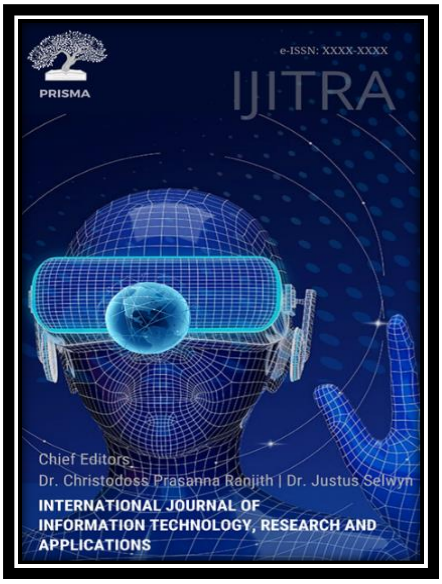

International Journal of Information Technology, Research and Applications (IJITRA)

Krishnaveni Veeranan, Pandian Vaidhyanathan, Thamarai Selvi, Antonyraj Martin, (2024). Impact of Mathematical Models in IT System Design and Optimization, 3(1), 01-11.

ISSN: 2583 5343

DOI: 10.59461/ijitra.v3i1.83

The online version of this article can be found at:
https://www.ijitra.com/index.php/ijitra/issue/archive

Published by:
PRISMA Publications

International Journal of Information Technology, Research and Applications (IJITRA) is a journal that publishes articles which contribute new theoretical results in all the areas of Computer Science, Communication Network and Information Technology. Research paper and articles on Big Data, Machine Learning, IOT, Blockchain, Network Security, Optical Integrated Circuits, and Artificial Intelligence are in prime position.

PRISMA
PUBLICATIONS

https://www.prismapublications.com/

Impact of Mathematical Models in IT System Design and Optimization

[1]Krishnaveni Veeranan, [2]Pandian Vaidhyanathan, [3]Thamarai Selvi, [4]Antonyraj Martin

[1]Lammersville Unified School District, Mountain House, CA, USA
[2]Information Technology Department, University of Technology and Applied Sciences, Sultanate of Oman
[3]Sohar University, Sultanate of Oman
[4]Mathematics and Computing Skills Unit, Preparatory Studies Center,
University of Technology and Applied Sciences, Salalah Sultanate of Oman

[1]krveeranan@lammersvilleusd.net, [2]vaidhy.vaidhyanathan@utas.edu.om,
[3]tvaidhyanathan@su.edu.om, [4]antonyraj@utas.edu.om

Article Info

Article history:

Received December 15, 2023
Accepted January 26, 2024
Published February 02, 2024

Keywords:

Graph Theory
Optimization
Combinatorial Problem
Routing
Fuzzy Logic

ABSTRACT

This research investigates the crucial role of mathematical models in designing and optimizing modern IT systems. The paper explores how mathematical tools simplify complex systems, enabling efficient design and improved understanding. The impact of mathematical models extends beyond initial design. The research emphasizes the importance of maintaining these models throughout a system's life cycle to ensure ongoing optimization.

Fuzzy Logic Controllers and Coverage Path Planning (CPP) algorithms are highlighted as key examples of how mathematical models are utilized in IT system design, particularly for robotic guided vehicles. The research focuses on real-world applications of CPP and the role mathematical models play in finding optimal solutions.

This study aims to benefit professionals in robotics research, logistics, and process automation. It explores how mathematical models can contribute to overcoming challenges in modern industries, such as increased production efficiency and reduced costs.

Corresponding Author:

Krishnaveni Veeranan
Lammersville Unified School District,
Mountain House, CA, USA
Email: krveeranan@lammersvilleusd.net

1. Introduction:

An analytical solution describes the physical system with a set of mathematical expressions to produce an exact solution or an approximation at every point. The common mathematical modeling techniques used in engineering practice are based on the law of conservation of mass, the law of conservation of momentum, the law of conservation of energy, and the second law of thermodynamics. These laws describe the relationship between the changes in a system and the forces and energy transfer with the surroundings. Computer generated solutions to certain problems can quickly become time consuming and costly. Mathematical modeling can be thought of as a way of expressing a mathematical description of a system, seeking to simplify the complex systems theory, and ignoring complex physical and environmental phenomena. Every system can be described mathematically to a degree, no matter how complex it may seem. [1] It is by the process of simplifying the problem that mathematical modeling begins to be useful. Models should be thought of as the most efficient means of establishing a workable accounting of a system's component parts and understanding the behavior of that system. However, the limitations of human computational ability make it impossible to derive exact solutions for even the simplest nonlinear differential equations that arise in practical system modeling. Consequently, the solution of practical problems usually requires the application of approximation techniques in conjunction with mathematical methods for identification or optimization. Model capacity is defined as the level of abstraction and the level of detail used in modeling a system. As models are more complex, the potential for the introduction of untraceable error and low resolution arises. The use of analytical methods in conjunction with model reduction techniques may decrease errors produced by complex models, although the rate of discrepancy introduced through this means may not be constant as systems change and develop. [2] [3] Mathematical models change over time with the progression of model dimensions. As the problem domain increases and decreases, models are subject to the necessary adaptation, to maintain model capacity and accuracy. Model dimensions, which include the domain of the problem set, act as a measure of the complexity of the system. Every system has several physical dimensions, be this space or property based, and a model ought to reflect this. For example, a model of the earth's atmosphere should at least be in possession of a 4-D solution, since three dimensions describe the physical space of the earth, and a further dimension is needed to describe how tangible properties, such as pressure, change. Models should not become overly complex but should aim to represent the system effectively and efficiently in as great a capacity as the computational method or understanding afforded. [4]

1.1. Background

Mathematical models have been a crucial tool in computer and information science since the introduction of Boolean algebra by George Boole in 1854. [5] They are used in IT system design to evaluate proposed designs based on goodness criteria, and the best design is chosen for implementation. Optimization is a central concept in computer and information science, used for various purposes such as finding optimal locations, minimizing resource usage, and determining query strategies. [6]

Modern IT systems have become complex and large-scale due to increasing demand for practical applications. Technological advancements and the increasing power of computer hardware have facilitated real-time adaptability. However, new challenges have arisen, such as the need to exploit vast amounts of data and the efficiency of optimization.

Technological and theoretical progress have opened new territories for computer and information science, making mathematical methods and models crucial in IT system design. By applying mathematical models, representations and products become precise and structured, making system understanding and maintenance easier. [7] [8]

1.2. Objectives

This research explores the impact of Fuzzy Logic Controllers and Coverage Path Planning algorithms on the design of IT systems and optimization mathematical models in robotic guided vehicles. Key elements include navigation systems, coverage path planning (CPP), IT system optimization, and specific mathematical models used in CPP optimization. The study focuses on real-world problems using CPP and how these models contribute to finding solutions. The findings will be beneficial to robotics research, logistics, and process automation professionals. The goal is to assess how the adoption of robots can help overcome challenges in modern industries, such as increasing production volume and quality, reducing waste and cost.

1.3. Scope

The research will explore the background of IT systems, their relevance in modern business, and the objectives driving their design. It will also explore the importance of maintaining mathematical models throughout system operation. The research emphasizes the importance of automated optimization techniques and systematic methods for improving algorithms in complex real-world problems, ensuring efficient systems design throughout a system's life cycle.

2. Mathematical Models in IT System Design

Mathematics plays a crucial role in business decision making, particularly in management science. It helps solve simple business problems and manage complex global organizations. IT systems must satisfy requirements such as reliability, manageability, availability, cost effectiveness, scalability, performance, and security. Mathematical models are used to understand and predict system behavior and performance. However, with advancing computer technologies and complex models, these models may become outdated. Empirical studies show that 60%-80% of IT activities are focused on support and maintenance activities over the system's lifecycle. [9] Applying mathematical models can lead to cost reduction and quality improvement in system management. For example, optimizing helpdesk assistant allocation can be achieved by using mathematical models that characterize the system, workloads, and traffic patterns. This can increase work efficiency by 35% and improve resource utilization by 42%. [10]

2.1. Definition and Importance

Mathematical models in IT system design are the process of using mathematical calculations and logic to be used in a system for performing complex and easy computations in a systematic way. If we want to find measures, conversions, and representations of a system, we need mathematical formulas and logic. This helps describe and predict the system by incorporating physical laws, unintended interactions, and empirical parameters. The most important thing is system control and model optimization. For example, we use a PID controller for system control and optimization to understand the system better. Mathematical models are also used for software optimization, process optimization, and control optimization in IT systems. The accuracy of the model can be used in many applications, such as increasing efficiency and reducing human effort in system design. Errors can be minimized, and accurate results can be determined. Models can also reduce time and complexity in analysis. The accuracy of the model depends on various parameters and factors. To improve the system and optimize it correctly, it is recommended and essential to create the model in compliance and verify and validate its accuracy.

2.2. Types of Mathematical Models

Mathematical models are divided into three main types: deterministic, stochastic, and heuristic. Deterministic models describe systems in mathematical equations, providing an exact solution. Stochastic models incorporate randomness or individual behavior, resulting in different outputs for the same inputs. They are used to simulate processes that evolve over time, like stock prices or queuing theory. Heuristic models, on the other hand, use trial and error methods to find the best solution. Deterministic models are used for determining issues, stochastic models for examining variability, and heuristic models for complex problems. [11] [12]

2.3. Benefits and Limitations

Mathematical models are a valuable tool for understanding and optimizing systems, but they also have limitations. They can be too restrictive and require careful consideration of input precision. In the real world, collecting precise input data is challenging due to technology limitations and time constraints. Traditional methods like trial and error are impractical, and the cost of changing a working system can be high. Despite these limitations, model-based design approaches are increasingly popular due to their cost-effectiveness and the ability to represent complex systems using mathematical models. It is essential to be cautious and critical when creating and using models, as they are only a simplified representation of reality and should be kept open-minded. [2] [13] [14]

3. Optimization Techniques in IT System Design

Optimization is a crucial discipline in system design, aiming to create the most efficient and ideal system within specific constraints. It involves determining the best configuration of a system's components or structure to maximize its potential. [16] [17] In IT system design, optimization techniques involve activities and processes to develop systems that operate efficiently and effectively, utilizing optimal resources such as processing power, data storage, and user interactivity time. The benefits of well-optimized systems extend beyond academics, as they can prevent cost and budget overruns, missed product delivery deadlines, and system failures. By understanding the key concepts and activities in optimization, it is hoped that less bad designs will enter professional systems work, reducing the risk of system failures in the industry. [18] [19] [15]

3.1. Overview of Optimization

Optimization in IT system design involves selecting the best solution from feasible alternatives and is a crucial tool for decision-making. It can be deterministic or stochastic, depending on the model's parameters and model specifications. There are two categories of optimization: linear and nonlinear. Linear optimization minimizes or maximizes linear functions, while nonlinear optimization numerically approximates nonlinear functions. Modern optimization methods and software, like LINGO and MATLAB, can solve complex linear optimization problems. Modern operations research focuses on creating high-performance decision support systems, and technology shifts from mainframe-oriented to distributed, real-time, multidisciplinary, internet-based spatio-temporal forecasting systems. Optimization efficiently utilizes resources and energy, directly impacting society. [20] [21]

3.2. Commonly Used Optimization Methods

There are several methods of optimization commonly used in IT system design [22] [23] [24] and these include:

1. Linear Programming: Here, the mathematical model is constructed with a linear objective function and a set of linear inequality or equality constraints. Then, the values of the variables are altered in such a way that the value of the objective function is minimized or maximized. Linear programming is widely used in different areas such as production scheduling, transportation, and financial portfolio management.

2. Genetic Algorithms: Genetic algorithms are problem-solving methods that mimic the process of natural evolution. These algorithms use the ideas of selection, crossover, and mutation operators to find the best solution to an optimization problem. Genetic algorithms have been applied to various optimization problems including robotics, scheduling, and route optimization.

3. Mixed Integer Programming: This is a class of optimization methods where the objective function is to minimize or maximize something, subject to a set of linear or non-linear inequality and higher than or equal to and less than or equal to constraints. The difference of these methods from other optimization methods is that they have calculations in terms of whole numbers - in the form of integer rather than decimal. These types of optimization methods are often applied where a solution must be a whole number, such as the case in production run.

4. Simulated Annealing: Simulated annealing is a combinatorial optimization method based on the annealing process in metallurgy. It aims to achieve global optimization for a given objective function by heating and cooling materials to reduce defects and create a free energy minimum state.

5. Decision Trees: Decision trees are a technique for making decisions by classifying possible outcomes. They start at the theoretical root and make binary decisions based on the answer to questions. The optimal solution is reached at each branch, making it suitable for design problems.

6. Queuing Theory: Queuing theory is a method used in IT systems to analyze resource requests and optimize performance. It models system behavior and servers mathematically, helping find the optimal number of resources for minimal delay and maximum capacity.

3.3. Application of Optimization Techniques in IT System Design

A simulation-based approach to IT system optimization is beneficial for users, suppliers, and maintenance engineers. Users can use the optimized system model to select their desired performance, configure the operating environment, and gain insights into the final solutions. This helps in system setup, maintenance, and development over its lifetime. [25]

Deterministic and simulation-based optimization are two main approaches to designing IT systems. Deterministic optimization uses an iterative trial and improvement method, discarding or altering algorithms that don't meet the predetermined objective function. Simulation-based optimization uses mathematical models to assess the effectiveness of overall IT systems, using system objectives like profit, growth, and efficiency. Variations in model results are used to pick the optimal solution or understand variable values. [26] [27]

Optimization is crucial in IT system design, from initial configuration selection to testing and maintenance. Complex computer systems have numerous parameters and constraints, making it difficult to consider all possible solutions. However, experience shows that a small subset of optimal solutions may be the only feasible and acceptable answer.

4. Impact of Mathematical Models on IT System Performance

Mathematical models can significantly improve the performance of IT systems, especially in factory control systems. Computer simulation models are often used to assess alternative methods. However, selecting a realistic and authentic model is crucial for system optimization. The first step in research is to construct a model, investigating the mathematical models used in the system type. The model's appropriateness depends on the study's objectives and aims. [28] Mathematical models can help system analysts understand the system's intrinsic workings, identify weak components, and study how changes affect the entire system. Simulation and optimization techniques like discrete event simulation and evolutionary algorithms can be enabled. [29] The accuracy of mathematical models is crucial for contracts, government policies, and senior management's decisions in the IT sector.

4.1. Enhancing System Efficiency

Mathematical models can enhance the efficiency of IT systems by predicting changes that might lead to efficiency improvements. By describing a system in mathematical terms, analyzing performance measures, and using simulations, designers can make changes to the model to see if they improve performance. This process, known as simulation, involves developing the model, validating it, running simulations under different conditions, and analyzing the results. The findings from the simulation can be used to make decisions about changes to the real system, either to enhance efficiency or evaluate the effects of other changes. By employing mathematical models and simulation work, significant efficiency gains can be achieved, contrasting with many topics, such as leisure and business processes, which are beyond the scope of even the most sophisticated mathematical models and current understanding of mathematical principles. [27]

4.2. Improving Resource Allocation

Mathematical models offer flexibility and power in resource allocation, allowing for easy re-evaluation of optimal solutions under various industry circumstances. They can also be applied to solving resource allocation problems in production lines, helping to determine the best task assignment and quantify efficiency, aiding in decision-making in the industry. This approach not only improves network throughput but also ensures fair resource distribution among users. [30]

A typical example is to use queuing models to analyze and optimize the performance of computer networks. Queuing models are built upon the queuing theory, which is a mathematical study of the formation of queues or lines as they are often called. By analyzing different queuing models that represent the network under different conditions, it is possible to optimize the network such that the average waiting time experienced by packets, or the probability of a packet being delayed, is minimized.

Resource allocation is the efficient distribution of resources, such as CPU, memory, storage, and input/output devices, in IT system design and operation. Using mathematical models can help ensure proper allocation and efficiency.

4.3. Minimizing Downtime and Delays

The IT industry has evolved over the past three decades to reduce downtime and delays, meet growing client demands, and develop new services. Despite the increasing cost of specialized maintenance downtime, IT frameworks can now be designed to ensure higher availability using continuous scientific models. Discrete-time replication is a proven method for demonstrating system strength, as it can be used to understand the impact on the system. However, there are various internal and external factors that must be considered.

Maintenance strategies, such as routine adherence, are essential for maintaining system health. The six-sigma approach emphasizes downtime and helps manufacturers prevent everyday issues leading to downtime events. Real-time simulations have gained popularity due to advancements in computer technology and the ability to test protocol changes and upgrades without causing downtime. [27]

5. Case Studies of Mathematical Models in IT System Design

The case study provides research-based guidance on strategically locating network facilities to minimize business impacts from network system transformation. It introduces the p-Center problem, critiques its limitations, and discusses future developments. The chronological order of theory to practice and potential issues provides a clear understanding of the profession's progress.

This demonstrates the use of mathematical tools in business operations and helps new industry members understand how theoretical models can be applied with real data. It emphasizes the potential of algorithmic practices in decision-making and strategic planning, leveraging advancements in computer processing power and parallel computing.

This case study specifically discusses the use of a well-known designing model used for solving location problems, the p-Center problem. First, the objectives, decision variables, and constraints of the model are presented and discussed in detail. Then it moves on to the analysis of some real-world scenario data set, of which the application and effectiveness of the base case and derived case studies are also illustrated.

The case study explores the use of mathematical models in network design, highlighting the challenges faced by communication service providers in identifying optimal locations and infrastructure resources for internet services.

5.1. Case Study 1: Network Optimization

The case study discusses network optimization under budget constraints. It introduces a mathematical model and defines the objective function of minimizing total network cost based on dependent variables and parameters. The problem is modeled using an algebraic approach, and sensitivity analysis is performed to investigate the impact of changes in parameters. The study concludes that the optimization approach successfully found the most efficient design, and that a wide range of network changes can be easily tested by changing model parameters. The case study explains the process, methods, and outcomes of using mathematical models in real network optimization scenarios, making it accessible to readers from various academic and professional disciplines. However, more comparisons with other types of networks and potential real-life impacts could be added to emphasize the study's significance. [31]

5.2. Case Study 2: Capacity Planning

The case study demonstrates the use of mathematical models in improving capacity planning in the retail industry. The business, which supplied multiple physical retail outlets, sought to reduce costs by identifying the optimal number of stock keeping units (SKUs) to hold at each outlet. [32] A two-step mathematical model was developed, using historical demand data to produce probability distributions of daily demand at each outlet. The model then used simulated annealing to identify the combination of SKUs at each location that resulted in minimum sustained availability across the retail network. The model provided a clear set of suggestions on which scenarios of SKUs to select, and the model also provided insight into the sensitivity of the 'optimum' solutions to changes in average demand. The model allowed the retail network to adjust SKU allocations at any time, resulting in a savings of around 3.2 million euros per year. [33] The case study concludes with a perspective on the successful deployment of the model and its wider implications for other capacity planning problems in the retail and warehousing sector.

5.3. Case Study 3: Workforce Scheduling

Workforce scheduling is a crucial aspect for large transportation companies, such as airlines and trucking, to efficiently manage their workforce. This involves assigning employees to different work shifts, days off, and locations based on labor rules. Developing a good schedule manually can be time-consuming and can be complicated by the mathematical methods used. To disseminate this technique, an operations research team has prepared an article explaining its application from the perspective of operations research. The article will cover a real-world case, objectives, main characteristics, linearity integer programming, mathematical modeling, implementation steps, and results. The article will also demonstrate the benefits of workforce scheduling, such as improved service levels and reduced labor hours. [34]

6. Challenges and Limitations of Mathematical Models in IT System Design

6.1. Data Accuracy and Availability

Accuracy and availability are crucial aspects of data management in IT systems. Accuracy refers to the accuracy of computation results, while availability refers to the usability of data. With the exponential growth of data, it is difficult to ensure perfect accuracy due to limited computing capabilities, storage, and human errors. To improve data accuracy, techniques like error checking, manual examination, and statistical methods can be used. However, availability is not guaranteed due to factors like natural disasters, terrorism, and malware attacks. General programming principles like error handling and good software design can help maximize data availability. Backup facilities can also be used to restore data instantly. Despite these challenges, IT experts continue to apply best practices and make constant efforts to improve in these areas. [35]

6.2. Complexity and Scalability

I. Complexity of mathematical models

Complex mathematical models in IT system design can be challenging to understand and maintain due to their inclusion of multiple parameters and the choice of a model with cryptic real-world relationships. The implementation of these models requires a connection between the model and the applied process. [5]

Complex models require more computational resources, increasing start-up time and limiting adaptiveness. Algorithms with high time complexity, such as O(N^2), are not computationally friendly and may take too long to process large data sizes. Large problems often have large data sizes, making linear time algorithms insufficient. Complex algorithms, with time complexity exceeding O(N^2), are only used for optimized problem solving, limiting their use to a small extent.

6.3. Real-Time Adaptability

Mathematical models are crucial in IT system design and optimization, as they calculate information based on input and data, predicting future system states and behaviors. Real-time adaptability is a process that allows a system to change parameters based on the calculations of the models, enabling it to respond to unexpected disturbances or environmental variations. This feature is essential for handling unexpected disturbances and environmental variations, enhancing system performance and allowing for quick recovery. Real-time adaptability is particularly important in vibration control systems, where the controller can respond to new inputs and weather variations instantly, improving system performance and ensuring aircraft safety. The versatility of mathematical models provides a robust platform for system designers to analyze system behavior and optimize systems. With the advancement of mathematical models, systems and products will have more effective, reliable, and optimal designs, and the field of research in IT system design and optimization will continue to grow and foster more innovations in the future. [36] [37]

7. Future Trends and Innovations in Mathematical Models for IT System Design

The rapid advancement of technology has led to a growing interest in developing mathematical models for IT systems design. These models offer a credible and meaningful way to understand and solve real-world problems, understanding processes behind design, and aiding communication between stakeholders. As big data and real-time analytics become more common, new and efficient mathematical techniques, such as artificial intelligence, will become common. This area focuses on developing innovative methods, applying existing techniques to new problems, and improving teaching of maths and computer science in schools.

Emergent technologies, such as 4D building information modeling, machine learning, cloud computing, and virtualization, are expected to have significant impacts in the future.

7.1. Machine Learning and Artificial Intelligence

The future of mathematical models is moving towards machine learning and AI, which enable learning from data and applying knowledge to make decisions. This makes incorporating mathematical models in IT system design more promising. Machine learning strategies include supervised learning, unsupervised learning, and reinforcement learning. Professor Charles Hutchings at Liverpool John Moores University emphasizes the importance of intelligent approaches and clever algorithms in modern IT systems. Genetic algorithms, inspired by nature, are one such optimization technique that can solve critical tasks by simulating natural analogues. Dr. Jason Pam, senior lecturer at the University of Wolverhampton, believes that genetic algorithms are ideal for solving complex optimization problems, especially in IT system design, due to their low memory consumption and inherently parallel nature. [38]

7.2. Big Data Analytics

Big data analytics (BDA) is the process of collecting, organizing, and analyzing large volumes of data to understand and predict human behavior. It is increasingly important in IT system design due to the growing amount of data generated from IT systems and business processes. BDA can be used in cyber security to detect and prevent cyber attacks and in customer relationship management to design marketing strategies and understand customer preferences. The development of big data infrastructures and tools like Hadoop and NoSQL has made BDA mature, and many companies have realized its benefits. The long-term trend is to integrate BDA with advanced technologies like machine learning and artificial intelligence to develop more intelligent functions and systems. [39]

7.3. Cloud Computing and Virtualization

Cloud computing uses cloud servers to store and manage data over the internet. Virtualization creates a virtual version of a physical IT system, allowing for more efficient use of hardware. Mathematical models are used to predict capacity and scalability of cloud services and simulate real-world business behaviors. These models help make decisions about cloud services, network usage, and processing needs, ensuring server availability, network capacity, and connection speed. Simulation and optimization techniques for virtualized systems address performance and resource optimization problems, such as server consolidation. Mathematical models represent physical servers, workload, and power usage, allowing for accurate predictions of suitable server configurations. [40]

8. Conclusion

Model-driven analysis and empirical work can lead to cost-effective system design solutions and avoid system downtime. Mathematical models provide detailed knowledge for various user groups, helping IT systems meet organizational goals. This research aims to understand the impact of mathematical models on IT system performance, as models underpin initiatives like system consolidation and resource optimization. New mathematical models have been developed and validated to compare the performance of this new paradigm to conventional model-driven approaches.

The application of mathematical models in IT system design and optimization offers great advantages and provides a basis for the discovery of new knowledge. The use of mathematical models has proved to be an invaluable tool when analyzing the effect of system changes on performance. The models have the advantage that it is possible to deal with many variables that may be dynamical in nature and that the construction of the models allows one to find out cause and effect relationships, sometimes not obvious when considering a particular system.

References:

[1] L. Kotzur, L. Nolting, M. Hoffmann, T. Groß, "A modeler's guide to handle complexity in energy systems optimization," Advances in Applied ..., vol. 2021, Elsevier, 2021.sciencedirect.com

[2] D. K. Panda and S. Das, "Smart grid architecture model for control, optimization and data analytics of future power networks with more renewable energy," Journal of Cleaner Production, 2021.exeter.ac.uk

[3] D. Baleanu, S. S. Sajjadi, et al., "On a nonlinear dynamical system with both chaotic and nonchaotic behaviors: a new fractional analysis and control," Advances in Difference Equations, vol. 2021, 2021.springeropen.com

[4] A. F. Siegenfeld and Y. Bar-Yam, "An introduction to complex systems science and its applications," Complexity, 2020.hindawi.com

[5] A. Adiga, D. Dubhashi, B. Lewis, M. Marathe, et al., "Mathematical models for covid-19 pandemic: a comparative analysis," Journal of the Indian Institute of Science, vol. 100, no. 4, pp. 793-807, 2020, Springer.springer.com

[6] S. Razavi, A. Jakeman, A. Saltelli, C. Prieur, et al., "The future of sensitivity analysis: An essential discipline for systems modeling and policy support," Environmental Modelling & Software, vol. 137, 2021, Elsevier.sciencedirect.com

[7] J. Shalf, "The future of computing beyond Moore's Law," Philosophical Transactions of the Royal Society A, 2020.royalsocietypublishing.org

[8] A. R. Tuite, D. N. Fisman, and A. L. Greer, "Mathematical modelling of COVID-19 transmission and mitigation strategies in the population of Ontario, Canada," Cmaj, 2020.cmaj.ca

[9] C. Vandelanotte, S. Trost, D. Hodgetts, T. Imam et al., "Increasing physical activity using an just-in-time adaptive digital assistant supported by machine learning: a novel approach for hyper-personalised mHealth …," Journal of Biomedical …, Elsevier, 2023.sciencedirect.com

[10] M. Chui, E. Hazan, R. Roberts, A. Singla et al., "The economic potential of generative AI," 2023.jaipuria.ac.in

[11] AA Juan, P Keenan, R Martí, S McGarraghy, et al., "A review of the role of heuristics in stochastic optimisation: From metaheuristics to learnheuristics," Annals of Operations Research, vol. 2023, Springer, 2023.uoc.edu

[12] I. M. Hezam, M. K. Nayeem, and G. M. Lee, "A systematic literature review on mathematical models of humanitarian logistics," Symmetry, 2020.mdpi.com

[13] S. S. Musa, S. Qureshi, S. Zhao, A. Yusuf, "Mathematical modeling of COVID-19 epidemic with effect of awareness programs," in Infectious Disease Modelling, Elsevier, vol. 6, pp. 448-460, 2021.sciencedirect.com

[14] A. J. Lopatkin and J. J. Collins, "Predictive biology: modelling, understanding and harnessing microbial complexity," Nature Reviews Microbiology, 2020.mit.edu

[15] J. Zhu, Z. Han, W. Chuang, Z. Lu, et al., "A review of topology optimization for additive manufacturing: Status and challenges," Chinese Journal of Aeronautics, vol. 2021, Elsevier, 2021.sciencedirect.com

[16] L. Abualigah, A. Diabat, P. Sumari, and A. H. Gandomi, "A novel evolutionary arithmetic optimization algorithm for multilevel thresholding segmentation of covid-19 ct images," Processes, 2021.mdpi.com

[17] X. Xu, H. Li, W. Xu, Z. Liu, L. Yao, et al., "Artificial intelligence for edge service optimization in internet of vehicles: A survey," Tsinghua Science and Technology, 2021.ieee.org

[18] T. Yu and H. Zhu, "Hyper-parameter optimization: A review of algorithms and applications," arXiv preprint arXiv:2003.05689, 2020.arxiv.org

[19] E. Osaba, E. Villar-Rodriguez, J. Del Ser, et al., "A tutorial on the design, experimentation and application of metaheuristic algorithms to real-world optimization problems," Swarm and Evolutionary Computation, vol. 64, 2021, Elsevier.ugr.es

[20] C. Li, Y. Chen, and Y. Shang, "A review of industrial big data for decision making in intelligent manufacturing," Science and Technology, an International Journal, Elsevier, 2022.sciencedirect.com

[21] E. Panfilova, N. Dzenzeliuk, O. Domnina, et al., "The impact of cost allocation on key decisions of supply chain participants," International Journal of ..., 2020.core.ac.uk

[22] A. K. Sangaiah, E. B. Tirkolaee, A. Goli, and S. Dehnavi-Arani, "Robust optimization and mixed-integer linear programming model for LNG supply chain planning problem," Soft computing, 2020.academia.edu

[23] C. N. Wang, N. L. Nhieu, and T. T. T. Tran, "Stochastic chebyshev goal programming mixed integer linear model for sustainable global production planning," Mathematics, 2021.mdpi.com

[24] S. S. Ali, H. Barman, R. Kaur, H. Tomaskova et al., "Multi-product multi echelon measurements of perishable supply chain: Fuzzy non-linear programming approach," Mathematics, 2021.mdpi.com

[25] A. Balachandran and D. Karlsson Tunhult, "A Conceptual Study on Model-Based Systems Engineering and Data Driven Methods in the Context of Complex Products and Systems.," 2020.diva-portal.org

[26] M. Mahdavi, H. H. Alhelou, N. D. Hatziargyriou, et al., "An efficient mathematical model for distribution system reconfiguration using AMPL," in IEEE Transactions, 2021.ieee.org

[27] Y. Mohamadou, A. Halidou, and P. T. Kapen, "A review of mathematical modeling, artificial intelligence and datasets used in the study, prediction and management of COVID-19," Applied Intelligence, 2020.springer.com

[28] N. AlSawaftah, W. Abuwatfa, N. Darwish, and G. Husseini, "A comprehensive review on membrane fouling: Mathematical modelling, prediction, diagnosis, and mitigation," Water, 2021.mdpi.com

[29] K. Diao, X. Sun, G. Lei, Y. Guo, et al., "Multiobjective system level optimization method for switched reluctance motor drive systems using finite-element model," in IEEE Transactions on ..., vol. xx, no. xx, pp. xxx-xxx, 2020.uts.edu.au

[30] R. Sameni, "Mathematical modeling of epidemic diseases; a case study of the COVID-19 coronavirus," arXiv preprint arXiv:2003.11371, 2020.arxiv.org

[31] R. Lotfi, Z. Yadegari, S. Hosseini, "A robust time-cost-quality-energy-environment trade-off with resource-constrained in project management: A case study for a bridge construction project," in Engineering Optimization, 2022, avesis.metu.edu.tr.metu.edu.tr

[32] O. J. Watson, G. Barnsley, J. Toor, A. B. Hogan, et al., "Global impact of the first year of COVID-19 vaccination: a mathematical modelling study," The Lancet Infectious Diseases, 2022.thelancet.com

[33] E. Sabet, B. Yazdani, R. Kian, and K. Galanakis, "A strategic and global manufacturing capacity management optimisation model: A Scenario-based multi-stage stochastic programming approach," Omega, 2020.ntu.ac.uk

[34] A. Rijal, M. Bijvank, A. Goel, "Workforce scheduling with order-picking assignments in distribution facilities," Transportation ..., 2021.HTML

[35] T. Meng, X. Jing, Z. Yan, and W. Pedrycz, "A survey on machine learning for data fusion," Information Fusion, 2020.aalto.fi

[36] A. R. Kunduru, "Artificial intelligence usage in cloud application performance improvement," in Mathematical Theory and Computer Science, 2023, cajmtcs.centralasianstudies.org.centralasianstudies.org

[37] W. Chen, H. Liu, and E. Qi, "Discrete event-driven model predictive control for real-time work-in-process optimization in serial production systems," Journal of Manufacturing Systems, 2020.HTML

[38] A. V. Singh, D. Rosenkranz, M. H. D. Ansari, et al., "Artificial intelligence and machine learning empower advanced biomedical material design to toxicity prediction," Advanced Intelligent Systems, vol. 2020, Wiley Online Library, 2020.wiley.com

[39] J. Sheng, J. Amankwah-Amoah, et al., "COVID-19 pandemic in the new era of big data analytics: Methodological innovations and future research directions," British Journal of Management, vol. 32, no. 4, pp. 1164-1183, 2021.wiley.com

[40] S. N. Ajani, P. Khobragade, M. Dhone, B. Ganguly, et al., "Advancements in Computing: Emerging Trends in Computational Science with Next-Generation Computing," International Journal of Intelligent Systems and Applications in Engineering, vol. 12, no. 7, pp. 546-559, Jan. 2024.ijisae.org