eleven DES methodological dimensions to assess technical completeness. Results show progressive stabilisation of planning and strong adherence to core simulation stages across Sprints. These findings indicate that DEScrum supports iterative DES development without compromising methodological rigour, while improving collaboration, incremental validation, and process transparency. 17 refs.
(Received in April 2026, accepted in July 2026. This paper was with the authors 2 weeks for 2 revisions.)

Key Words: *DEScrum Framework, Discrete-Event Simulation, Scrum, Iterative Development, Simulation Model Quality*

Pages 418-428

ANALYSIS OF PRE-EMPTION BASED VIRTUAL CELLULAR MANUFACTURING

Jing, H.; Wang, L. & Kwak, C.
E-Mail: cjkwak@pusan.ac.kr

Abstract
Family based dispatching (FBD) rules are a prominent approach for implementing virtual cellular manufacturing, designed to enhance system efficiency by lowering setup times. However, FBD rules can trigger bulk arrivals and cause downstream delays – consequences that remain largely unexplored in existing literature. Additionally, contemporary FBD research has predominantly focused on minimizing average flow time. To address these gaps, this study investigates a novel shop floor control challenge that integrates FBD rules and pre-emption alongside newly identified key factors. Utilizing a two-stage flow shop model to isolate the direct downstream impacts of FBD rules under a due date-related objective, this paper aims to identify ideal operational conditions for different pre-emption types. Ultimately, this research evaluates how different pre-emption types perform with the key factors, offering valuable insights into pre-emption, FBD rules, and the novel key factors. 33 refs.
(Received in April 2026, accepted in July 2026. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Simulation, Family Based Dispatching Rules, Group Scheduling Heuristics, Preemption*

Pages 429-440

SIMULATION ANALYSIS OF THE DEFORMATION OF RAILWAYS AND BUILDINGS IN MINED-OUT AREAS

Shi, K. P.; Chen, W. X.; Liao, L. J. & Su, W.
E-Mail: shi_kp2022@163.com

Abstract
The challenges associated with ground movement and surface deformation, which subsequently affect railways and buildings in mined-out areas, were addressed in this study. The Sha-Wu railway (China), which traverses mined-out areas, was taken as an engineering example. A 3D model was developed via ABAQUS software to simulate the advancing process of working faces under varying seam heights. The spatiotemporal characteristics of ground movement and surface deformation in the mined-out areas were analysed, and the coupling mechanism between residual deformation and deformation of railways and buildings was revealed. Results show that as the mining face advances, ground subsidence exhibits a funnel-shaped nonlinear expansion pattern in all directions. Nonuniform subsidence in mined-out areas induces interlayer separation and void phenomena in railway track structures. The building structural stress intensifies with increasing mining height, and the stress concentration is primarily at load-bearing components (beam-column joints and column bases). This research aims to provide references for railways and building reinforcement in mined-out areas. 19 refs.
(Received in May 2026, accepted in August 2026. This paper was with the authors 1 month for 2 revisions.)

Key Words: *Mined-Out Areas, Railway Engineering, Buildings, Surface Deformation, Subsidence*

Pages 441-452

METAHEURISTIC-HYBRID OPTIMISATION OF A COMPOSITE PLATE UNDER LOW-VELOCITY IMPACT

Tasic, J.; Cojbasic, Z. & Marinkovic, D.
E-Mail: dragan.marinkovic@tu-berlin.de

Abstract
The paper presents the development of optimisation strategies for composite materials subjected to impact loading. To ensure adequate impact resistance of a composite plate, the laminate plies can be oriented in different directions, with each ply and their combined interactions considered as design variables. Such an optimisation problem is highly challenging for single optimisation techniques and, hence, a combination of multiple methods is proposed. The main objective is to perform both discrete and continuous searches of the design space in order to find the optimal or near-optimal solution. For this purpose, a comparative study of several optimisation methods is conducted to evaluate their efficiency based on a defined objective function. Due to the pronounced nonlinearity of impact phenomena, finite element (FE) analysis is employed to assess the mechanical behaviour of composite materials and evaluate the objective function. The FE approach has proven both effective and reliable. The transient analyses are done in the commercial software package Abaqus using the explicit solver. 32 refs.
(Received in May 2026, accepted in July 2026. This paper was with the authors 3 weeks for 2 revisions.)

Key Words: *Composite Laminates, Contact-Impact Analysis, Finite Element Modelling, Metaheuristic Optimisation, Tsai–Wu Failure Criterion*

Pages 453-463

EXPERIMENTAL INVESTIGATION AND OPTIMISATION OF INCREMENTAL SHEET FORMING OF AISI 316L

Visagan, A.; Ganesh, P.; Elaiyarasan, U.; Naveenkumar, R. & Satthiyaraju, M.
E-Mail: visaganarjunan69@gmail.com

Abstract
Incremental Forming with a single-point tool is an efficient sheet-metal forming operation for producing various net shapes. The quality of the surface manufactured by the process is crucial for final applications and depends on the input values selected for the forming operation. In the present study, Incremental Sheet Forming assisted by a Static Pressure Support was used to form AISI 316L stainless steel sheets of uniform thickness. A Taguchi design of experiments was used, and a mixed L_{18} orthogonal array was constructed to carry out the experiments. The experiments were performed by changing the forming parameters such as tool nose diameter, forming step depth, bottom wall angle, rate of feed and tool rotational speed with various levels and their effect on the responses was studied. The results confirm that the forming step depth and the feed rate have the greatest influence on surface roughness and forming time, respectively. The developed optimisation method will be very helpful in the estimation of surface roughness and forming time of AISI 316L stainless steel formed during incremental sheet forming using static pressure support with various forming parameter conditions. 27 refs.
(Received in May 2026, accepted in July 2026. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Incremental Sheet Forming, Static Pressure Support, Optimisation, Surface Roughness, Forming Time*

Pages 464-475

SIMULATION OF ABSORPTION PROPERTIES ON A NOVEL EMBEDDED-TUBE HELMHOLTZ RESONATOR

Lu, Z. Y.; Liu, S. S.; Jin, L.; Li, X. W.; Hao, F. X.; Yang, Y. & Li, S. H.
E-Mail: yang.yang@sdust.edu.cn

Abstract
To address the low-frequency noise challenges in lithium-ion battery systems, such as thin-walled structures, auxiliary units, and power electronics, this study develops a novel embedded-tube Helmholtz resonator (ET-HR) with sinusoidal walls instead of the traditional straight-wave wall. Finite element modelling is performed on the sound absorption properties of the proposed ET-HR. The effect of structural configurations, including diameters, tube angles, and wave numbers, on sound absorption properties is revealed. The sound absorption peak shifts to a lower frequency with the decrease in the equivalent diameter and the increase in the length of the embedded tube. As the depth of the cavity increases, the sound absorption performance in the low-frequency range is improved. Finally, the ET-HR with multitube is designed, with experiments showing that it can achieve a sound absorption coefficient greater than 0.7 from 307 Hz to 733 Hz and 0.9 from 445 Hz to 681 Hz. This study provides a basis for the design of structures with efficient and adjustable sound absorption performance under finite thickness. 22 refs.
(Received in May 2026, accepted in August 2026. This study was with the authors 1 month for 2 revisions.)

Key Words: *Finite Element Simulation, Helmholtz Resonators, Sound Absorption Properties, Structural Parameters*

Pages 476-487

SIMULATION OF MINE DISASTER CHAIN MITIGATION VIA SEMANTIC NETWORK

Wang, Y. S.; Xiong, W.; Ye, L. & Guo, S. S.
E-Mail: yelin93@126.com

Abstract
Conventional risk analysis methods struggle to capture the nonlinear couplings and cascading propagation in mine disaster evolution. To accurately identify critical events and transmission pathways and quantitatively evaluate intervention strategies, a semantic-driven complex network framework was developed for mine disaster evolution analysis. On the basis of BERT embedding and K-means clustering, 42 disaster events were extracted from 120 accident reports, and a directed weighted evolution network was constructed. Network topology, small-world characteristics, modular structure, node centrality, and edge vulnerability were analysed to identify critical events and transmission paths. Random and targeted attack simulations were conducted to evaluate chain-breaking strategies. Results show that the network exhibits small-world characteristics with a modularity of 0.35 and four modules, with the strongest coupling between Modules 2 and 3. High gas concentration, gas accumulation, and gas explosion are key nodes, while gas-related paths show high vulnerability. The conclusions obtained from this study provide a novel quantitative approach for mine disaster mitigation. 23 refs.
(Received in June 2026, accepted in August 2026. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Semantic-Driven Complex Network, Disaster Chain Simulation, Chain-Breaking Disaster Mitigation, Novel Quantitative Approach*

Pages 488-499

DISTRIBUTION ESTIMATION ALGORITHM FOR CLOUD MANUFACTURING SCHEDULING OPTIMIZATION

Wan, H. & Li, Y.
E-Mail: SCGSXY165225_a@126.com

Abstract
To address the resource scheduling problem in complex production environments, this study proposes a production scheduling model based on Estimation of Distribution Algorithm. The model constructs a probability model using spatial distribution, evaluates the scheduling population based on high-quality individuals, introduces an archive mechanism to enhance solution diversity, and combines Deep Reinforcement Learning and Tabu Search algorithm for global optimization. It achieves adaptive production scheduling optimization under dynamically changing resources. In testing experiments, the model achieves an accuracy of 95.11 % in sample classification prediction tasks. The computational load and number of parameters for production data processing are 664.8 FLOPs and 90.54 M, respectively. The scheduling delay rate and resource utilization are 4.39 % and 97.96 %, significantly outperforming comparison models. These results indicate that the model provides stable and efficient production scheduling optimization and multi-constraint conditions, offering reliable algorithm support for production scheduling in cloud-based networked manufacturing environments. 18 refs.
(Received in March 2026, accepted in April 2026. This paper was with the authors 1 week for 2 revisions.)

Key Words: *Estimation of Distribution Algorithm, Networked Manufacturing, Cloud Computing, Production Scheduling, Resource Allocation, Deep Reinforcement Learning*

Pages 500-511

SYSTEM DYNAMICS SIMULATION OF REGULATORY INSTRUMENTS FOR POWER BATTERY RECYCLING

Li, X.; Zhan, S. Q.; Guo, M. Y. & Li, H. F.
E-Mail: lixin20@sdjzu.edu.cn

Abstract
Efficient recycling of end-of-life power batteries from new energy vehicles is central to the low-carbon transformation of transport and to reducing dependence on imported critical minerals. This study builds a tripartite evolutionary game involving the government, manufacturers and consumers, and embeds four heterogeneous policy instruments: a recycling technology innovation policy, a deposit-refund system, a subsidy policy and a tax incentive policy. The strategic interactions of single policies and their combinations are examined through system dynamics simulation across sixteen scenarios. The results show that, first, individual policies have limited reach and cannot achieve systemic synergy; second, the triple combination of deposit-refund, subsidy and tax incentive is the optimal scheme, balancing incentives and constraints; third, instrument intensity must stay within an appropriate range, since a moderate deposit preserves fiscal sustainability whereas excessive tax-rebate ratios or subsidy levels raise fiscal pressure and weaken effectiveness. The findings offer a quantitative reference for designing coordinated power battery recycling policies and advancing the circular economy. 34 refs.
(Received in April 2026, accepted in June 2026. This paper was with the authors 4 weeks for 2 revisions.)

Key Words: *Power Battery Recycling, Regulatory Strategies, System Dynamics, Simulation Model*

Pages 512-523

BATTERY-CONSTRAINED QUEUEING MODELLING WITH PRIORITY RESERVATION FOR MEDICAL UAV SYSTEMS

Liu, L. & Lu, X. C.
E-Mail: xclu@bjtu.edu.cn

Abstract
Medical UAV delivery systems rely on battery swapping to sustain continuous operation, making battery availability a key determinant of system performance. This paper develops a multiclass closed queueing network with a priority-based battery reservation mechanism and a Priority-Based Battery Allocation Approximate Mean Value Analysis (PBA-AMVA) method. The analytical model agrees well with discrete-event simulation, achieving a mean absolute percentage error (MAPE) of 2.88 % across all tested configurations. Results show that battery requirements depend on the absolute charging and flight durations rather than their ratio alone. For example, two scenarios with the same charging-to-flight ratio (3.0) require battery-to-UAV ratios of 0.52 and 1.12, demonstrating that conventional ratio-based sizing rules do not hold in finite shared-battery systems. Battery availability is identified as the primary bottleneck under heavy demand, while a reservation ratio of 0.10–0.20 improves emergency service with minimal throughput loss. A lookup table is provided for rapid battery capacity planning under varying operating conditions. 29 refs.
(Received in May 2026, accepted in July 2026. This paper was with the authors 2 weeks for 2 revisions.)

Key Words: *Medical UAV Delivery, Closed Queueing Network, AnyLogic Simulation, Task Priority, Resource Allocation*

Pages 524-535

GENERATIVE AI–ENABLED RESILIENCE ASSESSMENT OF MANUFACTURING SUPPLY CHAINS

Chu, Y. K. & Chen, Q.
E-Mail: chenqixqg@126.com

Abstract
Manufacturing supply chains are vulnerable to disruptions such as supply delays, demand fluctuations, equipment failures, and logistics interruptions, which may cause inventory imbalance, capacity reduction, and delivery delays. Existing studies often rely on predefined scenarios and static indicators, limiting the characterization of dynamic degradation and recovery processes. This study proposes a generative artificial intelligence–enabled simulation-based method for manufacturing supply chain resilience assessment. A discrete-event simulation model integrating suppliers, inventories, production workshops, finished-goods warehouses, and customer orders was developed. Generative artificial intelligence was used to generate diverse disruption scenarios, which were converted into structured simulation inputs. Through multiple simulation experiments, resilience was evaluated based on performance degradation, recovery time, order fulfilment, inventory stability, and operational cost. The proposed framework supports supply chain stress testing, vulnerability identification, and recovery strategy evaluation under complex disruptions. 15 refs.
(Received in May 2026, accepted in July 2026. This paper was with the authors 3 weeks for 2 revisions.)

Key Words: *Generative Artificial Intelligence, Manufacturing Supply Chain, Supply Chain Resilience, Discrete-Event Simulation, Disruption Scenarios*

Pages 536-547

COORDINATED SCHEDULING OF PRODUCTION AND ELECTRICAL LOADS USING HYBRID SIMULATION

You, H. Y. & Lv, Y. J.
E-Mail: sdkdlyj@163.com

Abstract
With the development of intelligent manufacturing, the coordination between production scheduling and electrical equipment load control has become increasingly important. Traditional schedule-first methods suffer from delayed load constraint handling, inaccurate load simulation, and insufficient proactive coordination. This study proposes a hybrid event–state coupling simulation method for coordinated production scheduling and electrical load management. A three-level process–equipment–load association model and a forward-looking adaptive coordination mechanism are developed to achieve bidirectional interaction between production events and load states. Multi-scenario simulation experiments demonstrate that the proposed method effectively suppresses load peaks, reduces load violation rates, and maintains production efficiency and system robustness. The proposed framework provides a practical solution for load-coordinated optimization and simulation analysis in complex manufacturing systems. 16 refs.
(Received in June 2026, accepted in July 2026. This paper was with the authors 2 weeks for 1 revision.)

Key Words: *Production Simulation, Electrical Equipment Load, Coordinated Scheduling, Hybrid Event–State Coupling, Three-Level Association Modelling*