



## II. Workshop on Applied Mathematics and Statistics

### Abstract Book

WAMS 2026

Department of Mathematics  
İzmir University of Economics

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## WAMS 2026

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II. Workshop on Applied Mathematics and Statistics

May 9, 2026

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## Welcome to WAMS 2026

II. Workshop on Applied Mathematics and Statistics, organized by the Department of Mathematics at İzmir University of Economics, aims to provide a strong academic platform for young researchers.

This event offers master's and doctoral students the opportunity to share their research, engage in interdisciplinary interactions, and establish academic collaborations, while also allowing undergraduate students to take their first steps into the academic world through poster presentations.

In this workshop, we feature invited talks, short presentations, and undergraduate poster sessions in the fields of Applied Mathematics and Statistics. You can find the abstracts of the talks and posters in the abstract book you have in hand.

Finally, we would like to thank the members of the Scientific Committee, Organizing Committee, as well as the administrative personnel and students who supported the organization, for their dedicated efforts in making this workshop possible.

İzmir University of Economics  
Department of Mathematics

### Scientific Committee

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Sıla Selenay KOÇ	İzmir University of Economics

<p align="center"><b>II. Workshop on Applied Mathematics and Statistics (WAMS)</b>  <b>Izmir University of Economics Department of Mathematics</b>  <b>Workshop Program</b>  <b>May 9th 2026</b></p>	
09:00-9:45	<i>Registration / Coffee Break / Poster Presentations</i>
9:45-10:00	<i>Opening Ceremony</i>
	Chair: Sıla Ovgü Korkut
10:00-10:45	<b>Invited Speaker: Gamze Tanoğlu</b> <b>Efficient Time Integration of Caputo Fractional Differential Equations Using Herglotz-Neuman Structure</b>
10:45-11:00	<i>Coffee Break</i>
	Chair: Femin Yalçın Küçükbayrak
11:00-11:15	<i>Ömer Akgüller : Geometric and Topological Approaches in Oncology Research: From Discrete Curvature to Sheaf Cohomology</i>
11:15-11:30	<i>Berrak Özgür: SIR Rumor Model with Fidelity Parameter and Forgetting Mechanism : A Stability Analysis.</i>
11:30-11:45	<i>Gökhan Torun: Algebraic Foundations of Quantum Teleportation: From Mathematical Simplicity to Physical Complexity.</i>
11:45-12:00	<i>Seçil Tezel: Prediction of Trend Topics for Scientific Research Articles Using Machine Learning Algorithms: A Comparative Approach.</i>
12:00-12:15	<i>Elif İlkin Ersoy: Numerical Solution of Online Gaming Addiction Model via Chebyshev Spectral Collocation Method</i>
12:15-13:30	<i>Lunch Break</i>
13:30-14:00	<i>Poster Presentations</i>
	Chair: Burak Ordin
14:00-14:15	<i>Toghrul Karimli: A Decision Support Mechanism for Operation Optimization of Ethylene Cracking Furnaces</i>
14:15-14:30	<i>Cebrail Balkan: Integrating Machine Learning for the Discovery and Classification of Yang-Baxter Equation Solutions on Algebraic Structures</i>
14:30-14:45	<i>Ebrar Günel: Structural Analysis of Bipolar Fuzzy Point-Based Subalgebras in Sheffer Stroke Nelson Algebras.</i>
14:45-15:00	<i>Gamze İlayda Erçelik: On the Relationship Between Riečan and Bosbach State Operators in Sheffer Stroke UP-Algebras.</i>
15:00-16:00	<i>Coffee Break / Poster Presentations</i>
	Chair: Halis Can Koyuncuoğlu
16:00-16:15	<i>Tolga Yamut: Neural Density Based Vine Classification</i>
16:15-16:30	<i>Mustafa Kırcaçlı: Some Results on Quantum MDS Codes.</i>
16:30-16:45	<i>Yusuf Can Sevil : Examining A Reinforcement Learning-Based Trading Strategy in Crypto Market.</i>
16:45-17:00	<i>Ecem Türkan Uçaroğlu: Comparative Investigation of Non-Local Fractional Derivative Operators in Modeling Memory-Dependent Economic Systems.</i>
17:00-17:15	<i>Ebru Aslan - Existence of Positive Solutions for Caputo Fractional Boundary Value Problems</i>
18.00	<i>Dinner/Nefes Restaurant</i>

## Efficient Time Integration of Caputo Fractional Differential Equations Using Herglotz–Nevanlinna Structure

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### Abstract:

Time-fractional derivatives are widely used to model physical processes with memory effects, such as anomalous diffusion. However, the numerical solution of time-fractional differential equations (TFDEs) remains challenging due to the convolution structure of the fractional derivative. Traditional approaches approximate the kernel function in time by sums of exponentials, which often require many terms because of the weak singularity at  $t = 0$ .

In this paper, we propose a simple time-stepping algorithm for TFDEs based on the theory of Stieltjes–Markov functions, a subclass of Herglotz–Nevanlinna functions. The key observation is that the Laplace transform of the kernel function possesses a Stieltjes–Markov structure, which enables an efficient rational interpolation strategy. The resulting approximation includes a Dirac measure with carefully determined strength, significantly reducing the number of required terms. Furthermore, the interpolation points are selected using Mellin’s inversion theorem, which explicitly relates the interpolation error in the transformed domain to the error in the time domain.

The performance of the proposed method is demonstrated through three test problems, including fractional ordinary differential equations with known analytical solutions and a fractional harmonic oscillator. The numerical experiments illustrate the accuracy and convergence properties of the method.

**Keywords:** time-fractional differential equations, Caputo fractional derivative, Herglotz–Nevanlinna functions, Stieltjes–Markov functions, rational interpolation, sum-of-exponentials approximation, Mellin inversion, fractional harmonic oscillator

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## Geometric and Topological Approaches in Oncology Research: From Discrete Curvature to Sheaf Cohomology

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### Abstract:

Cancer is fundamentally a disease of network dysregulation, where the interplay among thousands of genes, proteins, and signaling pathways gives rise to complex, high-dimensional structures that resist classical statistical characterization. In this talk, we present three complementary mathematical frameworks, discrete Ricci curvature, cellular sheaf theory, and information geometry, for extracting biologically meaningful invariants from cancer networks. First, we introduce the augmented Forman-Ricci curvature defined on simplicial complexes and its dynamic extension, which formulates network evolution as a geometric curvature flow. We demonstrate its application to colorectal cancer, where curvature signatures discriminate right- and left-sided tumors and reveal distinct pathway rewiring patterns consistent with known clinical phenotypes. Second, we construct cellular sheaves over drug-target interaction networks and employ the sheaf Laplacian and its cohomology to detect local-global inconsistencies invisible to standard graph-theoretic methods, yielding a novel drug repurposing pipeline. Third, we adopt an information-geometric perspective through signaling entropy, grounded in the Fisher metric on the probability simplex and the Maximum Caliber principle, to characterize tumor aggressiveness across seven TCGA pan-cancer cohorts. We show that signaling entropy behaves as a prognostic invariant and that its landscape exhibits distinct topological features across cancer types.

**Keywords:** Discrete Ricci curvature, Cellular sheaf cohomology, Signaling entropy, Network medicine, Computational oncology

### References

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## **SIRS Rumor Model with Fidelity Parameter and Forgetting Mechanism : A Stability Analysis**

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### **Abstract:**

In this study, an SIRS type rumor model is considered. The model includes a transmission fidelity parameter of rumor, and the transition from the Recovered class R (which consists of individuals who know the rumor but have stopped spreading it) to the Susceptible class S (consists of individuals who are unaware of the rumor) is handled with the help of an added forgetting mechanism. The basic reproduction number is found, equilibrium points of the system representing rumor-free and endemic states are introduced and local stability results are given.

**Keywords:** SIRS rumor model, Stability analysis, Routh-Hurwitz criterion

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## **Algebraic Foundations of Quantum Teleportation: From Mathematical Simplicity to Physical Complexity**

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### **Abstract:**

In this talk, I will discuss the mathematical beauty and physical challenges of quantum teleportation. The talk is organized into three core pillars. First, I will present the algebraic structure of the protocol, demonstrating how the process of state reconstruction is essentially a clever application of tensor products and basis transformations in Hilbert space. Second, I will analyse the statistical framework of the process, using reduced density matrices to show how quantum information remains hidden in a maximally mixed state until classical metadata is provided. I will further analyse Kraus operators to establish the benchmarks required to measure state fidelity. This part of the talk highlights the information-theoretic constraints that preserve causality. Finally, I will model environmental noise and decoherence as stochastic processes, analysing their mathematical structure and impact on state fidelity. Together, these three pillars reveal how quantum teleportation sits at the intersection of mathematical precision and physical complexity, offering deep insights into the foundations of quantum information theory.

**Keywords:** quantum teleportation, Bell state measurement, decoherence, state fidelity, quantum information

### **References**

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2. Bennett, C. H., Brassard, G., Crépeau, C., Jozsa, R., Peres A., and Wootters, W. K. (1993). Teleporting an unknown quantum state via dual classical and Einstein-Podolsky-Rosen channels. *Phys. Rev. Lett.*, 70(13), 1895. <https://doi.org/10.1103/PhysRevLett.70.1895>

## Prediction of Trend Topics for Scientific Research Articles Using Machine Learning Algorithms: A Comparative Approach

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### Abstract:

The rapid advancement of digitalization and the widespread use of the internet have led to an exponential increase in the volume of available information. Identifying key themes and emerging trends across disciplines has therefore become essential for both researchers and decision-makers. This study presents a comprehensive and hybrid framework for topic modeling to explore recent trends in the fields of “Web Intelligence” and “Intelligent Agent Technology.”

Within this framework, traditional topic modeling methods, namely Latent Dirichlet Allocation (LDA), Non-negative Matrix Factorization (NMF), and Latent Semantic Analysis (LSA), are integrated with context-aware embedding representations derived from BERT. The proposed hybrid approach combines document–topic vectors obtained from classical models with BERT-based embedding vectors through a  $\gamma$  (gamma) scaling factor, enabling a unified representation. Model performances are evaluated under varying numbers of topics using multiple topic coherence metrics, with particular emphasis on the  $c_v$  measure.

The experimental results demonstrate that hybrid models consistently outperform their standalone counterparts in terms of topic coherence. Among all evaluated methods, the LSA-SCIBERT hybrid model achieves the highest performance, producing more coherent and semantically meaningful topic structures. The analysis further reveals that the dominant trends in the examined domains include personalized information and search services, customer behavior analysis, e-commerce, artificial intelligence, decision support systems, and individualized education.

Overall, the findings highlight that hybridizing traditional topic modeling techniques with transformer-based embeddings significantly enhances topic quality and interpretability. The proposed approach provides a robust and scalable analytical framework for uncovering actionable insights in domains undergoing rapid digital transformation.

**Keywords:** Hybrid topic modeling, topic coherence, topic extraction

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## Numerical Solution of Online Gaming Addiction Model via Chebyshev Spectral Collocation Method

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### Abstract:

In this study, the PUARL (Predisposed-Uncovered-Addicted-Recovered-Leave permanently) model—a five-compartment epidemiological model—was employed to examine the dynamics of the spread of online gaming addiction within society. The model constructs the addiction process as a nonlinear system of differential equations by drawing an analogy with infectious disease dynamics; it also incorporates the inhibitory role of individual awareness in the transmission process through the psychological awareness coefficient. Numerical solutions were obtained using the Chebyshev Spectral Collocation Method, and the results were compared with the classical fourth-order Runge-Kutta method and the Mathematica default solver. To evaluate the accuracy of the obtained solutions, residual error analysis was conducted; additionally, absolute and relative error comparisons were examined. The effects of key parameters on the system dynamics have been briefly examined. The study aims to contribute to the mathematical modeling of gaming addiction and to establish an evidence-based foundation for the development of effective intervention strategies.

**Keywords:** Chebyshev polynomials, Runge-Kutta method, Residual error analysis

### References

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## A Decision Support Mechanism for Operation Optimization of Ethylene Cracking Furnaces

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### Abstract:

Ethylene cracking furnaces are the highest-value and most energy-intensive units in a petrochemical complex, yet their simultaneous operation optimisation across a heterogeneous fleet remains an intractable problem for conventional approaches. This study presents **EFOM** (Ethylene Furnace Optimization Model), a real-time decision support system developed and field-validated at the Petkim Ethylene Plant (Aliğa, İzmir, Turkey), which operates ten cracking furnaces with an annual ethylene capacity of 520 000 tonnes. EFOM integrates a kinetic simulation engine with a Binary Integer Programming (BIP) model solved via Gurobi to select the optimal combination of Coil Outlet Temperature (COT), dilution steam ratio (DS/HC), and feed rate for each furnace simultaneously, subject to more than fifteen downstream process bottleneck constraints. By calling the interface iteratively over the admissible parameter space, EFOM evaluates up to 54 billion feasible scenarios per eight-hour optimisation cycle, refreshed every fifteen minutes using feedstock specifications retrieved automatically from the plant's Laboratory Information Management System (LIMS) and PHD real-time historian. The system is deployed as a Real-Time Optimizer (RTO) above the plant's Advanced Process Control (APC) layer. Field validation against live plant data demonstrates a Pearson correlation exceeding 0.95 between model-recommended and observed optimal operating trajectories.

**Keywords:** Ethylene cracking, Steam pyrolysis, Binary integer programming, Real-time optimization, Coking prediction

### References

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## Integrating Machine Learning for the Discovery and Classification of Yang-Baxter Equation Solutions on Algebraic Structures

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### Abstract:

The primary objective of this talk is to systematically investigate the set-theoretic solutions of the Yang-Baxter Equation (YBE) over logic-based algebraic structures—such as BCK, GE, BCC, Many-Valued, and Basic algebras—by integrating Machine Learning (ML) models. Initially, a comprehensive dataset comprising existing solutions from the literature will be constructed and transformed into feature vectors suitable for ML architectures. The study aims to classify solutions according to their algebraic types using supervised learning algorithms (Decision Trees, Random Forest, SVM) and to uncover non-trivial relationships and correlations through unsupervised learning (k-means). By bridging advanced theoretical mathematics with modern data science, this interdisciplinary approach proposes a new research paradigm where mathematical structures are treated as "data". The resulting classification and prediction framework is expected to accelerate the discovery of new YBE solutions, providing foundational insights and inspiration for applications in quantum mechanics, knot theory, and quantum computing.

**Keywords:** Yang-Baxter Equation, Logic-Based Algebraic Structures, Machine Learning, Data-Driven Mathematics, Classification and Prediction

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## Structural Analysis of Bipolar Fuzzy Point-Based Subalgebras in Sheffer Stroke Nelson Algebras

Ebrar Gunel<sup>1</sup>, Hashem Bordbar<sup>2</sup>, Tahsin Oner<sup>3</sup>, Neelamegarajan Rajesh<sup>4</sup>

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### Abstract:

This paper studies bipolar fuzzy point-based subalgebras in Sheffer stroke Nelson algebras as a generalized approach to fuzzy algebraic substructures in non-classical logical systems. The main objective is to describe subalgebraic behavior using bipolar fuzzy membership conditions without requiring the strict closure conditions of classical subalgebras. We introduce the notion of bipolar fuzzy point-based subalgebras and investigate their basic properties by algebraic and order-theoretic methods. Several characterization results are obtained in terms of positive and negative membership functions, and necessary and sufficient conditions are established for these structures to coincide with classical subalgebras. In addition, the relationships between bipolar fuzzy point-based subalgebras and ordinary subalgebraic concepts are examined. Examples are included to illustrate the validity and non-triviality of the proposed definitions. The results provide a useful framework for further studies on fuzzy structures and logical applications in Sheffer stroke Nelson algebras.

**Keywords:** Sheffer stroke Nelson algebra, Bipolar fuzzy set, Quasi-subalgebra, Fuzzy ideal, Membership relations

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## On the Relationship Between Riečan and Bosbach State Operators in Sheffer Stroke UP-Algebras

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### Abstract:

State operators play an important role in the algebraic study of uncertainty, probabilistic reasoning, and expectation-like evaluations in many-valued logical systems. In particular, they provide an effective framework for describing internal state transformations in non-classical algebraic structures. Motivated by the increasing interest in algebraic systems generated by the Sheffer stroke operation, this paper investigates Riečan and Bosbach state operators on Sheffer stroke UP-algebras. The main objective is to introduce these two classes of state operators and to analyze their structural behavior within this algebraic setting. We first define Riečan and Bosbach state operators on Sheffer stroke UP-algebras and then establish their fundamental properties by using algebraic and order-theoretic methods. In addition, the relationships between Riečan and Bosbach state operators are examined in detail, and conditions under which one type of state operator implies the other are derived. These results reveal the interaction between state operators and the intrinsic structure of Sheffer stroke UP-algebras. The study extends the theory of state operators to a new algebraic framework and provides a foundation for further investigations of probabilistic and logical interpretations in Sheffer stroke-based algebraic systems.

**Keywords:** Riečan and Bosbach State Operators, Sheffer Stroke UP-Algebras

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## Neural Density Based Vine Classification

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### Abstract:

In this study, capabilities of statistical learning are investigated through classification applications on biological data. Specifically, the predictive power of neural network based density examined in machine learning classification task. Neural network generated marginal nodes integrated in vine framework and such vine calibration is employed to generate the underlying density functions of gene expression data. Benchmark gene expression survival data is used for the classification study. Vine classifiers are also compared with respect to various vine construction procedures.

**Keywords:** Vine Density, Copula, Neural Networks, Classification

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## Some Results on Quantum MDS Codes

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### Abstract:

In this talk, we present some recent results on quantum error-correcting codes. After a brief introduction to the basic principles of quantum error correction, we focus on the connection between classical maximum distance separable (MDS) codes and quantum MDS (QMDS) codes through Hermitian self-orthogonality. In particular, we discuss constructions arising from generalized Reed–Solomon codes and related algebraic methods over finite fields. The main goal of the talk is to explain how suitable families of classical MDS codes can be used to derive quantum codes with strong parameters, and to highlight the conditions under which these constructions produce QMDS codes.

**Keywords:** quantum error correction, quantum MDS codes, Hermitian self-orthogonality, generalized Reed–Solomon codes, finite fields

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## Examining A Reinforcement Learning-Based Trading Strategy in Crypto Market

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### Abstract:

Botrafy is a flexible trading framework that analyzes historical data for each market (Crypto, BIST, EU/US) and symbol, applies statistical techniques to interpret this data, and builds probability driven trading models through simulations. Even though it operates across diverse markets—from cryptocurrencies to equities—it streamlines all workflows within a unified code-base. By utilizing volatility-adaptive dynamic parameters, it aims to reduce risk while maximizing overall returns.

The main focus of this work is the Proximal Policy Optimization (PPO) algorithm, introduced by Schulman et al. (2017), which is a reinforcement learning approach suitable for sequential decision-making problems. In the context of financial trading, PPO provides a promising structure for training an agent to learn trading strategies based on historical market behavior, technical indicators, and risk-related features.

Since the strategy is still under development, this presentation focuses on the methodological workflow, the mathematical and statistical background of PPO, and preliminary experimental results from cryptocurrency market data. The performance of the developing model is discussed using financial evaluation metrics such as cumulative return, maximum drawdown, Sharpe ratio, Sortino ratio, and related risk-adjusted indicators. Also, this work contributes to the discussion on how reinforcement learning methods can be structured, tested, and improved for adaptive algorithmic trading under volatile market conditions.

**Keywords:** Botrafy, PPO, Reinforcement learning, Quantitative trading

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## Comparative Investigation of Non-Local Fractional Derivative Operators in Modeling Memory-Dependent Economic Systems

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### Abstract:

In the field of financial mathematics and economic forecasting, integer-order differential equations often fall short of capturing the intrinsic memory effects and hereditary properties of complex systems. This study proposes a novel mathematical framework for modeling cumulative retail sales by employing fractional-order calculus, which provides an extra degree of freedom through the fractional derivative order. A rigorous comparative analysis is conducted using high-frequency empirical retail data to evaluate the performance of diverse fractional operators, specifically focusing on the Caputo, Riemann-Liouville, Hilfer, and the Atangana-Baleanu (AB) derivatives. The methodology involves transforming daily sales observations into a cumulative time series to represent a system with historical dependencies. To overcome numerical instabilities and ensure the convergence of the Mittag-Leffler kernels, a min-max normalization technique was applied, and the outcomes of the research is polished by numerical methods.

**Keywords:** Fractional Calculus, Atangana-Baleanu Operator, Memory Effect, Economic Modeling, Mittag-Leffler Function.

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## Existence of Positive Solutions for Caputo Fractional Boundary Value Problems

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### Abstract:

In this study, we consider a class of nonlinear semipositone boundary value problems involving  $\varpi$ -Caputo fractional derivatives and the  $p$ -Laplacian operator, subject to highly nonlocal integral boundary conditions motivated by the references [1-5]. The problem incorporates fractional derivatives of different orders, Stieltjes-type integrals, and multi-point conditions, leading to a strongly nonlocal structure that has not been extensively studied in the existing literature.

Under the assumption that the nonlinear term is continuous and positive, we establish the existence of positive solutions by employing fixed point theory in cones, together with the construction of an appropriate Green's function.

To the best of our knowledge, the results presented in this work offer a unified and novel contribution to the theory of fractional boundary value problems with nonlocal conditions, and further extend semipositone analysis to the  $\varpi$ -Caputo framework.

**Keywords:**  $\varpi$ -Caputo fractional derivative; boundary value problems; existence results; semipositone problems; nonlinear  $p$ -Laplacian operator.

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## Optimization-Based Support Planning for 3D Printing

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### Abstract:

Additive manufacturing enables the fabrication of complex geometries and lightweight structures that are difficult to produce using conventional manufacturing techniques. When combined with topology optimization, this technology provides an efficient framework for designing high-performance structural components [1, 4]. However, the mechanical performance and manufacturability of topology-optimized parts are strongly influenced by manufacturing parameters such as printing orientation, material usage, and process conditions [2, 3]. In many existing studies, structural design parameters and manufacturing variables are optimized separately. However, this separation may lead to suboptimal solutions since manufacturing conditions directly affect structural performance and production efficiency. Therefore, this study proposes a unified optimization framework that simultaneously considers both structural design variables and manufacturing parameters.

The optimization problem is formulated as a nonlinear multi-objective optimization problem in which structural performance metrics such as von Mises stress and safety factor are optimized together with manufacturing objectives including printing time and material usage. The resulting problem is solved using a nonlinear goal programming approach in order to balance the trade-offs between competing objectives. The proposed model aims to improve the overall efficiency, reliability, and manufacturability of topology-optimized components produced through additive manufacturing.

**Keywords:** Additive Manufacturing, Topology Optimization, Multi-objective Optimization

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**Advisor:** Prof. Dr. Gözde Yazgı TÜTÜNCÜ

## Pareto-Optimal Selection of Hybrid Wind Farm Configurations: A Site-Specific Performance Analysis Using Global Wind Atlas Data

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### Abstract:

In today's world, accessibility to sustainable energy plays a vital role for our civilization. As an option for this phenomenon, wind energy systems are the basic topic of the current work. In this study, we tried to create a structure for a deficient issue: Hybrid wind farm systems. Wind energy system analysis contains two basic metrics: EENS (Expected Energy Not Supplied - reliability) and CF (Capacity Factor - production efficiency). These metrics are defined for single-model wind farms, and we needed to modify these terms and create modified model for our work by using a Jensen-based approximation method and etc. . We implemented our modified model in MATLAB and then compared the differences between datasets. Several dissimilar locations have been chosen from the Global Wind Atlas (a meteorological database), and the corresponding data was imported into the model. The results are satisfactory for us since our reference paper claimed that the most efficient farm should contain the most efficient turbine model, but we reached a result showing that hybrid farms can also be an optimal solution. Another result of our paper clarifies parameter sensitivity and the impacts of changing the parameters of the Weibull distribution, which models the wind speed random variable, on the optimality results. In conclusion, this study demonstrates that hybrid wind farm configurations can outperform single-model designs by providing more resilient and site-specific Pareto-optimal solutions under varying meteorological conditions.

**Keywords:** Hybrid wind farms, Pareto frontier analysis, Data-driven wind energy optimization, Capacity factor, Expected energy not supplied .

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**Advisor:** Prof. Dr. Gözde Yazgı TÜTÜNCÜ

## Implementation of the Three-Dimensional Goodwin Inflation Model on the Turkish Economy

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### Abstract:

This study aims to estimate the parameters of a three-dimensional extended Goodwin inflation model, which describes the coupled dynamics of labour share, employment rate, and inflation. Applied to Turkish macroeconomic data covering the period 2001–2023, the model requires numerical approximation for unobservable derivative terms in the governing equations. To address this, three numerical approaches are proposed and investigated: analytical derivation via polynomial fitting to state variables (M1), forward finite differences with polynomial smoothing (M2), and raw forward finite differences (M3). These methods are implemented using nonlinear least-squares (NLS) estimation, and the resulting differential systems are solved via the fourth-order Runge-Kutta (RK4) method to provide a framework for evaluating short-run trajectory fits and long-run phase plane dynamics.

**Keywords:** Goodwin inflation model, parameter estimation, finite difference methods, polynomial approximation, nonlinear least squares, Runge-Kutta method, limit cycles.

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**Advisor:** Asst. Prof. Dr. Neslişah İMAMOĞLU KARABAŞ

## Parameter Sensitivity Analysis in a Tumor-Immune Interaction Model

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### Abstract:

This study numerically investigates tumor-immune interactions using a seven-compartment mathematical model that incorporates tumor cells, natural killer cells, CD8+ T cells, CD4+ T cells, circulating lymphocytes, cytokines, and chemotherapy drug concentration. Building upon established framework models for immunotherapy and chemotherapy. We perform a normalized parameter sensitivity analysis to evaluate the influence of several model parameters during critical phases of tumor progression, such as the peak growth phase and steady state. The numerical results aim to clarify system behavior and assess the stability of long-term modeling approaches.

**Keywords:** Tumor-immune interaction, Parameter estimation, Sensitivity analysis, Levenberg-Marquardt algorithm

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<https://doi.org/10.1186/1471-2164-10-301>

**Advisor:** Assoc. Prof. Dr. Sevin GÜMGÜM TURHAN

## Statistical Simulation and Portfolio Optimization: Analyzing the Trade-off Between ESG Constraints and Financial Returns via Monte Carlo Methods

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### Abstract:

This study models the multi-dimensional optimization problem of integrating Environmental, Social, and Governance (ESG) criteria into financial decision-making. The mathematical framework extends the classical Markowitz Mean-Variance optimization into a three-dimensional multi-objective problem. Specifically, the model evaluates the fundamental conflict between three objectives: maximizing expected financial returns, minimizing portfolio variance, and maximizing ESG compliance, subject to budget and non-negativity constraints. A Monte Carlo simulation is utilized to generate random portfolio weights to map the feasible solution space. Subsequently, Pareto Optimization is applied to identify optimal portfolios and construct a 3D trade-off surface (Pareto Frontier) that visually quantifies the exact financial cost of increasing a portfolio's ESG score. Hypothesis testing is then conducted to determine if portfolios constrained by high ESG scores exhibit a statistically significant reduction in Sharpe ratios compared to unconstrained portfolios. Ultimately, this project aims to provide a robust mathematical decision-support tool for sustainable investments.

**Keywords:** Portfolio optimization, ESG constraints, Monte Carlo simulation, Pareto optimality, Multi-objective optimization, Sustainable finance

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**Advisor:** Asst. Prof. Dr. Ömür SALTİK

## A Numerical Study of the SEIR Epidemic Model: Parameter Sensitivity Analysis

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### Abstract:

In this study, a deterministic SEIR (Susceptible–Exposed–Infected–Recovered) epidemic model is analyzed to simulate the transmission dynamics of an infectious disease within a population. The model divides the population into four interacting compartments and describes the transitions between these compartments using a system of nonlinear ordinary differential equations. The fourth-order Runge–Kutta (RK4) method is employed to numerically solve the system and to investigate the time-dependent behavior of the population, providing high accuracy and stability suitable for modeling complex biological systems. The effects of key epidemiological parameters, including the recruitment rate, transmission rate, and incubation rate, are examined through graphical and numerical simulations. Different parameter values are compared to evaluate their influence on the spread and progression of the disease. The results indicate that the transmission rate has the most significant impact on epidemic dynamics, while the incubation rate determines the speed at which exposed individuals become infectious, and the recruitment rate affects the long-term population balance and the persistence of the disease.

**Keywords:** SEIR model, epidemic modeling, Runge–Kutta method, parameter sensitivity

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**Advisor:** Assoc. Prof. Dr. Sevin GÜMGÜM TURHAN

## A Constrained Nonlinear Optimization Approach to Optimal Dividend Policy and Profit Allocation

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### Abstract:

This study presents a nonlinear constrained optimization model to determine the optimal resource allocation of a firm across four strategic variables: Dividends ( $D$ ), Investment ( $I$ ), Reserves ( $R$ ), and Marketing ( $M$ ). Operating under strict budget, marketing efficiency, and nonlinear risk constraints, we introduce a new “AI Adaptation Constraint” ( $\theta$ ) to quantify the financial burden of disruptive technological shifts. The objective is to maximize a strategic utility function reflecting different corporate priorities. The problem is solved using the Sequential Quadratic Programming (SQP) algorithm via MATLAB’s `fmincon` solver.

To validate the model’s stability, we analyzed five distinct strategic scenarios—Cash Cows, Aggressive Growth, Risk-Averse Liquid Firms, Marketing Heavy, and a specific “AI Threat” case study (Duolingo)—using normalized financial data from major global and Turkish corporations (e.g., Amazon, Coca-Cola, THY, Aselsan).

Through Karush-Kuhn-Tucker (KKT) conditions and shadow price (Lagrange multiplier) analysis, we identified critical operational bottlenecks. Sensitivity analysis and 2D feasible region mapping revealed a structural break point: as the AI tolerance parameter tightens, the AI constraint becomes actively binding. This mathematically forces traditional firms to drastically cut dividends and marketing in favor of mandatory R&D investments to survive.

Ultimately, this project transforms theoretical optimization principles into a dynamic decision-support tool. The findings demonstrate that active constraints dictate corporate survival strategies, proving that exogenous technological pressures can mathematically override a firm’s inherent preference for short-term shareholder distribution.

**Keywords:** Constrained Nonlinear Optimization, Karush-Kuhn-Tucker Conditions, Dividend Policy, Profit Allocation, Sequential Quadratic Programming

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**Advisor:** Prof. Dr. Gözde Yazgı TÜTÜNCÜ

## Parameter Sensitivity Analysis of a Delay-Induced Tumor-Immune Interaction Model

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### Abstract:

This study examines the parameter sensitivity of a delay-induced tumor-immune interaction model involving immune effector cells, tumor cells, and normal cells. The system is formulated as a set of nonlinear delay differential equations in which the immune recruitment term incorporates a discrete time delay representing the latency of the immune response. Numerical simulations are performed using the classical fourth-order Runge–Kutta (RK4) method combined with a history function approach, based on parameter values adopted from the literature. The effect of the delay parameter on the system dynamics is first explored, followed by a detailed sensitivity analysis of key interaction parameters, including the immune inactivation rate, immune killing rate, tumor–normal cell interaction rate, normal cell growth rate, and tumor-induced normal cell death rate. The numerical results demonstrate that variations in these parameters significantly influence the temporal evolution of tumor, immune, and normal cell populations. In particular, increases in the intrinsic tumor growth rate and delay parameter lead to more pronounced growth patterns and dynamic fluctuations, while stronger immune response and normal cell regeneration tend to suppress tumor progression. These findings highlight the critical role of interaction parameters in shaping system behavior and provide quantitative insight into how different biological mechanisms contribute to tumor progression and immune response efficiency.

**Keywords:** Tumor-immune interaction, delay differential equations, parameter sensitivity, oscillatory dynamics

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**Advisor:** Assoc. Prof. Dr. Sevin GÜMGÜM TURHAN

## Reliability Analysis of Mixed Shock Models with a Protection Block

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### Abstract:

This study develops a reliability framework for engineering systems exposed to random shocks under a protection-block mechanism. The protection block reduces the effect of damaging shocks, but after its failure the system becomes more vulnerable. Shocks arrive according to a Poisson process and are classified into three categories using two thresholds  $0 < d_1 < d_2$ . The system fails after  $b$  consecutive intermediate shocks or upon the occurrence of a catastrophic shock. The results show that the protection block significantly improves system reliability, while higher protection failure rates lead to a decrease in system lifetime.

**Keywords:** mixed shock model, protection block, regime switching, run shock model, reliability analysis

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**Advisor:** Assoc. Prof. Dr. Cemal Murat ÖZKUT

## Time-Dependent Parameter Estimation for SEIRU Model of Ebola Outbreak

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### Abstract:

In this study, we use the data from the 1995 Kikwit Ebola outbreak to develop an enhanced SEIRU model and estimate the model parameters. Departing from the static-parameter approaches prevalent in literature, this model incorporates a time-dependent transmission coefficient ( $\beta(t)$ ) to represent intervention strategies and a dynamic reporting rate ( $\rho(t)$ ) to reflect increasing case-tracking capacity. The differential equations are solved using the 4th Order Runge-Kutta (RK4) method, and parameters are estimated via the Differential Evolution algorithm. The findings demonstrate that the integration of dynamic parameters significantly improves the model's fit to real-world data, particularly during the decay phase, providing more robust results for 400-day projections.

**Keywords:** SEIRU model, Runge–Kutta method, Differential Evolution, parameter estimation.

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**Advisor:** Assoc. Prof. Dr. Sevin GÜMGÜM TURHAN

## Stability Analysis of the SATU Mathematical Model of Math Anxiety

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### Abstract:

This study presents a rigorous mathematical and stability analysis of the SATU compartmental model, designed to capture the transmission dynamics of math anxiety among student populations. Math anxiety is modeled as a contagious phenomenon driven by peer and teacher interactions. Building upon previous numerical validations, this study refines the original mathematical framework by incorporating a standard incidence rate and uniform dropout rates to ensure analytical tractability. We derive the key nonlinear ordinary differential equations governing the system and compute the basic reproduction number ( $\mathcal{R}_0$ ) using the Next Generation Matrix method. Furthermore, we establish the existence of the Anxiety-Free Equilibrium (AFE) and Endemic Equilibrium (EE) points. Through the application of Jacobian matrices, the Routh-Hurwitz criterion, and Lyapunov functions, we conduct both local and global stability analyses. The results mathematically prove that when  $\mathcal{R}_0 \leq 1$ , the Anxiety-Free Equilibrium is globally asymptotically stable, guaranteeing the natural eradication of math anxiety. Conversely, when  $\mathcal{R}_0 > 1$ , the system transitions to a stable Endemic Equilibrium, indicating the persistence of the condition. Finally, the study provides actionable intervention strategies—such as reducing peer-to-peer transmission and expanding counseling access—to force the reproduction number below the critical threshold. These findings demonstrate that eradicating math anxiety is a mathematically achievable reality through systematic structural interventions.

**Keywords:** Mathematical modelling, math anxiety, SATU model, stability analysis, basic reproduction number

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**Advisor:** Asst. Prof. Dr. Demet ERSOY ÖZDEK

## Exact and Heuristic Approaches to the Symmetric Euclidean TSP: A TSPLIB-Based Comparison

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### Abstract:

This study examines solution approaches for the symmetric Euclidean Traveling Salesman Problem (TSP) using benchmark instances from the TSPLIB library. The main objective is to compare an exact Integer Programming (IP) formulation with a metaheuristic Simulated Annealing (SA) algorithm in terms of solution quality and computational efficiency. For the IP approach, a standard subtour-elimination-based model is considered, while the SA method is implemented with a neighborhood search strategy and a cooling schedule tailored to TSP instances. Computational experiments are performed on instances of varying size to assess the behavior of both methods under a common test environment. The preliminary results indicate that the IP model is effective for smaller instances where optimality can be certified, whereas SA provides competitive near-optimal solutions with substantially lower computational cost on larger instances. The study highlights the practical trade-off between exactness and scalability in TSP optimization.

**Keywords:** Traveling Salesman Problem, TSPLIB, Integer Programming, Simulated Annealing, Combinatorial Optimization

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**Advisor:** Prof. Dr. Güzde Yazgı TÜTÜNCÜ

## Residue Entropy: Theory and Applications

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### Abstract:

This study comprehensively examines the theory of residue entropy and its advanced applications, focusing on uncertainty analysis in reliability engineering. The study defines the concepts of Decreasing Uncertainty of Residual Life (DURL) and Increasing Uncertainty of Residual Life (IURL), which explain how failure uncertainty changes as a system ages. The preservation properties of these characteristics under parallel systems and "k-out-of-n" system architectures, along with their connections to the hazard function, are analyzed. To model uncertainty states and extreme values, Uniform, Exponential, and Gumbel distributions are comparatively examined through their probability density functions (pdf), moments, and entropy characteristics. Sklar's Theorem is introduced to resolve complex dependence structures in multivariate probability distributions, separating marginal distributions from dependence structures. In this context, Gumbel, Clayton, Frank, and FGM copula families, as well as "Vine Copula" architectures for high-dimensional data, are detailed. Finally, Kullback-Leibler (KL) Divergence, which measures information loss between models, Shannon Entropy, and Cumulative Residual Entropy (CRE), which consistently produces positive values, are analyzed. The study concludes by demonstrating the fundamental equivalence between mutual information and copula entropy.

**Keywords:** Residue Entropy, Copula Theory, Reliability Engineering, Cumulative Residual Entropy, Kullback-Leibler Divergence

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**Advisor:** Prof. Dr. İsmihan BAYRAMOĞLU

**Analysis and Replication of Machine Learning Algorithms for Medical Imaging: Brain Tumor and Lung Nodule Detection**

***Comparison of Entropy-Based and Pixel-Based Approaches***

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**Abstract:**

This study investigates the reproducibility of two prominent machine learning methodologies for medical imaging: a morphology-based Naïve Bayes approach for brain tumor detection and a Decision Tree approach for lung nodule classification. We replicated these methods and benchmarked them against pixel-based control experiments using MRI and X-ray datasets. Our results reveal that while object-based segmentation achieves high local accuracy (97%), it falters at the patient diagnosis level (66.84%). Furthermore, we demonstrate that contrary to expectations, simple Decision Trees significantly outperformed Naïve Bayes on raw MRI data (86.38% vs 68.96%), proving better suitability for pixel-correlated data. Finally, we show that high-resolution raw data processing for lung cancer (93% claim) is not reproducible (61% achieved) due to the curse of dimensionality.

**Keywords:** Medical Imaging, Machine Learning, Brain Tumor Detection, Lung Nodule Classification, Reproducibility

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**Advisor:** Asst. Prof. Dr. Ömür SALTİK

## A Mathematical Approach to Coherent Systems via System Signatures

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**Abstract:** Reliability theory plays a crucial role in the analysis and design of engineering systems where performance depends on the operational status of individual components. In practical applications, understanding how system structure influences lifetime and overall reliability is a primary objective. While traditional tools such as structure functions, minimal path sets, and minimal cut sets are effective for describing coherent systems, they often become algebraically complex as the number of components increases. This study focuses on the concept of system signatures as a compact and informative mathematical tool for analyzing the reliability of coherent systems. Under the assumption of independent and identically distributed (i.i.d.) component lifetimes, the system signature effectively separates the topological design of the system from the underlying failure distributions. This separation allows for the comparison of different system designs through a finite-dimensional probability vector rather than complex functional forms. This study first reviews the fundamental concepts of coherent systems, including path sets, cut sets, and reliability functions. Subsequently, the definition, calculation, and stochastic interpretation of system signatures are discussed. Furthermore, the role of signatures in expressing system lifetime distributions and evaluating the impact of system structure on reliability is examined. Overall, system signatures provide a powerful framework for making meaningful comparisons between alternative engineering designs and optimizing system performance.

**Keywords:** Reliability Theory, Coherent Systems, System Signature, Lifetime Distributions, Stochastic Comparison

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<https://doi.org/10.1016/j.spl.2013.01.012>

**Advisor:** Prof. Dr. İsmihan BAYRAMOĞLU

## Development of a MATLAB-Based Computational Tool for the Design and Optimization of Optical Thin-Film Coatings

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### Abstract:

Optical thin-film coating design is an inverse problem in which the thicknesses of multilayer structures must be selected to achieve a desired spectral response over a specified wavelength band. In this study, we present a MATLAB-based computational tool developed for the simulation and optimization of multilayer optical thin films. The forward optical response is modeled using the Transfer Matrix Method (TMM), while the inverse design problem is formulated as a constrained nonlinear optimization task in which layer thicknesses are adjusted to match a target transmission, reflection, or absorption profile [1, 2, 3]. The developed program provides an interactive graphical user interface that allows users to define material databases, construct manual layer stacks or search candidate sequences automatically, impose thickness bounds, and monitor optimization history together with the best spectral response. The framework also incorporates weighted objective terms related to target matching, spectral uniformity, and total coating thickness, enabling physically meaningful and application-oriented designs. The relevance of optimization-based thin-film design is further supported by recent wavelength-selective filter studies for human-safe far-UVC excimer lamps, where multilayer coating performance directly determines spectral selectivity and practical usability [6]. Overall, the proposed tool offers a practical computational environment for forward simulation, inverse design, and educational exploration of optical coating systems [4, 5].

**Keywords:** Optical thin films, Transfer Matrix Method, MATLAB, nonlinear optimization, inverse design, optical coatings

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**Advisor:** Prof. Dr. Gözde Yazgı TÜTÜNCÜ

## A News-Based Turkey Tension Index and Its Effects on the BIST 100

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### Abstract:

This study aims to construct a Turkey Tension Index (TTI) using data obtained from news sources and to examine the effects of the index on the BIST 100. For the construction of the index, news content between 01.01.2021 and 30.04.2025 from the selected news sources was collected using the web scraping method. Tension scores were calculated under seven thematic categories: economic, social, migration, political, terrorism, natural disaster, and military. In order to capture the effect of weekend news on the BIST 100, a "Monday effect" value was created by using the z-scores of Saturday, Sunday, and Monday. The validation of the index was supported by the sharp increases observed in the TTI during significant events such as the February 6, 2023 Kahramanmaraş earthquakes, the 2023 General Elections, and the 2024 Local Elections. The relationships between the TTI and BIST 100 return, absolute return, and trading volume were analyzed using a VAR model. The findings indicate that tension shocks do not create a permanent effect on return levels; however, they generate temporary and statistically significant effects on market volatility and trading volume in the short run. Impulse-response and variance decomposition analyses reveal that shock transmission is limited and that in the long run the variables are determined by their own dynamics. The obtained results indicate that the TTI affects the BIST 100 through risk and liquidity channels rather than prices and provides empirical evidence regarding the functioning of news-based tension indicators in emerging markets.

**Keywords:** Stock Market, BIST100, VAR Analysis, Index Construction, Web Scraping, Tension Index.

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## IzmiRisk: Data-Driven Water Risk Modeling A District-Level Analysis for Izmir

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### Abstract:

This study develops a data-driven framework to assess water security risk at the district level in İzmir, Turkey. A Water Security Risk Index (WSRI) is constructed by integrating four key indicators per-capita consumption, consumption growth rate, supply constraint, and water loss using entropy-based weighting.

Due to the lack of pre 2020 data, missing historical values were reconstructed using a bootstrap-based backcasting approach to ensure temporal continuity. The analysis combines statistical modeling, time-series analysis, and spatial methods. Temporal trends are evaluated using the Mann Kendall test, while spatial dependence is examined through Global Moran's I.

Results reveal a statistically significant decline in overall water security risk between 2010 and 2023, despite persistent inter-district variability. Spatial analysis indicates no significant clustering, suggesting that risk is geographically dispersed rather than concentrated. Exploratory data analysis further highlights variability in reservoir storage and district-level consumption patterns.

Future WSRI values are projected using regression-based models, providing a consistent and data-driven forecasting framework for the period 2024–2030. The findings are also supported by an interactive web-based dashboard (<https://izmirrisk.streamlit.app>), enabling dynamic visualization and analysis of water risk patterns.

This study contributes by transforming raw data into interpretable risk insights, offering a scalable and data-driven approach for urban water management and policy development.

**Keywords:** Water Security Risk Index (WSRI); Spatial analysis; Moran's I; Mann–Kendall test; Time series analysis; Regression modeling; Urban water management

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**Advisor:** Asst. Prof. Dr. Necla Koçhan

## Epidemiological Parameter Estimation for Brazil’s Mpox Outbreak Using a Time-Dependent SEIRU Framework

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### Abstract:

In this study, we develop a Time-Dependent Susceptible-Exposed-Infectious Reported-Unreported (TD-SEIRU) compartmental model to analyze the 2022–2025 Mpox outbreak in Brazil (14,928 cases, 1,387 days). We estimate the parameters as time dependent functions, namely a sigmoidal transmission rate  $\beta(t)$  capturing behavioral change and interventions, and a logistic detection rate  $\rho(t)$  reflecting the expansion of surveillance and testing capacity. Parameters are estimated via Differential Evolution (DE) global optimization using a weighted mean absolute relative error loss function evaluated over three observational proxies—daily incidence, active case count, and recovered case count—solved numerically with a fixed-step fourth-order Runge-Kutta scheme. The time-varying model substantially outperforms constant-parameter baselines in capturing both the epidemic peak (days 1–200) and post-2023 endemic transmission dynamics ( $R^2 > 0.90$  on the full series), with direct implications for surveillance system design in non-endemic settings.

**Keywords:** Mpox; TD-SEIRU; time-varying parameters; parameter estimation

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**Advisor:** Assoc. Prof. Dr. Sevin GÜMGÜM TURHAN

## A Multi-Objective Mixed-Integer Linear Programming Framework for Sustainable Dual-Campus Transportation Optimization

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### Abstract:

This study presents a data-driven optimisation framework for the shuttle transportation system of İzmir University of Economics (IEU), an institution serving over 12,000 students distributed across 39 administrative districts of a metropolitan area spanning more than 50 kilometres. The system addresses a dual-campus topology comprising the Balçova main campus and the Güzelbahçe campus, organised through a hub-and-spoke architecture with seven demand-consolidation hubs, six active shuttle routes, and an inter-campus transfer corridor. Urban campus transportation in emerging economies is largely underserved by mathematical optimisation methods, relying instead on fixed schedules designed through empirical observation rather than rigorous modelling.

A multi-objective MILP model simultaneously minimises three competing objectives: daily operational cost, daily CO<sub>2</sub> emissions, and a passenger Generalised Travel Cost capturing in-vehicle time, walking, waiting, and transfers. A systematic  $\varepsilon$ -constraint method generates the complete Pareto-optimal set and the trade-off frontier, with an automated knee-point recommendation identifying the best-compromise fleet. A demand consolidation procedure redirects passengers from underbooked hubs to nearby alternatives under formal feasibility conditions that bound any travel-cost increase, while a robustness assessment evaluates fleet stability under parameter uncertainty.

Validation on real institutional data demonstrates that the optimised knee-point fleet of 16 vehicles achieves a 10-year total cost of ownership of approximately 19.9 million Turkish lira with daily CO<sub>2</sub> emissions of 132 kg, representing a 71% reduction from the pure-diesel baseline while remaining well within the 500 kg/day institutional carbon ceiling. A critical inter-campus route finding reveals that the daily round-trip distance of the Balçova–Güzelbahçe corridor exceeds the operational range of smaller electric vehicles, mandating higher-capacity assignments — a constraint absent from prior campus transit studies operating on single-campus topologies. The study contributes a reproducible and operationally validated mathematical framework for sustainable campus mobility transferable to other multi-site institutions.

**Keywords:** Mixed-integer linear programming; Multi-objective optimisation; Pareto  $\varepsilon$ -constraint; Hub-and-spoke networks; Sustainable mobility.

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**Advisor:** Prof. Dr. Gözde Yazgı TÜTÜNCÜ