International Conference on Operations Research and Game Theoretic Approach in Decision Making

ICORGTDM24

Organized by

Indian Statistical Institute, Delhi Centre

Contents

Welcome to ICORGTDM24 (Golden Jubilee Celebrations: Indian Statistical Institute, Delhi Centre)

On behalf of the organizers of ICORGTDM24, I welcome you in the International Conference on Operations Research and Game Theoretic Approach in Decision Making will be organized during January 17 – 19, 2024 at Indian Statistical Institute, Delhi Centre.

This conference will be organized as a part of the Golden Jubilee Celebrations of the Indian Statistical Institute, Delhi Centre and it intends to review the current issues in the theory and applications of Operations Research and Game Theory to problems in business and industries. The objective of this conference is to provide a forum for new developments and applications of Operations Research and game theory. Leading scientists, experienced researchers and practitioners, as well as younger researchers will come together to exchange knowledge and to build scientific contacts. This conference will provide an excellent opportunity to disseminate the latest major achievements and to explore new directions and perspectives, and is expected to have a broad international appeal, dealing with topics of fundamental importance in Operations Research and other related sciences (Economics, Physics, Management Science and Engineering). For other events related to Golden Jubilee Celebrations of the Indian Statistical Institute, Delhi Centre visit webpage http://www.isid.ac.in/

This symposium also intends to bring out a publication of selected and refereed papers in a special issue of Annals of Operations Research. For details about this special issue click Annals of Operations Research.

The symposium topics include (but not limited to):

- Operations Research problems in Statistics
- Portfolio Optimization
- Linear and Nonlinear Programming
- Decision Theory and Multiple Criteria Decision Making
- Dynamic Programming
- Simulation and Statistical Modelling
- Inventory Theory and Applications

- Non-smooth Optimization
- Graph Theory in Operations Research
- Complementarity problems and Variational inequalities
- Stochastic Optimization
- Traveling salesman problem
- Knapsack, Vehicle Routing & Scheduling problems
- Static and Dynamic games
- Operations Research Problems in Reliability
- Game Theoretical applications of Operations Research
- Financial Optimization

Information about social events will be available to you at the time of registration.

S. K. Neogy
Organizing Committee Chair

Committees

Organizing Committee

S. K. Neogy (Chair), R.B. Bapat, Arunava Sen, Prabal Roy Chowdhury, K. Manjunatha Prasad, Manipal Academy of Higher Education, Manipal

Programme Co-ordinating Committee

R. B. Bapat, K. Manjunatha Prasad, Prabal Roy Chowdhury

Facilities Committee

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International Conference on Operations Research and Game Theoretic Approach in Decision Making

January 17-19, 2024

Program Overview

Inaugural Session Details

January 17, 2024 Time: 10:00 -10:30 Venue: Auditorium

Welcome address, Opening Remarks, About symposium, Vote of Thanks

Group Photograph 10:30-10:45
Tea Break: 10:45 -11:00

Sessions Details

January 17, 2024 Time: 11:00 -13:00 Venue: Auditorium

Invited Session I
Chairman : Reinoud AMG Joosten, University of Twente, The Netherlands.

1.	**Lina Mallozzi (University of Naples Federico II via Claudio 21, 80125 Naples, Italy)** One-leader/Multi-follower Stackelberg models and security games
2.	**S Dharmaraja (Indian Institute of Technology Delhi)** Study of Limit Theorems on Extended Inverse Hawkes Processes
3.	**Juan Enrique Martínez-Legaz (Universitat Autnoma de Barcelona, Spain)** On Power Cells
3.	**Anna B. Khmelnitskaya (Saint-Petersburg State University)** The number of ways to construct a connected graph: a graph-based generalization of the binomial coefficients

Lunch Break: 13:00 -14:00
Venue: Guest house Lawn

January 17, 2024 Time: 14:00 -15:30 Venue: Auditorium

Invited Session II
Chairman: Anna B. Khmelnitskaya (Saint-Petersburg State University)

1.	**S. K. Mishra (Banaras Hindu University,Varanasi, India)** Constraint Qualifications and Optimality Conditions for MPEC/MPVC Problems in terms of Tangential Subdifferentials
2.	**Reinoud Joosten &** Rogier Harmelink,(University of Twente, The Netherlands). Inductive τ-values in cooperative transportation games under computational time constraints
3.	**Vikas Vikram Singh** (Indian Institute) Technology Delhi, India) Distributionally robust Markov decision processes

Tea Break: 15:30 -16:00

January 17, 2024 Time: 16.00 -18:30 Venue: Auditorium

ISOGTDM24 Best Paper Award (Methodology & Applications)

Coordinator : K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)

1.	**Arnav Ghosh (Indian Institute of Technology Patna)** On Constraint Qualifications for Mathematical Programming Problems with Vanishing Constraints on Hadamard Manifolds
2.	**Sonali Sharma (Malaviya National Institute of Technology Jaipur)** A criterion for Q-tensors
3	**Akriti Dwivedi (Banaras Hindu University, Varanasi)** On approximate strong KKT points of nonsmooth interval-valued mutiobjective optimization problems using convexificators
4	**Rupesh Krishna Pandey ((Indian Institute of Technology Patna) NEWTON'S METHOD FOR INTERVAL-VALUED MULTIOBJECTIVE OPTIMIZATION PROBLEM**
5	**Punit Kumar Yadav (Malaviya National Instiute of Technology, Jaipur)** Generalizations of R0 and SSM properties for Extended Horizontal Linear Complementarity Problem
6	**G Singh (University of Delhi)** Some more subclasses of Q-matrix
7	**Karl D. Lewis (Indian Institute of Technology Madras)** Invariant sets of the replicator dynamics: Bilinear games
8	**Kirti (Thapar Institute of Engineering & Technology, Patiala)** A note on "Matrix games with linguistic intuitionistic fuzzy Payoffs: Basic results and solution methods
9	**Aysha Parveen (National Institute of Technology Raipur**) Performance analysis of a GeoX/G/1 queue with multiple vacations under the premise of an early arrival system
10	

January 17, 2024 Time: 16:00 -18:30 Venue: Conference Room

Technical Session-I

Chairman : S. K. Mishra (Banaras Hindu University,Varanasi, India)

1.	**Sujata Goala (Dibrugarh University, Dibrugarh, India)** Intelligent Machines and Shapley value
2.	**Gautam Beniwal (Manipal University Jaipur, Jaipur, Rajasthan)** Optimization of Multi-objective, Multi-stage Stochastic Transportations Programming Problem using Goal Programming Approach
3.	**Guman Singh (Manipal University Jaipur, Jaipur, Rajasthan)** Multi-objective Multi-product Stochastic Supply Chain Network Problem Using Goal Programming Approach
4	**Sarbjit Singh (Institute of Management Technology Nagpur) Optimal** production policy under time- and price-dependent demand and reliability
5	**Saikat Mukherjee (Department of Management Studies, Indian Institute of Technology Delhi, Hauz Khas, New Delhi)** The q-Allocation Hub Interdiction Problems:Model Formulations and Solution Approaches
6	**Sai Kumar M (Vellore Institute of Technology,Chennai)** SEPQ Model for Dairy Products: Integrating Green Technology for Carbon Emission Reduction
7.	**Arunadevi E (Vellore Institute of Technology,Chennai)** Next-Gen Inventory Optimization: Dual Warehouse model with unconventional Buy Now Pay Later Strategy
8.	**Jayashri P(Vellore Institute of Technology,Chennai)** Greening Business Operations: Sustainable Economic Order Quantity through Smart Financing and Green Technology Investments
9	**Chithraponnu R (Vellore Institute of Technology,Chennai**) A Robust RBC Inventory Management Ordering Policy for Subtype of A with the Cross-matching Policy for Heterogenous Demand

January 17, 2024, Time: 18:30-20:00 Cultural Programme

Venue: Auditorium

January 17, 2024, Time: 20:00-21:00 Conference Dinner

Venue: Guest house Lawn

January 18, 2024 Time: 10:00 -11:30 Venue: Auditorium

Invited Session III

Chairman: Lina Mallozzi (University of Naples Federico II via Claudio 21, 80125 Naples, Italy)

1.	**Yasunori Kimura (Toho University, Funabashi, Japan)** Fixed point problems and approximation techniques of its solutions on geodesic spaces
2	**Joydeep Dutta (IIT KANPUR)** Error Bounds for Linear Programming : A Variational Inequality Approach
3.	**Andreay Garnaev (Rutgers University, North Brunswick, NJ 08901, USA)** A Bayesian jamming game in which each player has a continuum of uncertainty about the other

Tea Break: 11:30 -12:00

January 18, 2024 Time: 12:00 -13:00 Venue: Auditorium

Invited Session IV

Chairman: Prabal Roy Chowdhury, Indian Statistical Institute Delhi Centre

1.	**Bo Chen (University of Warwick, United Kingdom)** Auctions and Bidding
2.	**N. Hemachandra**, **(Indian Institute of Technology Bombay, India)** Strategic interaction between service providers and the user-set in (abandonment) queues

Lunch Break: 13:00 -14:00
Venue: Guest house Lawn

January 18, 2024 Time: 14:00 -15:30 Venue: Auditorium

Invited Session V

Professor T Parthasarathy Memorial Session

Chairman: S K Neogy, Indian Statistical Institute, Delhi

1.	**S K Neogy (Indian Statistical Institute Delhi Centre)** On some Research contributions of Professor T Parthasarathy
2	**Nagarajan Krishnamurthy (Indian Institute of Management, Indore)** Prof. T. Parthasarathy's works on Stochastic Games
2.	**KS Mallikarjuna Rao (Indian Institute of Technology Bombay)** Replicator Dynamics in Stochastic Games'

Tea Break: 15:30 -16:00

January 18, 2024 Time: 16:00 -18:30 Venue: Auditorium

Technical Session-II A

Chairman : Joydeep Dutta, Indian Institute of Technology, Kanpur, India

1.	**Ayushi Baranwal (Department of Mathematics and Computing, Indian Institute of Technology (Indian School of Mines), Dhanbad-826004, India)** Isoperimetric-type Constrained Variational Control Problem with Uncertainty: Robust Optimality and Duality
2.	**Prabhjot Kaur (Panjab University, Chandigarh, India)** An iterative algorithm to solve a bi-objective two-stage hierarchical transportation problem
3.	**Subham Poddar (Indian Institute of Technology Patna)** Optimality Conditions for Robust Nonsmooth Uncertain Multiobjective Complex Programming Problems
4	**Thirumulanathan D (Indian Institute of Technology Kanpur)** KKT Reformulations for Single Leader and Multi-Follower Games
5	**PritamAnand (Dhirubhai Ambani Institute of Information and Communication Technology (DA-IICT), Gandhinagar)** Improving the reliability of quantile estimate with sparse and localized support vector quantile regression model
6	**Parul Tomar (Thapar Institute of Engineering & Technology,Patiala)** An advanced similarity measure for Pythagorean fuzzy sets and its applications in transportation problem: An important observation
7	**Tejpal Meedal (Manipal University Jaipur, Rajasthan, India)** Two-ware house inventory system for deteriorating items Under Preservation technology effect with advertisement-dependent demand in an inflationary environment
8	**V Varagapriya (Indian Institute of Technology Delhi, Hauz Khas, New Delhi, 110016, India)** Rank-1 transition uncertainties in constrained Markov decision processes
9.	**Saroja Kumar Singh (Department of Statistics, Ravenshaw University, Cuttack, India)** Classical and Bayesian Estimation of Performance Measure in Erlang Single Server Queues
10	**Akash Jain (Netaji Subash University of Technology (NSUT) , Dwarka, New Delhi)** Novel Fuzzy DEA model over range directional measures with Pythagorean Interval Valued Data

January 18, 2024 Time: 16:00 -18:30 Venue: Conference Room

Technical Session-II B

Chairman: KS Mallikarjuna Rao (Indian Institute of Technology Bombay)

1.	**Vivek Laha (Banaras Hindu University, Varanasi-221005, India)** On quasidifferentiable mathematical programs with equilibrium constraints
2.	**Shivani Sain (Indian Institute of Technology Patna)** Characterizations of the Solution Set of Nonsmooth Semi-Infinite Programming Problems on Hadamard Manifolds
3	**Varun Kumar (Department of Data Science, Prasanna School of Public Health, Manipal Academy of Higher Education, Manipal)** Modelling the Location-or-Routing Problem (LoRP) for solving household waste collection
4.	**Saransh Tiwari (Decision Sciences Area, Indian Institute of Management Lucknow)** Developing composite indicator in stochastic environment: A cross-efficiency Stochastic DEA approach
5.	**Kanchan Mittal (Department of Mathematics, IIT Madras, India)** Forward-Backward-Forward algorithms for bilevel equilibrium problems
6.	**A. Verma (National Institute of Technology Raipur)** A service facility in discrete-time queueing system associated with (s, S) inventory policy
7	**Bhawna Kohli (Sri Guru Nanak Dev Khalsa College, University of Delhi, Delhi-110005, India) SUFFICIENT OPTIMALITY CONDITIONS and DUALITY RESULTS for a MULTIOBJECTIVE BILEVEL PROGRAMMING PROBLEM**
8.	**Umashankar Bajpei (Banaras Hindu University, Varanasi, 221005, Uttar Pradesh, India)** Quasi-convex Semi-infinite programming problems in term of GP-Subdifferential
9	**Shiwani Singh (Banaras Hindu University, Varanasi, 221005, Uttar Pradesh, India)** New Generalizations and Refinements of (p, q)-Hermite-Hadamard Inequalities for Convex Functions
10	**Priyanka Bharati ((Banaras Hindu University, Varanasi, 221005, Uttar Pradesh, India)** On robust solution of nonsmooth mathematical programs with equilibrium constraints

January 18, 2024 Time: 16:00 -18:30 Venue: Seminar Room

Technical Session-II C

Chairman: S K Mishra (Banaras Hindu University, Varanasi-221005, India) On

1.	**Prachi Sachan (Banaras Hindu University, Varanasi-221005, India)** Higher order optimality conditions in multiobjective optimization problems using directional convexificators
2.	**Prashant Jaiswal (Banaras Hindu University, Varanasi-221005, India)** On Quasidifferentiable Multiobjective Optimization Problem in Banach spaces
3	**Vandana Singh (Banaras Hindu University, Varanasi-221005, India)** Nonsmooth constraint qualifications and stationary conditions for mathematical programs using tangential subdifferentials
4.	**Ram Krishna Vinayak (Department of Mathematics, Indian Institute of Technology Delhi)** Unlocking Collective Intelligence: A Novel Game for Optimal Group Formation in the Classroom
5.	**Soham Das (Department of Mechanical Engineering, Insitute of Technology Delhi, Hauz Khas, New Delhi)** An evaluation of the stochastic ruler method as a solution methodology for discrete stochastic optimization
6.	**Sonia (Janki Devi Memorial College, University of Delhi)** SOME NEW TECHNIQUES FOR SOLVING GENERALIZED VECTOR QUASI-VARIATIONAL INEQUALITY PROBLEM OVER PRODUCT SET
7	**Ratna Dev Sarma (Rajdhani College, University of Delhi**)) A NOTE ON STABILITY ANALYSIS OF GENERALIZED VECTOR VARIATIONAL INEQUALITIES
8.	**Yogendra Pandey** (Satish Chandra College, Ballia) Optimality Conditions for Multiobjective Optimization Problems with Switching Constraints
9	**Shweta Kalson** (Delhi Technological University, New Delhi, India) Uncertainty inherent in Human Decision-making in Crime Analysis
10	**Saad Ashraf (University of Delhi, Delhi, India)** A multi-pickup and delivery dispatching problem for same day courier delivery with different customers based on priority

January 19, 2024 Time: 10:00 -11:30 Venue: Auditorium

Invited **Session VI**
Chairman: Yasunori Kimura, Toho University, Funabashi, Japan

1.	**K.C. Sivakumar (Indian Institute of Technology Madras, India)** Adequate Matrices Revisited
2.	**K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)** Moore-Penrose Inverses in Network Optimization Problems
3.	**Anurag Jayswal*** (Indian Institute of Technology (Indian School of Mines), Dhanbad-826004, India) Controlled multidimensional optimization problems: An auxiliary approach

Tea Break: 11:30 -12:00

January 19, 2024 Time: 12.00 -13.00 Venue: Auditorium

Invited **Session VII**
Chairman: K. Manjunatha Prasad (Manipal Academy of Higher Education, Manipal)

1.	**Gajendra Pratap Singh (School of Computational and Integrative Sciences Jawaharlal Nehru University, New Delhi)** Transition Firing Sequence Optimization in Boolean Petri Nets
2.	**Pankaj Gupta (University of Delhi, India**.) Sustainable financial portfolio selection

Lunch Break: 13:00 -14:00
Venue: Guest house Lawn

January 19, 2024 Time: 14:00 -15.00 Venue: Auditorium

Invited Session VIII

Chairman: Anna B. Khmelnitskaya (Saint-Petersburg State University)

1.	**Nagarajan Krishnamurthy (IIM Indore)** Competition between National Brand and Private Brand
2.	**Dipti Dubey (Department of Mathematics, Shiv Nadar University)** On N and Almost N matrices: some contributions of Late Professor T. Parthasarathy

January 19, 2024 Time: 14:00 -15.00 Venue: Conference hall

Technical session IIIA

Chairman: Anurag Jayswal* (Indian Institute of Technology (Indian School of Mines), Dhanbad-826004, India)

1.	**Divyanee Garg, (IIT Delhi)** Optimal Portfolio Selection applying the Mean-Deviation Expectile Value at Risk
2.	**Ravina Sharma (Banaras Hindu University, Varanasi, 221005, Uttar Pradesh, India)** Quantum Hermite-Hadamard Inequalities for Generalized Convex Functions
3.	**Nidhi (Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat, India**.) Cost optimization of a fault-tolerant machining system with balking and vacation
4	**Dheerendra Singh (Banaras Hindu University, Varanasi, 221005, Uttar Pradesh, India)** Mathematical Programs Using Tangential Subdifferentials

Tea Break: 15:00 -15:30

January 19, 2024 Time: 15:30 -18:30 Venue: Auditorium

Technical Session IIIB

Chairman: Nagarajan Krishnamurthy (IIM Indore)

1.	**Rekha (Shiv Nadar Institution of Eminence, Delhi NCR, India)** Challenges in Designing Sensing Matrix
2.	**Anveksha Moar (University of Delhi, Delhi-110007)** Nonlinear Scalarization in Set Optimization based on the Concept of Null Set
3.	**Priya Sharma** (University of Delhi, Delhi 110007, India) A New Method for Fuzzy Large-Scale Multi-Criteria Group Decision- Making
4.	**Jyoti Kohli (University of Delhi)** IMPACT OF CARBON EMISSION ON ONE-WAY SUBSTITUTION OF ITEMS UNDER INFLATION AND SCREENING
4	**Soumya Rath (Banaras Hindu University, Varanasi, India)** Duality for quasiconvex semi-infinite programming problems,
5.	**Anjali Naik (Department of Mathematics, IIT Delhi)** Slack-based Non-Convex Data Envelopment Analysis Model
6	**Anuvinda (Indian Institute of Science Education and Research Bhopal)** Nexus between Total Factor Productivity and Back sourcing Decision: Empirical Evidence from the Manufacturing Sector of India
7	**Riddhi Jangid (Jawaharlal Nehru University, New Delhi Delhi-110067, India)** Petri Nets Reachability in Apriori Algorithm: A Comprehensive Approach to Market Basket Analysis
8	**Ardhana M Prabhash** (Indian Institute of Science Education and Research Bhopal, MP, India) Performance of Food Processing Companies in India: An integration of Machine Learning and DEA
9	**Shanky Garg** (Guru Gobind Singh Indraprastha University (GGSIPU), Dwarka, Delhi, India) Effectively Managing Drugs in the medical industry using the MCDM approach
10	**Santosh Kumar (University of Delhi, Delhi, India)** An optimization model for a sustainable transportation problem for location of refuelling station
11	
12.	

January 19, 2024 Time: 15:30 -18:30 Venue: Conference Hall
Technical Session IIIC

Chairman: A. K. Das (Indian Statistical Institute, 203 B. T. Road, Kolkata)

1.	**Anupam (Department of Mathematics, Netaji Subhas University of Technology, Dwarka)** Performance analysis of DRX mechanism using batch arrival vacation queueing system with N-policy in LTE-A networks
2.	**Amita Sharma** (Department of Mathematics, Netaji Subhas University of Technology, Dwarka) Data-driven robust portfolio optimization model with an application to enhanced indexing
3.	**Bharat Kumar (PDPM-Indian Institute of Information Technology Design and Manufacturing, Jabalpur)** Projected Type Iterative Methods for Large and Sparse Linear Complementarity Problem
4	**Anjali (Delhi Technological University, New Delhi, India)** Human Behavior Analysis using Entropy-based Cloud Transformation
5.	**Shubham Kumar (PDPM-Indian Institute of Information Technology Design and Manufacturing, Jabalpur)** Necessary and Sufficient Conditions for the Unique Solvability of Absolute Value Equations
6	**Joyanta Kumar Majhi (Indian Statistical Institute, 203 B. T. Road, Kolkata)** Impacts of blockchain adoption on a two-level supply chain with demand uncertainty
7	**Ajay Singh (Birla Institute of Technology and Science, Pilani, India)** Multi-Objective Optimization and Transient Analysis of Discrete-Time Multi-server Multi-Class Priority G-Queue with Vacation
8	**Vijaypal Poonia (Birla Institute of Technology and Science, Pilani, India)** Development of a Multi-objective Optimization Model for Circular Economy
9	**Shubham Kumar (PDPM-Indian Institute of Information Technology Design and Manufacturing, Jabalpur)** Solution of Uncertain Multiobjective Optimization Problems by Using Nonlinear Conjugate Gradient Method via Robust Optimization Approach
10	**Mahendra Devanda, (BITS Pilani, Rajasthan, India)** Exploring Hierarchical Repair Strategies for Multi-Unit Redundant Machining Systems
11	**R. Deb (Jadavpur University, Kolkata)** On some properties of stochastic tensor complementarity problem
12.	**A. K. Das (Indian Statistical Institute,203, B. T. Road, Kolkata-700108, India)** Two Conjectures in Complementarity Theory

ABSTRACT OF THE PAPERS

One-leader/Multi-follower Stackelberg models and security games

Lina Mallozzi

Department of Mathematics and Applications \R. Caccioppoli"

University of Naples \Federico II" - mallozzi@unina.it

We study hierarchical games where the second stage consists of a finite noncooperative game. To ensure that the lower level problem admits solutions, its mixed extension is considered. The situation describes the so-called security games, where the strong Stackelberg solution, also called optimistic Stackelberg solution, is the concept commonly used. In this joint work with Panos Pardalos, by using the Shannon entropy, a regularization scheme for the two-stage game is introduced and some properties are presented, as the asymptotic subgame perfectness.

On Power Cells

Juan Enrique Martínez-Legaz

Universitat Autnoma de Barcelona, Spain

Given a set $T \subseteq R^n$ and a nonnegative function r defined on T, we consider the power of $x \in R^n$ with respect to the sphere with center $t \in T$ and radius $r(t)$, that is, $p_r(x,t) := \|x-t\|^2 - r^2(t)$, with $\|\cdot\|$ denoting the Euclidean distance. The corresponding power cell of $s \in T$ is the set

$$C_T^r(s) := \{x \in R^n : p(x,s) \leq p(x,t), \text{ for all } t \in T\}.$$

We study the structure of such cells and investigate the assumptions on r that allow for generalizing known results on classical Voronoi cells.

This is joint work with Elisabetta Allevi and Rossana Riccardi.

Auctions and Bidding

Bo Chen

University of Warwick, United Kingdom

The 2020 Nobel Prize in Economics was awarded to Paul Milgrom and Robert Wilson for their improvements to auction theory and inventions of new auction formats. Their theoretical discoveries have improved auctions in practice and benefitted sellers, buyers and taxpayers around the world (RSAS, 2020).

Auction theory provides an explicit model of price making and auctions are of consider- able practical significance. Auction theory is closely linked to game theory, combinatorial optimization and computational complexity. In the first half of my talk, I will give a brief overview of auction theory and practice. I will introduce some key concepts and results in auction theory, then provide some examples of

best auction practice, and conclude with pointers to some seminal full-review articles. In the second half of my talk, I will present my recent studies on some auction problems in the electricity capacity market.

A Bayesian jamming game in which each player has a continuum of uncertainty about the other

Andreay Garnaev,

Rutgers University,

North Brunswick, NJ 08901, USA

We consider a user's communication with a receiver in the presence of an adversary equipped with a jammer and aimed to harm this user's communication in the most competitive situation for the user and adversary in which they do not have access to complete information on the channel states of each other although they could have access to exact information on their own channel states. The scenario is modeled by a Bayesian power control game. Since channel gain is a function of the distance to the receiver, the distance also can be considered as a channel state. Thus, the model also covers scenarios where both players (user and adversary) could know their own location via a Global Positioning System (GPS), but none of them know the exact location of the other. That is why, the considered Bayesian game can be applied, on one hand, to model an anti-jamming communication strategy of a ground control center (user) with a drone (receiver) to perform its mission, and, on the other hand, to model an anti-drone strategy of the adversary who is aimed to prevent the drone's mission. To model access to exact information about own channel state, a player's type has to be associated per the channel state. In particular, if players may be located anywhere within a certain area, it leads to a continuous distribution of their allocations, and, so, to a continuum of players' types and associated best response equations. It is important to note that the classical game-theoretical approach is based only on a finite number of the best response equations. A suggested novel approach allows us to derive the equilibrium of such problems in closed form for any distribution over channel states, and, so, in particular, even for a continuum of the best response equations. The established uniqueness of equilibrium reflects the stability of the suggested anti-jamming and anti-drone strategies.

Inductive τ-values in cooperative transportation games under computational time constraints

Reinoud Joosten & Rogier Harmelink,

University of Twente,

School of Behavioural, Management and Social Sciences,

POB 217, 7500 Enschede, The Netherlands.

The τ-value gives each player in a cooperative game an amount in between his minimal-right and his utopia amounts. The utopia amount is the player's marginal contribution to the grand coalition. The remainder for a given player in a certain coalition containing him is the amount left after the sum of the utopia amounts of all other players is subtracted from the worth of that coalition. The minimal-right amount of the player is then the largest remainder taken over all coalitions containing him.

For cooperative transportation games, computing the worth of a coalition may involve solving a traveling salesman or a vehicle routing problem which are NP-hard. Moreover, there are exponentially many such coalitions to consider. On top of that, computing the τ-value is NP-hard itself. We deal with the constraint that a solution, i.e., an allocation of savings or profits, may be required before all worths of the coalitions are known.

An inductive τ-value is the efficient allocation closest to the set of all convex combinations of approximations of the utopia vector and the minimal rights vector. First, the worth of the grand coalition is determined which (by assumption) is always possible. As long as the time constraint is not met, the worths for all coalitions with cardinality 1 are computed, then for those with cardinality 2, and so on. Simultaneously, the utopia and minimal rights vectors of the game restricted to the coalition at hand are determined. If the computation time reaches the constraint while establishing worths for coalitions with cardinality U+1, the vectors obtained determine the approximations of the utopia and minimal rights vectors based on the completed calculations up to U. If the constraint is not binding, the inductive τ-value coincides with the τ-value.

We show that the inductive τ-value satisfies two recently introduced axioms, namely sensitivity up to cardinality U, i.e., a value depends on the worths of all coalitions with cardinality at most U, and insensitivity beyond cardinality U, i.e., a value is independent from all worths of coalitions with cardinality larger than U, the grand coalition excluded. These axioms incorporate important aspects of fairness regarding the impact of computations being based on restricted information.

Fixed point problems and approximation techniques of its solutions on geodesic spaces

Yasunori Kimura

Toho University, Japan

Fixed point problem is one of the most crucial topics in nonlinear and convex analysis, and there are many applications to the problems in operations research. We mainly discuss the operators defined on complete geodesic spaces.

In geodesic spaces, the convex combination is one of the most fundamental notions. Nevertheless, its geometric structure is different from that in linear spaces. For example, let us take a weighted average among more than two points using the classical definition. It may not be unique according to the order taking convex combination between two points.

In this talk, we consider this fact and introduce a new definition of a weighted average among a finite number of points. We also show several different types of iterative methods converging to a fixed point of a given mapping.

The number of ways to construct a connected graph: a graph-based generalization of the binomial coefficients

Anna B. Khmelnitskaya

Saint-Petersburg State University

(jointly with Gerard van der Laan, Dolf Talman)

The topic of this paper does not relate directly to the game theory, but the interest for this study was strongly influenced by our study of Shapley-type solution concepts for cooperative games with limited cooperation introduced by means of communication graphs. If there are no restrictions on cooperation, the classical Shapley value assigns to each player, as a payoff , the average of the player's marginal contributions with respect to all possible orderings of the players. However, in cooperative games endowed with a communication graph not all orderings of the players are feasible since only connected players are able to cooperate. We evaluate a player communication ability in a connected graph through the number of ways the graph can be constructed starting with this player and adding successively players adjacent to those already added before. When the graph is a path on $n + 1$ vertices, these numbers are exactly the binomial coefficients in row n of Pascal's triangle. Hence, for other connected graphs, these numbers, called the connectivity degrees of the vertices, generalize the binomial coefficients. We show that the connectivity degrees have properties that for paths reduce to well-known properties of the binomial coefficients. We obtain an explicit formula representation of the connectivity degree that straightforwardly generalizes the binomial coefficient formula. We show that when the number of vertices in a graph minus one is prime, the connectivity degree of every cut vertex is divisible by this prime. Furthermore, the connectivity degree of a vertex is equal to the sum of this vertex connectivity degrees in all subgraphs obtained by deleting precisely one of the non-cut vertices of the graph. Similar to the binomial coefficients in a row of Pascal's triangle, in a tree the ratio of the connectivity degrees of every two adjacent vertices is equal to the ratio of the numbers of vertices in two subgraphs resulting from deleting the edge between these vertices. For arbitrary connected graph the latter is true only when an edge is a bridge, the deletion of which splits the graph into two components. We also prove that the connectivity degrees of the vertices in a tree, when normalized to sum up to one, are equal to the steady state probabilities of some Markov chain on the vertices of the graph. Furthermore, on a connected graph the connectivity degrees of its vertices can be seen as a measure of centrality. On the class of trees we provide an axiomatic characterization of this connectivity centrality measure.

Strategic interaction between service providers and the user-set in (abandonment) queues

N. Hemachandra

Indian Institute of Technology Bombay, India

Queuing-based service systems are ubiquitous in telecommunication, computer networks, transportation systems, call centers, etc. This work is focused on strategic interaction between queueing-based service facilities (service provider) and the user-set (market). This strategic interaction can be viewed as a two-player non-cooperative game between the service provider and the user-set. The market offers an arrival rate at stationarity that depends on the Quality of Service (QoS) provided by the service provider. In many queuing-based service facilities, the service provider implements a cost/revenue optimal policy as an admission control (threshold) limit on the number of customers. We first review the strategic interaction between arriving customers and such a service provider and provide sufficient conditions for the existence of equilibrium points and equilibrium sets with two different QoS measures: 1) the asymptotic rate of the customers lost and 2) the fraction of customers lost in the long run. We then generalize the results to strategic interaction for a service provider with impatient customers who abandon the service facility when the service is delayed. For such queues with impatient users, we consider appropriate QoS measures: either the fraction or the rate of the customers who abandoned. The standard state-space representation of the number of customers in the system may not suffice for defining these QoS measures. Hence, we use a two-dimensional state space representation for computing these QoS measures of the fraction or the rate of the impatient customers who abandon the service facility. For the smaller optimal control limits we obtain the stationary distribution in closed form, while, for larger optimal control limits one can use efficient computational schemes. We also point out the additional challenges to the equilibrium analysis of queues with abandonment.

Error Bounds for Linear Programming : A Variational Inequality Approach

Joydeep Dutta,

IIT KANPUR

(Joint work with C. Charitha, IIT Indore).

Though the Hoffman error bound for a linear system of equalities and inequalities are well known, the importance of error bounds for linear programming problem to the best of our knowledge has been sufficiently emphasized. This is primarily because of the fact that it appears to be simple application of the Hoffman error bound but with the additional assumption that the lower bound is known. What happens if the lower bound is not known. Error bounds for linear programming problems become crucial for interior point algorithms. In this talk we show that a primal dual pair of linear programming problem can be equivalently modelled as an affine variational inequality problem with a skew-symmetric matrix. First we will show how to develop error bounds for an affine variational inequality using the Auslender gap function and then compute to to show that the Auslender gap function at the feasible points turns out to be the duality gap for the matrix associated with the prima-dual problem and thus allows us to provide an error bound for the primal-dual pair of linear programming problem where we need not know the lower bound of the primal problem.

Prof. T. Parthasarathy's works on Stochastic Games

Nagarajan Krishnamurthy

Indian Institute of Management, Indore

In this talk, we shall look at Prof. T. Parthasarathy's contributions to the field of stochastic games, including his pioneering works on the orderfield property of stochastic games and algorithms for solving some classes of stochastic games.

Constraint Qualifications and Optimality Conditions for MPEC/MPVC Problems in terms of Tangential Subdifferentials

S. K. Mishra

Department of Mathematics Institute of Science

Banaras Hindu University

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The talk presents suitable generalized usual constraint qualifications and optimality conditions in mathematical programming problems with equilibrium constraints and vanishing constraints in terms of tangential subdifferentials. The presentation deals with (namely, generalized standard Abadie constraint qualifications, MPEC Abadie constraint qualifications, MPEC KKT constraint qualifications, MPEC Zangwill constraint qualifications, MPEC weak reverse convex constraint qualifications and MPVC-LICQ, MPVC-MFCQ, VC-MFCQ, VC-GCQ, WACQ, WKTCQ, and WZCQ) in terms of tangential subdifferentials and studies relationships among these constraint qualifications. Further, we have established sufficient optimality conditions for mathematical programs with equilibrium/vanishing constraints involving tangential subdifferentials.

Replicator Dynamics in Stochastic Games'

KS Mallikarjuna Rao

Indian Institute of Technology Bombay

We propose replicator dynamics for stochastic games with average payoff and discuss stability properties of the Nash equilibrium. This is a joint work with Divya Murali and A.J. Shaiju.

Study of Limit Theorems on Extended Inverse Hawkes Processes

S Dharmaraja

Department of Mathematics

Indian Institute of Technology Delhi

An inverse Hawkes process is a process having constant intensity and stochastic jump size, depending on the past number of jumps, while a Hawkes process has the intensity which is stochastic. An extended

inverse Hawkes process is a process obtained by combining a Hawkes process and an inverse Hawkes process. The focus of this talk is to investigate the asymptoticbehaviour of an extended inverse Hawkes process with general structure of the exciting functions. In particular, the results obtained are the generalized versions of the Law of Large Numbers and of the Central Limit Theorem.

Sustainable financial portfolio selection

Pankaj Gupta

University of Delhi, India.

Recently, sustainable investing has caught on with investors and has become the norm. For the newly listed assets with scant information on the sustainability aspects, it becomes harder to pursue sustainable investing. To this end, we propose a sustainable financial portfolio selection approach based on a comprehensive three-stage methodology.

Adequate Matrices Revisited.

K.C. Sivakumar

Indian Institute of Technology Madras, India

The notion of adequate matrices was introduced by Ingleton. He proved that an invertible matrix is adequate iff it is a P-matrix. In this talk, I will present a few results on singular adequate matrices in relation to their Moore-Penrose and group inverses. Time permitting, a proposal to consider a generalization to operators over the space of symmetric matrices, will be presented.

Controlled multidimensional optimization problems: An auxiliary approach

Anurag Jayswal*

Department of Mathematics and Computing

Indian Institute of Technology

(Indian School of Mines), Dhanbad-826004, India

This talk aims to present an auxiliary method for addressing the multidimensional control optimization problem with first-order PDE constraints (MCOP). For this, two different approaches have been used, namely the absolute value penalty function and the modified function method. First, we penalized the problem (MCOP) and construct an unconstrained problem associated with it, and show that the equivalence between the solutions of both the problems via convexity and saddle point criteria. Next, we linearize the original problem (MCOP) using the modified objective function approach which reduce the complexity of the problem. Later on, we penalized the modified problem using the concept of the absolute value exact penalty function approach, and show that a minimizer of the new modified unconstrained problem and the solution of original problem are same via the above discussed approach. Also, some examples are given to validate the main results.

*A joint work with Miss Ayushi Baranwal.

Distributionally robust Markov decision processes

Vikas Vikram Singh

Indian Institute of Technology Delhi, India

Markov decision process (MDP) is a decision making framework where a decision maker is interested in maximizing the expected discounted value of a stream of rewards received at future stages at various states which are visited according to a controlled Markov chain. Many algorithms including linear programming methods are available in the literature to compute an optimal policy when the rewards and transition probabilities are deterministic. In this paper, we consider an MDP problem where the reward vector is known and the transition probability vector is a random vector which follow a discrete distribution whose information is not completely known. We formulate the MDP problem using distributionally robust chance-constrained optimization framework under various types of moments based uncertainty sets, and statistical-distance based uncertainty sets defined using ϕ-divergence and Wasserstein distance metric. For each uncertainty set, we propose an equivalent mix-integer bilinear programming problem or a mix-integer semidefinite programming problem with bilinear constraints. As an application, we study a machine replacement problem and perform numerical experiments on randomly generated instances.

Transition Firing Sequence Optimization in Boolean Petri Nets

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Petri nets are the graphical tool proposed by Carl Adam Petri in 1962. They can be used in designing, modelling and studying the discrete event-driven dynamical systems e.g., series, parallel, concurrent, asynchronous, conflict, distributed systems, etc. Application of Petri nets in optimization problems contributes in studying the systems dynamics, performance characteristics and resource utilization. In this talk we consider a reachability tree of a Boolean Petri net and we try to operate the transition operation by triggering the transitions for firing by the particular tactical method and construct the level-wise partitions of reachability marking vector set to reduce the redundancies of transition firing so that resultant firing sequence is shortest and optimal in nature by keeping the properties of Boolean Petri net unchanged. A Boolean Petri net is a special class of 1-safe Petri net that generates every marking vector in its reachability tree.

Moore-Penrose Inverses in Network Optimization Problems

K. Manjunatha Prasad

Manipal Academy of Higher Education, Manipal

In this talk, some interesting applications of generalized inverses in the network theory are revisited. Interesting properties of generalized inverses are employed to make the proof of several known results simpler, and several techniques such as bordering method and inverse complemented matrix methods are used to obtain simple expressions for the Moore-Penrose inverse of incidence matrix and Laplacian matrix. Some interesting and simpler expressions are presented in some special cases such as tree graph, complete graph and complete bipartite graph.

On N and Almost N matrices: some contributions of Late Professor T. Parthasarathy

Dipti Dubey

Department of Mathematics

Shiv Nadar University

Matrix classes play a significant role in the theory of linear complementarity problem.The linear complementarity problem is the problem of finding a complementary

pair of nonnegative vectors in a finite dimensional real vector space that satisfies a given system of linear inequalities. Two such matrix classes are the class of of N-matrices and almost N-matrices. In this talk, we will revisit the class of N-matrices and almost N-matrices and highlight some of Late Professor T. Parthasarathy's significant contributions to these matrix classes and to the linear complementarity theory.

Competition between National Brand and Private Brand

Manish Kumar and **Nagarajan Krishnamurthy**

IIM Indore

The private brand (PB), also known as the store brand, has become widely popular. Retailers who have their own PB also use various techniques to increase the sales of the competing national brand (NB), though the products cannibalize each other. For example, retailers provide price discounts on NB products to increase sales and attract new customers. In order to address the dilemmas faced by the retailer and the manufacturer, the study models the problem as a two-echelon supply chain consisting of one manufacturer and one retailer, and solves the Stackelberg game. The retailer needs to decide the price and advertisement effort for the introduced PB considering the already existing competing NB. The manufacturer needs to respond to the introduction of competing PB. The results of the study give the conditions under which it is beneficial for the retailer to introduce PB and those under which the retailer gets benefits by providing a price discount on NB products. The results also show how the manufacturer should respond with wholesale price changes and with advertisement effort changes considering the retailer's decisions on PB as well as their price discount decision on NB. The results also give us the optimal pricing and advertisement decision for the retailer in the case of the introduction of PB.

Contributed Talks

On some properties of stochastic tensor complementarity problem

R. Deb a,1 and A. K. Das b,2

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In recent years many researchers have devoted their time to study traffic equilibrium problem. In this paper we consider the stochastic tensor complementarity problem (STCP) with the motivation to provide theoretical background for stochastic traffic equilibrium problem. Stochastic tensor complementarity problem is an approach of tensor complementarity problem under uncertainty. In real life problem uncertainty is an inevitable behaviour of the factors namely cost, demand, supply, trade, material, weather and many other sources. Uncertain traffic equilibrium problem is one of the important issues which can be reformulated as tensor complementarity problem. To study the stochastic tensor complementarity problem we consider expected residual method (ERM) based on Fisher-Burmeister function and establish some necessary and sufficient conditions for the solution set of stochastic tensor complementarity problem. We investigate some properties of the model ERM$(\mathscr{A}(\omega), q(\omega))$ and obtain some crucial properties of stochastic tensor complementarity problem with the help of expected residual method. We propose some properties of the stochastic tensor complementarity problem in connection with R_0 tensor. Furthermore we study some necessary and sufficient conditions of the solution set of STCP$((\mathscr{A}(\omega), q(\omega))$ for the fixed cost vector $q(\omega)$.

Impacts of blockchain adoption on a two-level supply chain with demand uncertainty

Joyanta Kumar Majhi and A. K. Das

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Blockchain technology is thought to have the potential to improve supply chain performance. However, while using blockchain technology, its benefits and associated costs must be balanced. This study builds a supply chain where a manufacturer sells products through a retailer who experiences demand uncertainty. Two different market scenarios are considered in this study. We mathematically find that the blockchain adoption techniques of supply chain members depend on blockchain-operational cost and demand volatility. When adoption of blockchain is cost effective and demand fluctuation is small and medium, the use of blockchain is beneficial for the individual and the supply chain, but if demand fluctuations is large and blockchain adoption is costly, it is more helpful to avoid the implementation of blockchain. In order to demonstrate the strength of our findings, we also carry out numerical experiments to examine the effects of a competitive market and fluctuations in the level of uncertainty in demand. In light of these findings, we additionally give both theoretical and practical suggestions for supply chain managers for choosing the optimal blockchain adoption circumstances in a supply chain.

Projected Type Iterative Methods for Large and Sparse Linear Complementarity Problem

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In many scientific computing and engineering applications, the linear complementarity problem (LCP) often arises, e.g., in the free boundary problem and the Nash equilibrium point of the bimatrix game, the American option pricing problem, mathematical economics, operations research, control theory, optimization theory, stochastic optimal control, economics, elasticity theory. Assuming $A \in R^{n\times n}$ and a vector $q \in R^n$, the linear complementarity problem denoted as LCP(q, A) is to find the solution $x \in R^n$ to the following system

$$x \geq 0, \quad Ax + q \geq 0, \quad x^T(Ax + q) = 0. \tag{1}$$

The well-known algorithm to solve the LCP is Lemke's algorithm. Based on the processability of Lemke's algorithm, a large number of matrix classes are introduced to study their properties. The linear complementarity problem can be solved in a

number of ways by an iterative process; namely the projected methods, the modulus based matrix splitting iterative methods. A general fixed point method (GFP) is proposed by Xi-Ming Fang (2021) with assuming the case where $\Omega = \omega D^{-1}$ with $\omega>0$ and D is the diagonal matrix of A. The GFP approach takes less iterations than the modulus-based successive over-relaxation (MSOR) iteration method. However, the GFP approach calculates the numerical solution component by component of vectors which takes a long time. We present a class of new projected iterative methods by using the ideas of Xi-Ming Fang (2021) and Rashid Ali et. al. (2022). We establish a class of new projected iterative methods based on matrix spitting for solving the large and sparse linear complementarity problem. We provide a fixed-point equation and demonstrate that this equation is equivalent to an linear complementarity problem. Also, we provide some convergence condition for the proposed method. To prove the convergence, we consider the radius of convergence and show that the radius of convergence is strictly less than one. For our cases, the convergence ensures the uniqueness of the solution based on the matrix classes considered. Several numerical examples demonstrate the effectiveness of the suggested methods, which are superior to the modulus-based matrix splitting methods in terms of the number of iteration steps and the time required by the CPU. The time required for each iteration in the proposed methods varies from 0.24 milliseconds to 0.75 milliseconds depending on the complexity analysis. After several initial fluctuations, the convergence rate is found to be linear. The rate of convergence is approximately 50%. Finally, the paper will cover some open questions and future research.

Solution of Uncertain Multiobjective Optimization Problems

by Using Nonlinear Conjugate Gradient Method via Robust Optimization Approach

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Optimized solutions in engineering and design may become less effective when errors occur. Inreal-life situations, there is usually uncertainty, and the information used to solve problems is often incorrect or incomplete. In science and business, errors in measurements or predictions are common. Even if we ignore uncertainties in the data, solutions cannot be perfect because real-world implementation is not infinitely precise, as assumed in ideal scenarios. Numerous real-world applications of uncertain multiobjective optimization problems (UMOPs) can be found in science, engineering, business, and management. To handle the solution of uncertain optimization problems, robust optimization is a relatively new _eld. UMOP can be converted into a deterministic multiobjective optimization problem (MOP) with the help of the robust optimization methodology, referred to as a robust counterpart. Ehrgott et al. (2014) presented that the solution of the robust counterpart to the UMOP is the solution for the UMOP. Additionally, the robust counterpart of UMOP is solved by the scalarization method (e.g., weighted sum method and \epsilon Constraint method). By pre-selecting some parameters and reformulating them as deterministic scalar optimization problems, scalarization methods, based on the scalarization technique, compute the efficient or weak efficient solution. This method has a drawback in that the parameter selection may result in an unbounded (i.e., no solution exists) scalarized problem even when the robust counterpart has solutions. Another drawback of this strategy is that the parameters are not predetermined, so it is up to the modeler and the decision-maker to make those decisions. To overcome these difficulties, we will solve the robust counterpart of UMOP with the help of the conjugate gradient method, and no parameter information is needed for this method. In the present study, conjugate gradient methods for the robust counterpart of UMOP are developed to find the solution of UMOP. We consider an objective-wise worst-case cost-type robust counterpart and use the conjugate gradient methods to solve a UMOP. A conjugate gradient descent algorithm is created using theoretical _ndings. It is demonstrated that the conjugate gradient descent algorithm's generated sequence converges to the robust counterpart's weak Pareto optimal solution, which will be the robust weak Pareto optimal solution for UMOP. The convergence analysis involves the extensions of the Fletcher{Reeves, conjugate descent, Dai{Yuan, Polak{Ribi_ere{Polyak, and Hestenes-Stiefel parameters that retrieve the smooth vector optimization. Finally, we verify conjugate gradient descent algorithm with some numerical examples, and compared it with the existing method like weighted sum method. It is also proved that the algorithm works for convex as well as non convex problem

Necessary and Sufficient Conditions for the Unique Solvability of Absolute Value Equations

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The absolute value equations (AVE) $Ax + |x| = b$ with known $A \in \mathbb{R}^{n\times n}$, $b \in \mathbb{R}^n$ and unknown vector $x \in \mathbb{R}^n$ is significant because it can be applied to various domains of mathematics and applied sciences. For instance, the linear complementarity problems (LCP), bimatrix games, mixed-integer programming, a system of linear interval matrix, boundary value problems, convex quadratic optimization, absolute value matrix equations (AVME) and the hydrodynamic equation can be formulated as AVE. The linear complementarity problems (LCP) and absolute value equations (AVE) have an equivalence relation. The relationship between LCP and AVE allows for converting one problem into another, offering alternative perspectives for analysis and solution. This equivalence aids in theoretical understanding and developing numerical methods applicable to both mathematical formulations. The further generalization of the absolute value equation is AVME $AX + |X| = B$ where $A, B \in \mathbb{R}^{n\times n}$ are given and $X \in \mathbb{R}^{n\times n}$ is unknown.

This paper outlines the necessary and sufficient conditions to guarantee the unique solvability of absolute value equations. In addition to discussing the basic form of these equations, we also take a look at some generalizations, which include generalized absolute value equations and absolute value matrix equations. In the end, the paper will address some unresolved questions and future research.

Intelligent Machines and Shapley value

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The paper studies a firm that hires two individuals who operate an intelligent machine which is capable of distinguishing effort and efficiency level of the individuals from the output. The management of the firm does not know how efficient an employee is while hiring her. This induces a game of incomplete information where the sets of actions of each employee in each stage game are the sets of effort levels. The benefit part of the pay-off function of each employee comes from her Shapley share in the total output, and the cost part of the pay-off function comes from the effort that she puts. A characterization of ex-ante Nash Equilibrium is established.

Optimization of Multi-objective, Multi-stage Stochastic Transportations Programming Problem using Goal Programming Approach

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Stochastic multi-objective optimization has its close connection with human life problem considered to play significant role. This paper deals with multichoice multi-objective
transportation problem (MCMOTP) when at least one of the objectives has multiple aspiration levels to achieve, and the parameters of supply and demand are random variables that has not been predetermined. In the present work, firstly, problem is converted into an equivalent deterministic problem using the

chance constrained programming to determinate the individual solution. Secondly, implementing a transformation method using binary variables that reduces the multichoice multi-objective transportation problem into a multi-objective transportation problem (MOTP), selecting one aspiration level for each objective from multiple levels, reduced problem can be solved with goal programming. In this paper, we have shown that by applying the two- phase approach, an efficient solution obtained for the stochastic multi objective programming problem. A numerical example is given to illustrate the suggested methodology.

Multi-objective Multi-product Stochastic Supply Chain Network Problem Using Goal Programming Approach

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In this paper, we develop a multi-objective stochastic programming approach for supply chain design under uncertainty. Demands, supplies, processing, transportation, shortage, and capacity expansion costs are all considered as the uncertain parameters. This problem is modelled using a multi-objective mixed integer mathematical programming. our multi-objective model includes (i) maximizing the total profit of logistics (ii) the minimization of the sum of current investment costs and the expected future processing, transportation, shortage, and capacity expansion costs, (iii) the minimization of the financial risk or the probability of not meeting a certain budget. Several sets of constraints are considered to handle the real situations of three echelon supply chains. The goal programming was adopted to solve the proposed multi- objective mixed-integer mathematical programming. An illustrative numerical example was provided to show the mechanism of the proposed model and the solution procedure.

On Constraint Qualifications for Mathematical Programming Problems with Vanishing Constraints on Hadamard Manifolds

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This article is devoted to the study of mathematical programming problems with vanishing constraints on Hadamard manifolds (in short, MPVC-HM). We present the Abadie constraint qualification (in short, ACQ) and (MPVC-HM)-tailored ACQ for MPVC-HM and provide some necessary conditions for the satisfaction of ACQ for MPVC-HM. Moreover, we demonstrate that the Guignard constraint qualification (in short, GCQ) is satisfied for MPVC-HM under certain mild restrictions. We introduce several (MPVC-HM)-tailored constraint qualifications in the framework of Hadamard manifolds that ensure satisfaction of GCQ. Moreover, we refine our analysis and present some modified sufficient conditions which guarantee that GCQ is satisfied. Several non-trivial examples are incorporated to illustrate the significance of the derived results. To the best of our knowledge, constraint qualifications for mathematical programming problems with vanishing constraints in manifold setting have not been explored before.

Optimal production policy under time- and price-dependent demand and reliability

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In this paper, we study an inventory system for products where demand depends on time and price. We consider the effect of reliability and a two-level trade credit. We suppose that the demand rate is a price- and time-dependent function. The objective is to determine the economic lot size and the best selling price to maximize the total profit per unit of time given a product's reliability and trade credit. We present an efficient procedure to determine the optimal solution to the inventory problem for all possible scenarios. This procedure is illustrated with several numerical examples. A sensitivity analysis of the optimal inventory policy with respect to the parameters of the demand rate function is also given. Finally, the main contributions of this paper are highlighted, and future research directions are introduced.

The q-Allocation Hub Interdiction Problems:Model Formulations and Solution Approaches

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In this paper, we study the q-allocation hub interdiction problem. Hub Interdiction problems have been traditionally studied in multiple allocation settings where there is no restriction on the number of hubs that can serve a spoke node. The q-allocation hub interdiction problem studied in this paper is a more general form that encompasses both multiple and single allocation as special cases. We present a branch-and-cut approach to solve this problem. We also present several improvements on the procedure to generate an accelerated approach to solve large instances of the problem to optimality. Our extensive computational results
show the efficiency of our approach in solving previously unsolved instances of the problem.

SEPQ Model for Dairy Products: Integrating Green Technology for Carbon Emission Reduction

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In the contemporary era of sustainable development, the implementation of eco-friendly inventory systems is paramount, aiming to reduce carbon emissions and foster economic growth. Carbon emissions are a pivotal factor in the ongoing issue of global warming, and production firms stand out as major contributors to this environmental concern. The carbon footprint associated with inventory systems primarily stems from production activities,
transhipments, inventory holding, and the perishability of goods.

Efficient green inventory systems become especially crucial when managing perishable products, given the unique challenges they pose. Spoilage and deterioration of perishable items not only result in substantial losses for production firms but also adversely impact consumer satisfaction. Perishable goods such as vegetables, fruits, milk, and frozen foods face continuous decay, negatively influencing consumer purchasing decisions and demand for these products. Therefore, special attention must be devoted to developing green inventory strategies for
perishable items to address environmental concerns and ensure customer satisfaction. Addressing this concern, a model for Sustainable Economic Production Quantity (SEPQ) has been formulated for dairy products with a fixed lifespan, incorporating a controllable carbon emissions rate achieved through investments in Green Technology (GT) initiatives.

This study examines carbon emissions arising from inventory production, storage, and transportation. Additionally, the impact of preservation technology on the deterioration rate of perishable items is considered.

Production-related carbon emissions stem from energy-intensive processes, storage emissions are linked to the use of preservation technologies, and transportation for demand fulfillment contributes to emissions during the shipment processes.
The proposal introduces a practical exponential ramp-type time-dependent demand model, incorporating partial backlogging to address shortages and enhance real-world applicability. The primary objective of this research is to optimize overall profit while concurrently minimizing environmental impact. This is achieved through the implementation of sustainable inventory management practices and the adoption of green technology to reduce carbon emissions. A Numerical example and sensitivity analysis have been presented to elucidate the model characteristics.

Next-Gen Inventory Optimization: Dual Warehouse model with unconventional Buy Now Pay Later Strategy

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Warehouses stand as the beating heart of business triumph, serving as strategic hubs for efficient order fulfilment, buffer stock management, and storage. They are essential in optimizing costs, ensuring timely customer delivery and strengthening business resilience. In the broader business landscape, warehouses function as central nodes, orchestrating the seamless flow of goods and significantly contributing to overall operational efficiency.
Embracing technological advancements further amplifies their role, transforming them into dynamic and indispensable assets in the modern commerce tapestry. Particularly relevant are ameliorating items, distinguished by their ability to enhance quality over time, in contrast to degraded items. Commonly found in perishables like wine and cheese, these goods mature with age, presenting unique inventory challenges to ensure optimal quality upon delivery to customers.
The paper explores a dual-warehouse inventory model that incorporates quadratic price and time-dependent demand, and holding costs with a cubic relationship to the volume of stored inventory. The model incorporates the Buy Now Pay Later feature, addressing complete backlogging and integrating amelioration and deterioration processes following a Weibull distribution. The primary focus lies in strategically determining the storage allocation for goods produced by a system. This involves distinguishing between a company's "Own Warehouse (OW)," with a fixed capacity for storing goods, and a "Rented Warehouse (RW)," an external facility leased when inventory surpasses the OW capacity. Customer orders are fulfilled initially from RW, transitioning to OW if necessary. As a key part of the decision process for retailers, the Two-Warehouse Inventory Model aims to maximize total profit while minimizing costs. The model's durability is showcased through a numerical illustration, validating its effectiveness in addressing genuine, real-world contexts with a remarkable level of precision. The sensitivity analysis examines variations by adjusting the values of key parameters to increase the depth of inquiry. This comprehensive approach enriches understanding and provides.

Greening Business Operations: Sustainable Economic Order Quantity through Smart Financing and Green Technology Investments

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A green inventory system with a mission to reduce carbon emissions is essential in today's era of sustainable development. It is important to manage perishable items with special attention since deteriorating items result in significant losses which lower customer satisfaction. A perishable item is defined as something that degrades with time, such as fruits, vegetables, dairy products, and blood. The perishable products are adversely affecting
demand as they decay continuously, which also influences the customers' purchasing decisions. The central aim is to optimize carbon emission reduction with strategic investments in green technology under the Sustainability Economic Order Quantity (SEOQ). Banks provide green credit financing as a final service to encourage industrial investors to commit to green investments and attain sustainability. To make business operations sustainable and efficient, inventory management must be overseen simultaneously with carbon emissions reductions.

In this paper, an inventory model for perishable items with freshness-dependent demand that deteriorates with the expiry date. To illustrate a real-life scenario, holding cost, preservation technology, carbon emission, green investment, and green financing are the key parameters considered in designing the model. A comparative analysis of different cases is studied to determine the optimal way to minimize carbon emissions and total inventory costs. The study has been carried out to investigate the optimal cycle time and replenishment quantity with green technology investment and preservation technology investment in industrial management. The primary focus lies in the strategical approach of determining the technology to minimize the carbon emission to conservation of natural resources, and overall environmental preservation, fostering a healthier and more sustainable planet for future generations. This model is limited to perishable items that deteriorate with time. Business entrepreneurs can use this model to reduce carbon emissions, thereby reducing the government's carbon tax emission costs and maximising the total profit.

Isoperimetric-type Constrained Variational Control Problem with Uncertainty: Robust Optimality and Duality

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In this paper, we introduce a new class of variational control problem (VCP) with isoperimetric-type constraints involving uncertainty and study to find its optimal solution. For

this, we construct a robust variational control problem with isoperimetric-type constraints as-
sociated with the problem (VCP) and derive the robust necessary optimality conditions using
the Lagrange functional. We prove its sufficiency by imposing the convexity assumption over in-volved functionals. We also construct the Wolfe type dual and its robust counterpart associated with the problem

(VCP) to prove robust weak, strong and converse duality results. Further, an illustrative algorithm is given and the theoretical results are accompanied by applications to determine their utility.

A Robust RBC Inventory Management Ordering Policy for Subtype of A with the Cross-matching Policy for Heterogenous Demand

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The escalating demand for blood within the clinical sector necessitates improvements in patient supply and demand dynamics. Persistent challenges in maintaining blood bank products for particular blood types contribute to shortages. To overcome the shortages in the blood subtypes, upgrade the blood bags according to the phenotype frequency of the population. The recent literature review, medical case study, and clinical demand demonstrate that the population phenotype frequency of blood subtype A plays a role after the phenotype frequency of the ABO system and the Rh factor system. This model delves into the intricate dimensions of blood subtype A, considering patient age, gender, and treatment specifics for transfusions to elevate service levels. The aforementioned consideration is known as heterogeneous demand, and with this, the proposed model introduces a novel idea for RBC inventory management ordering policies in the A1A2BO system. However, managing inventory from a broader perspective requires a nuanced approach, as low-level demand for specific products may result in the wastage of red blood cells (a shelf life of 42 days).

The model aims to minimise the overall cost, encompassing ordering, holding, wastage, shortage, penalty costs, and fixed subtyping costs, concurrently maximising the service level. To mitigate this, the proposed ordering policy incorporates a cross-matching strategy for A1A2BO substitution. Strategically, cut-off policies for the exact match and substitution are integrated to optimise service levels for both patients and blood bank management. In this model, a two-stage stochastic mixed-integer nonlinear programming method (TS-MINLP) is used to develop an order-up-to-level policy for the enhanced A1A2BO system. The proposed model is illustrated with a numerical example to show how decision-makers can utilise it. The results are useful to the clinical sector, which aims to upgrade the blood banks to meet the population's needs and show healthcare equity to the clinical sector.

IMPACT OF CARBON EMISSION ON ONE-WAY SUBSTITUTION OF ITEMS UNDER INFLATION AND SCREENING

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Inventory management is a structured strategy for sourcing, reserving, and retailing inventory which includes both raw materials and finished goods. In recent times, it has become a need for every supplier to understand the importance of an adequate quantity of inventory that is to be purchased to meet the demand. Substitution of items with similar ones ensures the fulfilment of demand and growth in business. Environmental issues such as carbon emission, greenhouse gases, etc. are the major concerns

in today's world. Reserving and controlling inventory in the market results in carbon emissions. To combat the rising concern of carbon emissions, firms adopt measures that result in some additional costs. This paper aims to optimize the total average cost of the inventory which takes into account one-way substitution of items consist a fraction of defective items and an additional cost to reduce the carbon emission. Sensitivity analysis and a numerical example are provided to validate the results.

Optimality Conditions for Robust Nonsmooth Uncertain Multiobjective Complex Programming Problems

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In this paper, we consider a nonsmooth uncertain multiobjective complex programming problem (abbreviated as, (NUMCP)) with data uncertainty in objective as well as constraint functions. We formulate the associated robust counterpart of (NUMCP), namely, robust nonsmooth multiobjective complex programming problem (abbreviated as, (RNMCP)). We use the scalarizing method to formulate a scalar optimization problem (abbreviated as, (SOP)) of (RN-MCP). We establish necessary and sufficient optimality criteria for the considered (SOP) and derive ε-efficiency theorem for (RNMCP). Non-trivial examples are provided to demonstrate the validity of the derived results.

KKT Reformulations for Single Leader and Multi-Follower Games

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We consider a bilevel optimization problem having a single leader and multiple followers. The followers choose their strategies simultaneously, and are assumed to converge to a Nash equilibrium strategy profile. We begin by providing a practical example of such a problem in an oligopoly setting. We then show the existence of a solution when the objective function of each follower is strongly convex in its optimizing variable.

We then consider the KKT reformulation of the bilevel problem, and show using examples that the solutions of both the problems need not be the same, even when each of the followers' problem is convex. In particular, we show that the global minima of the bilevel problem and its KKT reformulation may differ if the follower's problem does not satisfy the Slater's condition. We also show that the local minima of the bilevel problem and its KKT reformulation are the same if, in addition to convexity and Slater's constraints, the local minimum point remains a local minimum for every Lagrange multiplier in each of the followers' problem. We again show using examples that the local optima of the two problems may differ if the conditions are not satisfied.

Improving the reliability of quantile estimate with sparse and localized support vector quantile regression model

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The Quantile Regression (QR) model is very useful in decision-making and planning in finance, health, energy, agriculture and different other verticals, particularly when the relationship between independent variable x and dependent variable y is highly random. For given $\tau \in (0,1)$ and training set T $= \{(x_i, y_i) : x_i \in \mathbb{R}^n, y_i \in \mathbb{R}\}$, the QR model seeks infimum of functions $f_\tau : \mathbb{R}^n \to \mathbb{R}$, satisfying $P(y_i \leq f_\tau(x)|x) = \tau$. If the distribution function $Q(y|x)$ is known apriori, the quantile function can be directly obtained by estimating the inverse of the distribution function $Q(y|x)$. But, in most applications, the distribution function $Q(y|x)$ is not known. In these cases, the QR model is estimated by minimizing the pinball loss function in a non-parametric framework.

The Support Vector Quantile Regression (SVQR) model minimizes the pinball loss function along with l_2-norm regularization in its optimization problem for obtaining kernel-generated quantile estimate. However, there are a few serious drawbacks to the SVQR model.

(a) Individual Calibration:- The pinball loss function in the SVQR model only asymptotically ensures that τ fraction of training y_i values would lie below the estimated function $f_\tau(x)$ (*Average Calibration*). But, the actual goal of the quantile regression is the *Individual Calibration*, which requires that τ fraction of y_i values should lie below the estimated function $f_\tau(x)$ for any data point $x \in \mathbb{R}^n$. The SVQR model fails to ensure the *individual calibration*, which questions the reliability of its quantile estimate for a given test point.

(b) Non-sparse solution:- The SVQR model does not ensure the sparse solution. Sparsity is always a desirable property in a regression model. A sparse regression model offers better explainability and generalization along with faster prediction ability.

Taking motivations from these, we propose a Sparse and Localized Support Vector Quantile Regression (SL-SVQR) model for quantile estimation. The SL-SVQR model divides the input space into k disjoint clusters using a clustering technique and learns a sparse quantile estimate for each cluster. For learning the sparse quantile estimate, our model minimizes the pinball loss function along with l_1-norm regularization in its optimization problem, which can be efficiently solved via the linear programming method. The proposed SL-SVQR model offers a more reliable quantile estimate than the SVQR model by ensuring the calibration in each cluster with a sparse solution. We have carried out an extensive set of experiments on artificial, benchmark and real-world datasets to verify our claims.

An advanced similarity measure for Pythagorean fuzzy sets and its applications in transportation problem: An important observation

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In a recently published paper, it is pointed out that although several methods are proposed in the literature to solve Pythagorean fuzzy transportation problems. However, there does not exist any method in which similarity measure is used to transform a Pythagorean fuzzy transportation problem into its equivalent crisp transportation problem. To fill this gap, the authors of the published paper, firstly, proposed a similarity measure for Pythagorean fuzzy sets. Then, they discussed the superiority of their proposed similarity measures over several existing similarity measures. Thereafter, they proposed a method by modifying an existing method to solve Pythagorean fuzzy transportation problems. Furthermore, to show the superiority of their proposed method over some existing methods, they solved a numerical example by their proposed method. Finally, they pointed out that as the optimal transportation cost, obtained by their proposed method, is less than the optimal transportation cost obtained by existing methods. So, it is better to use their proposed method as compared to existing methods. After a deep study, it is observed that in the numerical example, solved by the authors of the recently published papers, the transformed crisp transportation problem

is not equivalent to the considered Pythagorean fuzzy transportation problem. Also, it is observed that if the equivalent crisp transportation problem is solved by the method, proposed in the recently published paper, then the obtained optimal transportation cost is greater than the existing optimal transportation cost.

Therefore, in actual case, the recently proposed method is not better than existing methods. The aim of this note is to make the researchers aware about this fact. It is pertinent to mention that if researchers will not be aware about this fact then one may use recently proposed method to solve real-life Pythagorean fuzzy transportation problems, which is scientifically incorrect.

A note on "Matrix games with linguistic intuitionistic fuzzy Payoffs: Basic results and solution methods

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Verma and Aggarwal (Artificial Intelligence Review (2021) 54:5127-5162) pro- posed a method, based upon linguistic intuitionistic fuzzy (LIF) mathematical programming problems (MPPs) corresponding to person I and person II, to solve LIF matrix games (matrix games in which each payoff is represented by a LIF number). In this note, a numerical example is considered to show that on solving LIF MPPs corresponding to payoff matrix of person I and payoff matrix of person II, proposed by Verma and Aggarwal, different value of game is obtained. While, in actual case, on solving LIF MPPs corresponding to payoff matrix of person I and payoff matrix of person II, the same value of game should be obtained. Therefore, the LIF MPPs, proposed by Verma and Aggarwal, are not valid and hence, it is inappropriate to use Verma and Aggarwal's method to solve LIF matrix games. Also, it is pointed out

that to resolve the inappropriateness of Verma and Aggarwal's method may be considered as a challenging open research problem.

Two-ware house inventory system for deteriorating items Under Preservation technology effect with advertisement-dependent demand in an inflationary environment

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This research paper explores a two-warehouse system integrated with preservation technology, where demand is intricately linked to both advertising efforts and selling prices. Preservation plays a pivotal role in inventory control, mitigating the effects of item deterioration. Recognizing demand as a pivotal component in inventory management effectiveness, our study focuses on strategies to enhance product demand. We particularly emphasize the efficacy of product advertising in elevating demand and attracting customers. The primary objective of this research is to determine the optimal frequency of advertisement for our commodities. The entire study is contextualized within an inflationary

environment. To validate and illustrate our model, we present a mathematical case, and a sensitivity analysis is conducted to scrutinize the impact of varying parameters within the model. This research contributes valuable insights into inventory control strategies, shedding light on the interplay between preservation, demand, and advertising frequency in a dynamic market setting.

Rank-1 transition uncertainties in constrained Markov decision processes

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We consider an infinite-horizon discounted constrained Markov decision process (CMDP) with uncertain transition probabilities. We assume that the uncertainty in transition probabilities has a rank-1 matrix structure and the underlying uncertain parameters belong to a polytope. We formulate the uncertain CMDP problem using a robust optimization framework and show that the resulting robust CMDP problem restricted to the class of stationary policies is equivalent to a bilinear programming problem. For the case of a single uncertain parameter, we propose sufficient conditions under which an optimal policy of the robust CMDP problem is unaffected by uncertainty. As an application of the robust CMDP problem, we consider a variant of machine replacement problem. The numerical experiments are performed by considering randomly generated instances of the machine replacement problem and a well-known class of problems called Garnets.

Classical and Bayesian Estimation of Performance Measure in Erlang Single Server Queues

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Queueing systems with Markovian arrivals, Erlangian service times, and single servers are the focus of this article, that is, queues, in Kendall notation. Statistical methods are proposed to estimate important parameters in such queues which are based on finite samples of the number of customers who arrived during the service periods. Complementary methods are proposed on the line of the classical maximum likelihood and of the Bayesian methods, which are based on flexible prior distributions. Extensive Monte Carlo tests are presented, showing the effectiveness and efficiency of the proposed methods.

Novel Fuzzy DEA model over range directional measures with Pythagorean Interval Valued Data

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Abstract As we all are living in Industry 4.0 and there is a perpetual bombardment of data which is further associated with ambiguity, imprecision, and vagueness in data. In order to cater to this situation Lofty Zadeh in 1965 proposed the concept of fuzzy sets based on membership function. Further developments in fuzzy sets lead to extension of fuzzy sets like Intuitionistic which involves non-membership degrees as well and the Pythagorean fuzzy set is a recent one. Inspired by the Model given by Wu et al,we have made a Novel Pythagorean Fuzzy-DEA model over Range directional measures given by Portela et al (2004) to evaluate the efficiency of DMU where pythagorean fuzzy parameters are based on the Likert scale. Further, We try to estimate the supper efficiency of our model. Finally, at the end, we will take synthetic data of 35 Decision making units (DMUs) which is of significant sample size validating both the boundedness and feasibility of our proposed model.

On quasidifferentiable mathematical programs with equilibrium constraints

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The presentation deals with mathematical programs with equilibrium constraints involving quasidifferentiable functions defined over a real Banach space. We develop Fritz–John and

Karush–Kuhn–Tucker type necessary optimality conditions in terms of quasidifferentials of the functions at an optimal point. As these optimization problems do not satisfy standard constraint qualifications, we provide suitable versions of some constraint qualifications in terms of quasidifferentials. Some sufficient optimality conditions are also examined under generalized convexity assumptions. Some future research possibilities are discussed to accommodate a large class of nonsmooth and nonconvex optimization problems.

Invariant sets of the replicator dynamics: Bilinear games

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We provide a new class of special solutions to the replicator dynamics defined over games with one-dimensional real strategy sets and bilinear payoff functions. We prove that the set of profiles of exponential measures is invariant under the replicator dynamics for this class of games. Oechssler & Riedel (2002) and Cressman (2005) proved that the set of Gaussian measures is invariant under the single population replicator dynamics for a large subclass of quadratic games. Cressman et al. (2006) extend this result to the multi-dimensional strategy space using a technique involving moment-generating functions. Karev (2020) further explores the invariance of various distributions like the Gaussians, truncated Gaussians, exponentials, and uniform measures for quadratic games on R. Lewis & Shaiju (2023) establish the invariance of profiles of Gaussian measures under the two-population replicator dynamics on quadratic games. The study of the replicator dynamics restricted to its invariant sets has proven to be useful in deducing the instability of the unrestricted dynamics. In this paper, we study the replicator dynamics on bilinear games and prove that the set of exponential measures is invariant. There are no general results on the existence and uniqueness of the replicator dynamics when the strategy sets are non-compact and the payoff functions are unbounded. Our result explicitly establishes the existence of solutions when the payoffs are bilinear and the initial conditions are exponential measures.

A criterion for Q-tensors

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A tensor $\mathcal{A}$ of order m and dimension n is called a Q-tensor if the tensor complementarity problem has a solution for all $\mathbf{q} \in \mathbb{R}^n$. This means that for every vector $\mathbf{q}$, there exists a vector $\mathbf{u}$ such that $\mathbf{u} \geq \mathbf{0}, \mathbf{w} = \mathcal{A}\mathbf{u}^{m-1} + \mathbf{q} \geq \mathbf{0}$, and $\mathbf{u}^T\mathbf{w} = 0$. In this talk, we will discuss a criterion to determine whether a tensor is a Q-tensor. We prove that within the class of rank-one symmetric tensors, the Q-tensors are precisely the positive tensors. Additionally, for a symmetric Q-tensor $\mathcal{A}$ of order m and dimension 2 with $rank(\mathcal{A}) = 2$, we show that $\mathcal{A}$ is an R_0-tensor. The idea is inspired by the recent work of Parthasarathy et al. (J Optim Theory Appl 195:131- 147, 2022) and Sivakumar et al. (Linear Multilinear Algebra 70:6947-6964, 2021) on Q-matrices.

Characterizations of the Solution Set of Nonsmooth Semi-Infinite Programming Problems on Hadamard Manifolds

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This article is concerned with a class of nonsmooth semi-infinite programming problems on Hadamard manifolds (abbreviated as, (NSIP)). We introduce the Guignard constraint qualification (abbreviated as, (GCQ)) for (NSIP). Subsequently, by employing (GCQ), we establish the Karush-Kuhn-Tucker (abbreviated as, KKT) type necessary optimality conditions for (NSIP). Further, we derive that the Lagrangian function associated with a fixed Lagrange multiplier, corresponding to a known solution, remains constant on the solution setn of (NSIP) under geodesic pseudoconvexity assumptions. In addition, we derive certain characterizations of the solution set of the considered problem (NSIP) within the framework of Hadamard manifolds. We provide illustrative examples that highlight the importance of our established results.

Modelling the Location-or-Routing Problem (LoRP) for solving household waste collection

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Household waste collection, a pivotal element of urban infrastructure, faces increasing challenges due to population growth, resource constraints, and environmental concerns. Inefficient collection routes not only impact operational costs and service quality but also contribute to greenhouse gas emissions and environmental pollution. This extended abstract proposes a location-routing problem (LoRP) model to optimize household waste collection, leading to improved efficiency, sustainability, and service equity.

Some more subclasses of Q-matrix

G Singh

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(joint work with VN Mer, P Kumar, S. K Neogy)

In this presentation, we discuss two subclasses of Q-matrix,namely N-matrices of exact order k and Nbar-matrices of exact order k and study their basic properties. We also prove sufficient conditions for these classes to satisfy Q-property. We construct an example for Nbar-matrix of exact order 3.

Developing composite indicator in stochastic environment: A cross-efficiency Stochastic DEA approach

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Composite indicators are defined to be based on sub-indicators that have no common meaningful unit of measurement and there is no obvious way of weighting these sub indicators. They are developed by the aggregation of multiple individual indicators into a single index based on some well-defined model. They serve an important purpose to convey the overall information, thus, overcoming the complexity and difficulty of analysing and understanding the information available in many individual indicators affecting a system. Owing to their ability to convert the information contained in multiple individual indicators into a single wholesome number, they have gain widespread use by international agencies including United Nation.

Despite their increasing popularity, composite indicators remain controversial. The legitimacy of composite indicators is often questioned due to the unfavourable dependency of entities' scores and rankings on the preliminary normalization step and the dispute among experts/stakeholders on the precise weighting system used to aggregate sub-indicators. The use of the data envelopment analysis (DEA) has been found crucial in getting beyond these barriers in existing literatures. Their measurement-unit-independence is a selling point in the contextof composite indicators since it eliminates the need for a normalization step. Second, itgenerates adaptable weights for each examined entity, closing the knowledge gap in the 'correct' set of weights. Also, the approach has the additional benefit of being simple to understand.

Due to its benefit of determining weights through an optimization process, the conventional self-evaluation DEA approach has been widely used in the computation of composite indexes; however, it has the drawback that each entity, also known as decision-making unit (DMU), evaluates itself using its own optimal weights and disregards the optimal weights of other DMUs, which seems to be relatively less democratic and acceptable in nature.

In this paper, we put forward the view that to make the approach more acceptable to DMUs, the composite index score of each DMU should be jointly determined by all the DMUs. Cross-efficiency approach of DEA is an appropriate and reasonable mechanism to serve our purpose.

However, there exists a limitation in the cross-efficiency evaluation using optimal multipliers (weights) of other DMUs. Firstly, the cross-efficiency scores obtained may not be unique. In situation of multiple optimal solutions, it may happen that the cross-efficiency of some DMUs may be higher compared to others based on one set of optimal multipliers while the cross-efficiency of same DMUs may deteriorate based on the other set of alternate optimal solution. So, there is a need to obtain composite index based on uniquely determined cross-efficiency. Secondly, cross-efficiency model under variable returns to scale

(VRS) assumption may yield negative scores. Composite indicator construction represents a class of multi-criteria decision-making problems wherein a situation of handling only multiple outputs and no input against which the DMUs are to be evaluated is very common. In existing literatures, researchers asserted that an input-oriented constant returns to scale (CRS) model with a single constantoutput and an output-oriented CRS model with a single constant input coincide with the respective VRS models, but a CRS model without outputs (or without inputs) has no meaning. So, cross-efficiency model needs to be formulated under VRS. In this paper, we propose a cross-efficiency model, for composite indicator construction, under VRS that yields unique scores. This is the first contribution of our paper. As a second contribution of this paper, we attempt to address the problem of composite indicator construction in the stochastic setup. The traditional DEA models are developed under the assumption that all the inputs and outputs data are deterministic with full certainty. They do not consider any data uncertainty and variability. However, in many real-life situations, inputs and outputs data are subjected to random variations, and thus, the production possibility set in such cases has a stochastic nature. The efficiency evaluation in the stochastic environment is related to how the DMUs deal with such random data. Moreover, the traditional DEA models evaluate the performances of DMUs based on past existing data. This again highlights the fact that DEA models have been mostly utilized to evaluate the ex-ante performance. But, in addition to past performance evaluation in management, future planning is equally important. So, there is a need to estimate the future efficiency of DMUs. Being aware of this problem now will help in developing crucial and suitable methods to boost productivity later. One technique used for making such predictions is called stochastic programming. We predict future efficiency by drawing samples at random from data collected from each company over a given time period, then analysing, and interpreting the results of these analyses, and finally conducting tests of probability distributions. So, we attempt to propose a stochastic DEA model which can incorporate future information into its analytic framework. Moreover, existing literature on stochastic DEA demands for the development of ranking method in the stochastic environment. So, we propose a cross-efficiency stochastic DEA model to construct composite indicators in the stochastic environment. By considering random data and estimating their probability distributions, we seek to estimate the composite indicator score in the future.

To begin with, we extend our proposed cross-efficiency model for composite indicator developed in stage one of this paper in a stochastic setup. Then, by using the chance-constrained programming theory, we extend our deterministic cross-efficiency models to a stochastic setup. The constraints and the objective of the proposed stochastic cross-efficiency models are then converted to equivalent deterministic forms through a series of steps to attain computational feasibility. We further aim to study the properties of the developed stochastic models via statistical evaluations and computational handling and identify its potential limitations and implementation difficulties. Finally, we illustrate the applicability of ourproposed models via a simple example.

Convergence of Forward-Backward-Forward algorithms for bilevel equilibrium problems

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This work introduces forward-backward-forward (FBF) algorithm for bilevel equilibrium problems associated with bifunctions on a real Hilbert space. This modifies the forward-backward algorithm by relaxing coercivity with monotone and Lipschitzness. Further, we present the FBF dynamical systems and investigate the generated trajectory's existence, uniqueness and weak convergence. We provide a

numerical experiment to demonstrate the efficiency of the FBF dynamical systems. Moreover, we illustrate the proposed method for the equilibrium problem under saddle point constraint.

A service facility in discrete-time queueing system associated with (s, S) inventory policy

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We study a service facility problem for a Geo/Geo/1 queue associated with (s, S) inventory policy. The arrival of customers in the queue follow Bernoulli process, where each customer requires a single item for the service. The service time is modeled as geometrically distributed. An external vendor replenishes items in accordance with the (s, S) inventory policy with a positive replenishment time, following a geometric distribution. The system has limited waiting places for customers. We derive joint probability distributions for the number of customers and on-hand inventory levels at both outside observer's and random epochs. Various performance measures are calculated to establish a comprehensive cost function for the system. Through numerical experiments, we identify optimal parameter values of waiting space ($N*$), reorder level ($s*$) and maximum inventory size ($S*$), that minimize the cost function, providing valuable insights into system optimization.

SUFFICIENT OPTIMALITY CONDITIONS and DUALITY RESULTS for a MULTIOBJECTIVE BILEVEL PROGRAMMING PROBLEM

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In this paper, we consider a multiobjective bilevel programming problem and develop sufficient optimality conditions for it using the concepts of generalized convexity in terms of tangential subdifferential. Further, Wolfe type and Mond Weir type duals via tangential subdifferential have been associated to the problem and various duality results have been established.

NEWTON'S METHOD FOR INTERVAL-VALUED MULTIOBJECTIVE OPTIMIZATION PROBLEM

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In this paper, we consider a class of interval-valued multiobjective optimization problems (in short, (IVMOP)) and formulate an associated multiobjective optimization problem, referred to as (MOP). We establish that the Pareto optimal solution of the associated (MOP) is an effective solution of (IVMOP).

Using this characteristic of the associated (MOP), we introduce a variant of Newton's algorithm for the considered (IVMOP). The proposed algorithm exhibits superlinear convergence to a locally effective solution of (IVMOP), provided the objective function of (IVMOP) is twice generalized Hukuhara differentiable and locally strongly convex. Furthermore, if the second-order generalized Hukuhara partial derivatives of the objective function of (IVMOP) are generalized Hukuhara Lipschitz continuous, the rate of convergence is quadratic. We provide a suitable numerical example to illustrate the developed methodology. Moreover, we employ the proposed algorithm to solve a real-life portfolio optimization problem.

Generalizations of R0 and SSM properties for Extended Horizontal Linear Complementarity Problem

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In this paper, we first introduce column R0-W and column SSM-W property for the set of matrices which is a generalization of R0 and the strictly semimonotone matrix. We then prove some existence results for the extended horizontal linear complementarity problem when the involved matrices have these properties. With an additional condition on the set of matrices, we prove that the column SSM-W property is equivalent to the unique solution for the corresponding extended horizontal linear complementarity problems. Finally, we give a necessary and sufficient condition for the connectedness of the solution set of the extended horizontal linear complementarity problems.

Quasi-convex Semi-infinite programming problems in term of GP-Subdifferential

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In this paper, we prove Karush-Kuhn-Tucker type necessary and sufficient condition of optimality for non-smooth upper semicontinuous quasi-convex semi-infinite programming problems in terms of GP-subdifferential using quasi-convex Slater constraint qualification and these results will be very helpful to find optimal solution of quasi-convex semi-infinite programming problems. In optimization, optimality as well as duality of function play very important role and many results of mathematical programming tackle by duality. Moreover,we formulate weak, strong and strict converse duality for Mond-Weir type dual problem for non-smooth quasi-convex semi-infinite programming problems.

New Generalizations and Refinements of (p, q)-Hermite-Hadamard Inequalities for Convex Functions

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The aim of this paper is to prove generalized estimations for the (p, q)-Hermite-Hadamard inequalities for convex functions using a parameter. By using the same parameter, we show that our results reduce to the earlier obtained (p, q)-Hermite-Hadamard inequalities. Furthermore, we establish a new lemma to obtain some new generalized post-quantum inequalities for convex functions.

On robust solution of nonsmooth mathematical programs with equilibrium constraints

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In this talk we study the nonsmooth mathematical programs with equilibrium constraints with uncertainty in constraint functions within the framework of robust optimization, denoted by UNMPEC. Firstly, we derive the necessary optimality conditions for a robust counterpart of UNMPEC, denoted by RNMPEC under suitable constraint qualification. Further, we give the sufficient optimality conditions for RNMPEC. Also, we formulate the Wolfe and Mond-Weir types dual problem.

Higher order optimality conditions in multiobjective optimization problems using directional convexificators

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In this talk we study mutiobjective optimization problems with inequality constraints involving higher order strongly convex functions not necessarily continuous. We derive Karush-Kuhn-Tucker type necessary and sufficient optimality conditions under suitable constraint qualifications to identify strict minimizers of higher order using the tool of directional convexificators. The results are also illustrated by examples.

On Quasidifferentiable Multiobjective Optimization Problem in Banach spaces

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This talk is devoted to the study of quasidifferentiable multiobjective optimization problem in Banach spaces with the inequality and equality constraints, which is denoted by QMOP. The Karush-Kuhn-Tucker-type necessary optimality conditions for a weak Pareto solution are derived for such a nonsmooth multiobjective optimization problem. Further, we establish sufficient optimality conditions under the assumptions of generalized convexity of the functions in terms of Minkowski sum of their subdifferentials and superdifferentials. The results are well illustrated by an example.

On approximate strong KKT points of nonsmooth interval-valued mutiobjective optimization problems using convexificators

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The aim of this paper is to study interval-valued mutiobjective optimization problems involving inequality and set constraints. We derive Karush-Kuhn-Tucker type necessary optimality conditions to identify approximate efficient solutions for the problem under consideration under suitable constraint qualifications using the tool of semi-regular convexificators. We also derive sufficient optimality conditions under approximate convexity assumptions. The dual models are also formulated to establish duality results.

Nonsmooth constraint qualifications and stationary conditions for mathematical programs using tangential subdifferentials

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This article deals with a class of nonsmooth mathematical programming problems with vanishing constraints (MPVC) in terms of tangential subdifferentials. We present several constraint qualifications (namely, MPVC-LICQ, MPVC-MFCQ, VC-MFCQ, VC-GCQ, WACQ, WKTCQ, WZCQ) using the notion of tangential subdifferentials. We establishrelationships among these constraint qualifications. Further, applying these constraint qualifications we obtain several stationary point conditions of Karush-Kuhn Tucker typeunder different situations.

Unlocking Collective Intelligence: A Novel Game for Optimal Group Formation in the Classroom

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The ongoing debate regarding individual and group assignments often overlooks the power of cooperation in optimizing learning. This paper tackles this challenge head-on, deploying a rigorous game-theoretic frame- work with mathematical models to analyze their effectiveness in deterring cheating and promoting academic growth.

We introduce a novel game designed specifically to study group assignment dynamics. Through this framework, we demonstrate the limitations of individual assignments reliant on escalating punishments and their minimal impact on learning costs. In stark contrast, our model reveals the emergence of stable groups as platforms for self-sustaining cooperation. Higher maintenance costs within these groups incentivize larger sizes and foster full member participation, independent of reward structures. This decoupling from rewards allows for flexible task distribution and a more dynamic learning environment.

Therefore, we propose a paradigm shift – from individual accountability to collaborative synergy. The paper advocates for prioritizing group assignments, equipped with carefully designed roles and responsibilities, to leverage the power of this self-sustaining cooperation. By embracing game-theoretic

principles and utilizing our novel game for further exploration, educators can unlock the transformative potential of collaboration, transforming classrooms into vibrant communities where learning flourishes through shared endeavors.

An evaluation of the stochastic ruler method as a solution methodology for discrete stochastic optimization

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In this study, we consider optimization problems with an objective to minimize the expected value of a stochastic output function over a discrete solution space. Common solution approaches include: (i) enumeration of the entire solution space, (ii) parameterization of the stochastic problem to convert it into a deterministic one, and then solving using a suitable deterministic optimization algorithm, and (iii) stochastic optimization methods. The first approach can become expensive as the size of the problem instance increases (Kleywegt et al, 2002). In the second approach, multiple realizations of the input parameter estimates are generated for parameterization; often, to avoid inaccurate parameterization, a large number of realizations might be needed leading to high computational overheads for large problem instances. On the other hand, in stochastic optimization methods, a single realization (or a batch of realizations) of the output function is needed at every step or iteration of an optimization algorithm to guide the search process for an optimal solution (Nguyen et al, 2014; Fu, 2015). Often in case of complex systems, the realizations for parameterization or for stochastic optimization methods are generated by simulation (Fu, 2015)- stochastic optimization methods employing simulation for generating the output function realizations are called simulation optimization methods. The stochastic ruler method (SR method) of Yan and Mukai (1992) is a simulation optimization method, which has convergence in probability to the global optimal solution, is easily implementable and retains no information of past solutions thus reducing space complexity (Hong et al, 2015). In this method, at every iteration, candidate solutions are evaluated by comparing realizations of the output function to realizations generated from a ruler, which we consider to be the uniform random variable. The ruler limits are chosen such that all possible output function values across all solutions are encompassed. Among all candidate solutions, an optimal solution has the highest probability of the output function realizations being less than the realizations generated from the ruler. We contribute by analytically demonstrating that: (i) the rate of convergence of the method to the global optimal solution is affected by the expectation but not by the variance, skewness or any other higher moment of the output function (evaluated for different candidate solutions) (ii) the rate of convergence can be increased monotonically if the lower limit of the ruler is increased and brought close to the lowest output function value possible. To numerically demonstrate these results, we construct a toy stochastic p-median facility location problem (F LP) with triangularly distributed demands (with a single optimal solution). Then, we analytically show that its optimal solution is equal to the optimal solution of a deterministic p- median F LP whose demands are given by the expected values of demands of the stochastic version. We solve the deterministic version numerically to obtain the optimal solution. Then, we implement the SR method on the stochastic version to check the rate of convergence, which we express in terms of number of visits to the optimal solution in 1×105 iterations of the SR method.

Finally, we conclude that as the SR method is not impacted by the variance, skewness or other higher moments of the output function, hence by a careful selection of the ruler, it can be applied to discrete stochastic optimization problems while achieving the desired accuracy without incurring high computational overheads in terms of iterations or runtimes. A limitation is the fact that the rate of convergence can be adversely impacted by its dependence on the expectation of the output function.

SOME NEW TECHNIQUES FOR SOLVING GENERALIZED VECTOR QUASI-VARIATIONAL INEQUALITY PROBLEM OVER PRODUCT SET

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In this paper, we have worked on generalized vector quasi-variational inequality problem (GVQVIP) over product sets. Vector variational inequalities (VVIs), introduced in 1980, have gained immense popularity among researchers because of their applications in various fields such as Optimization, Economics etc and so many of its forms have been studied in the last four decades. Recently, it has been shown that the unilateral indentation problem can be stated as quasi-variational inequality [6]. Because of their applications in various diverse fields such as transportation problems, game theory, economics etc., various forms of variational inequality problems over product sets have been studied by severalresearchers [1, 2, 3, 4, 5]. The common approach for finding solutions to these problems usually involves some kind of monotonicity of the function involved. For example, pseudomonotonicity is used in [1, 2, 3, 5] and quasi-monotonicity is used in [4] to establish the existence of the required solutions. In this paper, we provide solutions to the generalized vector quasi-variational inequality problems (GVQVIP) over product sets with a different set of conditions and without involving monotonicity. Rather, we use upper semicontinuity and admissibility of the function space. Also to obtain our result, we have introduced $< FG - C >$ −condition to find an- other set of solutions to the (GVQVIP) over product sets. A third set of solution is provided using continuous selection of mappings. We have given examples to explain our results as well as to show how our results differ from the ones existing in the literature.

Performance analysis of a GeoX/G/1 queue with multiple vacations under the premise of an early arrival system

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An analysis of a discrete-time GeoX/G/1 queue with multiple vacations is conducted within the framework of an early arrival system. The principle objective of this paper is to conduct a performance analysis of the system. For the purpose of analysing the distributions of system length and waiting time, we use the supplementary variable approach and the theory of difference equations. Due to the fact that it is not necessary to compute the transition probability matrix of the embedded system length process, our method has an advantage over methods currently in use for assessing queueing models. Using this approach, we are able to determine the waiting time distribution for any customer in a batch as well as the

distributions of the system length at several epochs, including the random, post-departure, and outside observer's epochs. Finally, we examine several performance measures and numerical results

A NOTE ON STABILITY ANALYSIS OF GENERALIZED VECTOR VARIATIONAL INEQUALITIES

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Abstract. Stability analysis for variational inequalities is an important area of research and has been studied by various researchers adopting different approaches. Amongst them, the one using sequential approach for perturbed inequality problems, introduced in [3], has been studied in [1, 2], where Painleve-Kuratowskin convergence for the solution sets of VVI problems is considered. However, these studies are no longer valid for generalized vector variational inequality problems for abstract spaces as sequences are not adequate for studying convergence of general topological spaces. Till now, no such studies on stability analysis have come to our notice which can cater to the generalized vector variational inequality problems over topological vector spaces. The present paper is a an attempt to bridge this gap, wherein net theory has been suitably applied to develop the theory of stability analysis using Kuratowski-Painleve convergence of the nets of GVVIP and of their solutions. Here we have obtained results pertaining to Kuratowski-Painlev´e lower and upper convergence of the nets of the solution sets.

Optimality Conditions for Multiobjective Optimization Problems with Switching Constraints

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In this chapter, we consider multiobjective optimization problems with switching constraint (MOPSC). We introduce linear independence constraint quali- fication (LICQ), Mangasarian-Fromovitz constraint qualification (MFCQ), Abadie constraint qualification (ACQ), and Guignard constraint qualification (GCQ) for multiobjective optimization problems with switching constraint (MOPSC). Further, we introduce the notion of Weak stationarity, Mordukhovich stationarity, and Strong stationarity, i.e., W-stationarity, M- stationarity, and S-stationarity, respectively, for the MOPSC. Also, we present a survey of the literature related to existing constraint qualifications and stationarity conditions for mathematical programs with equilib- rium constraints (MPEC), mathematical programs with complementarity constraints (MPCC), mathematical programs with vanishing constraints (MPVC), and for mathematical programs with switching constraints (MPSC). We establish that the M- stationary conditions are sufficient optimality conditions for the MOPSC using generalized convexity. Further, we propose a Wolfe-type dual model for the MOPSC and establish weak duality and strong duality results under assumptions of generalized convexity.

Uncertainty inherent in Human Decision-making in Crime Analysis

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The conduct of a criminal involves the actions and behaviours exhibited by an individual engaged in unlawful activities or prohibited behaviour, often characterized by the violation of legal statutes or ethical norms. Challenges become more intricate in uncertain environments, particularly when human subjective evaluations play a crucial role, as exemplified in the Analytic Hierarchy Process (AHP). Human subjective knowledge is effectively conveyed through linguistic term set as a qualitative measure. The transformation between a given qualitative term set to its respective quantitative expression is represented by a Cloud model.

An essential factor in linguistic decision-making using cloud models involves the conversion process between linguistic variables and cloud. Our Proposed research analyzes criminal activities through the utilization of a cloud-based model. First, we propose a linguistic assessment scale that can be used to perform the transformation between the clouds and linguistic variables of any reciprocal linguistic term set of odd labels. This scale can be used to transform linguistic assessment information (of the type $1/n \sim n$) into numerical assessment values. We conducted a survey using a Relative Importance scale set to solicit public opinions on the severity of different criminal activities. Subsequently, employing the CM-AHP (Cloud model-Analytic Hierarchy Process) methodology, Weight Cloud models (WCM's) will be assigned to each criminal activity based on the survey responses. Ultimately, this approach will yield a ranked assessment, indicating the perceived severity of each crime based on collective public opinions. Our work is specifically focused on scrutinizing the uncertainty inherent in human decision-making related to crime analysis.

Optimal Portfolio Selection applying the Mean-Deviation Expectile Value at Risk

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An expectile is a minimizer of the expectation of an asymmetric quadratic function concerning a point forecast $x \in R$ of a random variable X. The negative of the expectile, employed as a risk measure, is the expectile value at risk (EVaR). Its recent emergence in risk management has drawn attention, for its coherent and elicitable property. In the existing literature, limited research has focused on incorporating EVaR within portfolio optimization (PO) models, exploring it as an alternative risk measure to value at risk (VaR) and conditional value at risk (CVaR).

Our work incorporates the mean deviation EVaR PO model and its robust counterpart under the box uncertainty. We implement a rolling window approach using historical data from several global indices for our empirical analysis; each window comprises an in-sample period and an out-of-sample period. We conduct a comparative analysis against a CVaR-based model in similar settings, demonstrating the financial advantages of our proposed model.

A multi-pickup and delivery dispatching problem for same day courier delivery with different customers based on priority

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This paper discusses a multi-pickup and delivery dispatching problem where a set of pickup and delivery orders in a dispatching cycle need to be assigned and routed using the available fleet of riders. The objective is to minimize the total distance travelled by the fleet during the dispatching cycle. A rider starts its route from its location by picking up all assigned orders before making the respective deliveries. After completing all assigned deliveries, the riders relocate to the closest available locations instead of returning to their original location. The riders commence their new routes in the next dispatching cycle from their relocated positions. There are two kinds of customers using the service. Priority customers pay extra to ensure that they receive their deliveries faster. This can result in longer delivery times for regular customers for which they are compensated. A mixed integer linear program (MILP) has been used to model and solve the problem.

Quantum Hermite-Hadamard Inequalities for Generalized Convex Functions

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In this paper, we derive a quantum analogue of Hermite-Hadamard-type inequalities for twice differentiable convex functions whose second derivatives in absolute value are strongly (α,m)-convex. We obtain new bounds using the HÖlder's and power mean inequalities. Moreover, we provide suitable examples in support of our theoretical results. We correlate our findings with comparable results in the literature and show that the obtained results are refinements and improvements.

Cost optimization of a fault-tolerant machining system with balking and vacation

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The article examines a Markovian queueing model that incorporates balking and a server on vacation. The model is used to assess the effectiveness of the machine repair problem, where the admission of failed machines for repair jobs is regulated by an F-policy. When the number of failed machines in the system reaches its maximum capacity, no additional failed machines are permitted to enter until the count of failed machines decreases to a predefined threshold level 'F'. To obtain the steady-state queue size distribution, a recursive technique is used. Various performance indices are established, and numerical experiments are conducted to understand how different system parameters affect the behavior of these

indices. The cost function for the machine repair problem is framed and minimized using the particle swarm optimization algorithm.

Mathematical Programs Using Tangential Subdifferentials

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In this paper, we deal with constraint qualifications, the stationary concept and the optimality conditions for nonsmooth mathematical programs with equilibrium constraints. The main tool of our study is the notion of tangential subdifferentials [1,2]. Using the notion of tangential subdifferentials, we present constraint qualifications (namely, generalized standard Abadie, MPEC Abadie, MPEC Zangwill, constraint qualifications) [3] and stationary concepts [3], and also establish relationships between constraint qualifications. Further, we establish sufficient optimality conditions for mathematical programs using tangential subdifferentials and suitable generalized convexity notion. We also give some examples that verify our results.

Multi-Objective Optimization and Transient Analysis of Discrete-Time Multi-server Multi-Class Priority G-Queue with Vacation

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Wireless communication networks can be effectively modeled using discrete-time multi-class priority queues. There is also an objective to reduce energy usage in these systems, which can be accomplished by incorporating the concept of vacation into the priority queue structure. This study investigates a discrete time multi-server multi-class priority G-queue system featuring a single vacation mode and server breakdowns. In the proposed model, all customers are classified into three different priority classes, and the entire system is modeled as a five-dimensional Markov chain. Then the transient analysis of this Markov chain is performed by using the recursive method. Using the transient probability distribution, we derived various performance metrics for the system, taking both queueing and reliability analyses into account. Finally, we obtained Pareto solution using multi-objective optimization technique for the reward cost and energy-saving vacation policy.

Development of a Multi-objective Optimization Model for Circular Economy

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The concept of circular economy has experienced a growing influence in academia, industry, and government in recent years. A circular economy aims to overcome the linear pattern of "take-make-dispose" by proposing a circular system in which the value of products, resources, and materials is preserved for as much as possible and as long as possible in the loop. Circular economy contains the reuse, remanufacturing and recycling, resulting in the development of sustainable economy model. A mathematical model is optimized to reduce carbon footprint and cost, and maximize the social benefit for

achieving sustainability goals, enhanced customer experience, delivery quality, and value addition. This requires a multi-objective model wherein social, environmental, and economical factors will be optimized, simultaneously. The purpose of this paper is to design and optimise a multi-objective circular economy model and obtained trade-offs between the social, environmental, and economical objectives. The proposed multi-objective mixed-integer linear programing mathematical model that considers multiple suppliers, manufacturing center, distribution center, customer zones, collection/repair centres, remanufacture center, recycling center, disposal center. The proposed model is solved with the ε-constraint method and weighted sum method to discover Pareto solutions. The Pareto front is a set of non-dominated solutions in which no other solution is simultaneously better to all objectives. The model is coded in Python "pyomo" library and solved using 'ipopt' solver. According to this study the circular economy concept is economically beneficial to the organization, environmentally friendly, and socially beneficial by providing jobs.

Human Behavior Analysis using Entropy-based Cloud Transformation

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Entropy gauges the uncertainty of an event and reflects its inherent unpredictability or disorder. The existing literature has primarily emphasized reducing uncertainty within the information theory framework. Effective decision-making navigates the crucial challenge of uncertainty, wherein randomness and fuzziness emerge as the prevalent forms of this complex issue. Cloud models formally describe the transformation between qualitative-quantitative knowledge and adeptly handles uncertainty by carefully addressing randomness and fuzziness, offering a strong framework for managing complex and unpredictable situations. Our proposed research introduces Shannon entropy as a crucial measure for assessing uncertainty, with significant potential to enhance model accuracy and decision-making in cloud model. As a result, we develop a novel algorithm called the Entropy-Based Cloud Transformation Algorithm (EBCT). Next, we demonstrate the application of Behavioral Analysis using EBCT through a survey, exploring the key criteria individuals prioritize in personal and professional environment. Based on our results, we affirm that the incorporation of shannon entropy in the Backward Cloud Transformation provides a clearer representation of uncertainty. Finally, we exhibit a comparative simulation to assess and validate the new algorithm.

Exploring Hierarchical Repair Strategies for Multi-Unit Redundant Machining Systems

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In this research, we address the challenge of repairing a complex machine system with warm spares and multiple operational units. When a unit malfunctions, prompt repair is crucial. Our two-stage hierarchical repair facility comprises primary repairers responsible for the preparatory stage, handling routine maintenance and low-skilled repairs. In contrast, the execution stage involves a highly skilled secondary repairer dedicated to addressing critical issues. We focus on efficient work sequential allocation between these stages, optimizing work distribution for quicker resolution of critical problems. To analyze the system, we use the Matrix Recursive Method to determine steady-state probabilities. Our mathematical model, solved with a recursive method, allows us to calculate performance indices based on

probability distributions. Additionally, we create a cost function and fine-tune decision parameters to minimize expected costs per unit of time. We employ Particle Swarm Optimization, a meta-heuristic technique, to optimize these parameters for a cost-effective service system. This approach streamlines the repair process, enhancing overall efficiency. Our research aims to provide practical insights into managing complex machinery repairs, ensuring optimal resource utilization and cost-effectiveness.

An optimization model for a sustainable transportation problem for location of refueling stations

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An essential component of contemporary living is transportation, however the conventional combustion engine is quickly becoming outdated. Furthermore, meeting sustainable development goals is critical for a country's sustainable future, particularly for developing countries like India. Therefore, alternative fuel transportation must be the cornerstone of a healthy ecosystem. The proposed work developed a multi-objective optimization model to facilitate the adoption of alternative fuel vehicles and the location of re-fueling stations to address the challenges associated with using them. The weighted metric approach has been employed to obtain preferred compromise solution. To illustrate the practicality of the suggested optimization model, a case study on the Apprel sector in India has been explored.

Nonlinear Scalarization in Set Optimization based on the Concept of Null Set

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(Joint work with Pradeep Kumar Sharma and C.S. Lalitha)

In this presentation, we present a nonlinear scalarization function for scalarizing set optimization problems. This function is based on the work of Wu (Journal of Mathematical Analysis and Applications, 2019), where a concept of null set was introduced. We present a concept of pseudo algebraic interior in a hyperspace and define a weak set order relation based on the concept of null set. We explore various properties associated with this nonlinear scalarization function. Furthermore, we delve into the characterization of set order relations and scrutinize optimality conditions for solution sets in set optimization. Finally, we conclude by giving a numerical example to compute a weak minimal solution to demonstrate the practicality of this nonlinear scalarizing function.

A New Method for Fuzzy Large-Scale Multi-Criteria Group Decision- Making

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In response to the challenges posed by fuzzy large-scale multi-criteria group decision-making (FLSMCGDM), we introduce a novel approach that adeptly handles the complexity and volume of data originate from a large-scale of decision-makers (DMs). Our proposed methodology uniquely considered the self-confidence of the individual DMs by collecting their

assessment in the form of novel intuitionistic fuzzy self-confidence (IFN-SC) numbers. IFN-SC consist of two components wherein first component is the fuzzy numerical term, and second component is the linguistic term depicting the self-confidence of the DMs. The number helps in capturing the uncertainty associated with the real-world problems two folds. This comprehensive approach ensures more robust and informed decision-making in FLSMCGDM scenarios. A hybrid three phase clustering algorithm is applied that combine fuzzy numerical value similarity and self-confidence similarity to effectively group DMs with similar opinions into coherent clusters. In the first phase, the optimal number of clusters are calculated with the help of silhouette score. Further, in second and third phase, the hybridization of hierarchical and K-means clustering algorithm strengthens the clustering process. In order to determine the cluster weights, a non-linear optimization model is formulated which aims to maximize the similarity of each alternative with the positive ideal solution (PIS) and minimize the similarity with the negative ideal solution (NIS). Particle swarm optimization (PSO) algorithm is used to solve the optimization model. TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) is used to rank the alternatives. Lastly, the practicality and effectiveness of the proposed approach is illustrated through its application in addressing future healthcare emergencies. The model's advantages are rigorously validated using various analyses.

An iterative algorithm to solve a bi-objective two-stage hierarchical transportation problem

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This paper discusses a bi-objective two-stage hierarchical transportation problem (BTSHTP) in which the set of source-destination links is partitioned into two disjoint sets viz., primary and secondary. The transportation in these sets is carried out in a hierarchical order i.e., one after the other, however, the transportation among source-destination links belonging to a

particular set is done in parallel. This hierarchy gives rise to a two-stage process of transportation of the homogeneous product from various sources to various destinations. The transportation among the links of primary set is done in Stage-I of the problem whereas the transportation among the links of secondary set is done in Stage-II (after the completion of Stage-I transportation). The objective is to minimize the 'total cost of transportation' and 'total time of transportation' of both the stages, simultaneously. The conflicting nature of these objectives suggests developing a solution algorithm that finds all the Pareto optimal solutions of the problem so obtained. In this paper, an iterative solution algorithm is proposed

which is based on solving a restricted single objective (cost minimizing) transportation problem, related to the original problem, at each of its iterations. The performance of the algorithm is illustrated with the help of a numerical problem. The worst case computational complexity of the proposed algorithm is calculated for an m × n sized instance. Further, the algorithm is coded in MATLAB and the average run time of the proposed algorithm, for various BTSHTP instances is calculated.

Duality for quasiconvex semi-infinite programming problems

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In this paper, we deal with quasiconvex semi-infinite programming problem (QCSIP) using Greenberg-Pierskalla subdifferential (GP-subdifferential). We reformulate Wolfe type dual problem (WSID) for (QCSIP) and establish weak, strong and strict converse duality theorems between (QCSIP) and the corresponding (WSID) under the assumption of GP-subdifferential. Further, we establish interrelation between the optimality for linear semi-infinite program- ming problems (LSIP) and nonlinear (QCSIP) using GP-subdifferential. More- over, we characterize optimality for (QCSIP) using the gap function in terms of GP-subdifferential.

Slack-based Non-Convex Data Envelopment Analysis Model

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The DEA theory assumes free disposability and the shape of the convex hull or convex cone of the production possibility set. The principle of convexity is the foundation of most pro- duction models, eliminating potential explanations for why technology might not be convex. Several reasons, including indivisibilities, economies of scale, and economies of specialization, mare responsible for the manifestation of non-convexity in production technology. The litera-ture describes an approach called the FDH model, which is used to determine the efficiency of DMUs in nonconvex technology-based DEA models. These models are essentially derived from the BCC models, with an added condition. Alternatively, we can describe these models as being derived from Radial DEA. In traditional convex technology-based DEA models, non-radial models are found to be more effective than the radial model due to the important role of slacks. There is a gap in the existing literature regarding a non-radial slack-based DEA model. Therefore, further development of the theoretical concepts for the non-radial FDH model is imperative. It has been demonstrated via empirical data that the slack-based FDH model works better than the radial FDH models.

Nexus between Total Factor Productivity and Back sourcing Decision: Empirical Evidence from the Manufacturing Sector of India

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Outsourcing is considered as a business strategy to achieve competitiveness and market performance. However, evidence from recent years shows that, in the long run outsourcing might not be a first-best strategy to achieve these goals. Considering this, firms are revising their early outsourcing decisions and

following counter strategies like back sourcing to avoid the long run cost associated with outsourcing. Using the firm level data, this study empirically analyses the factors that influence the decisions of the Indian manufacturing firms to opt for the strategy of back sourcing. A greater emphasis is given to understand how total factor productivity (TFP) and its components (i.e., technological change, scale change factor and technical efficiency change) influences a firm's decision to back source. Productivity is estimated using the non-parametric Malmquist productivity index method and then further decomposed using Ray and Desli decomposition. The bootstrap procedure proposed by Simar and Wilson is used to compute bias corrected total factor productivity estimates. A detailed analysis shows strong evidence for the prevalence of back sourcing strategy among Indian manufacturing firms. All components of TFP positively influence a firm's back sourcing decision and the other driving factors of back sourcing are the research and development expenditure, firms' size, their profit, the Government policies for promotion of the industrialsector, and firms' exports.

Petri Nets Reachability in Apriori Algorithm: A Comprehensive Approach to Market Basket Analysis

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Petri net is considered as an effective tool in graph theory that is applicable to represent and analyze discrete event type dynamic systems. Application of Petri nets in optimization problems contributes in studying the systems dynamics, performance characteristics and resource utilization. In this paper, we consider the reachability tree of a defined class of Petri nets and try to merge the marking nodes using homomorphism into a graph such that the depiction of the behavioral properties of the modeled nets remains unchanged and the number of reachable markings are minimized. Using this approach, we apply the Petri net model in market basket analysis (MBA) problem for association rule mining and, using the most commonly applied Apriori algorithm we suggest the use of reachability in solving the problem. Applications of studying MBA are in optimizing supply chain and inventory control problems and many others. This approach with reachability is novel and helps in understanding the customer behavior and transactional patterns.

Performance of Food Processing Companies in India: An integration of Machine Learning and DEA

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This study mainly focuses on application of the supervised machine learning framework for the performance prediction and missing value imputation of the data associated with the Food Processing Companies in India. By using machine learning algorithms, we impute the missing values of input-output variable. The target variable sales returns are predicted using various machine learning algorithms. Also, we use Data Envelopment Analysis (DEA) to assess the efficiency of food processing companies in India. For this purpose, we carry out two parallel analysis, i.e., one with only actual data and the other with imputed data (along with actual data). This integration of DEA and machine learning algorithms

will be able to provide a better estimation of the performance of the sector under consideration. We analyze the performance of the food processing companies in India by using the supervised machine learning algorithms. We predict the performance of various companies by imputing the missing values of input-output variables. The Decision Tree Regressor, Random forest, Ridge Regressor, Linear Regressor, Lasso Regressor,and Adaptive Boosting are used on imputed train data, to predict the target variable. Evaluation criteria shows that the Random forest model performs better for the prediction of the target variable. This algorithm provides low variance and bias, with good generalization regarding the model. Later, the imputed values of input-output variables are used for the estimation of efficiency scores of the food processing sector in India (2011-21). We use the non-parametric DEA approach for this purpose. DEA efficiency scores are sensitive to the sample size, and this study uses the imputed input-output data to address the issue of finite sample (in this context) to the extent possible. The average efficiency of the food processing sector during the period 2011-2021 is 0.63 in the case of actual data. However, in the case of estimation using imputed data, the average efficiency of the food processing sector is 0.39– showing greater potential for improvement of the industry under consideration, as against the earlier results.

Effectively Managing Drugs in the medical industry using the MCDM approach

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Expenditure on health in India is around 63% which is the highest in the world. Despite being the hub of the cheapest medicine, Indians spend a large portion of their hard-earned on medicines. A variety of medicines with the same salts that are prescribed by medical practitioners are kept in medical stores. This will lead the patients to buy expensive medicines having the same salt. It will not only impact the patient's pocket but also cause a threat to the environment due to expiries. Therefore, there is a need to effectively manage their inventories by the health managers. For this purpose, we try to classify the medicines based on their consumption using the Multi-Criteria Music 3D model (MCM) in which we classify each inventory item into different categories. Through this model, health managers can easily detectwhich medicines and in which quantity the medicines should be there in the medical stores.

Challenges in Designing Sensing Matrix

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Compressive sensing is a well-established mathematical concept for perfect signal recovery and violates the Nyquist sampling rule. The success of the compressive sensing concept lies in the system matrix or sensing matrix following the strict condition of restricted isometry property (RIP). The major portion of the literature and research in compressive sensing theory is captured by how to construct a system/sensing matrix so that it follows the RIP. Researchers have had some success and found that if the system/sensing matrix follows another property known as mutual coherence, compressive sensing theory also makes perfect signal recovery. Still, the problem is constructing a fast and efficient sensing matrix

with low mutual coherence and satisfying restricted isometric properties for perfect signal recovery. The construction of some of the sensing matrices with desirable properties often involves solving optimization problems, which can be computationally expensive. On the other hand, if we are able to construct a sensing matrix using some technique, then checking if the matrix satisfies the sufficient condition of mutual coherence or RIP is a combinatorial problem. Our aim is to present how, over the years, researchers worked on the design system/ sensing matrix in such a way that it has low mutual coherence and has perfect signal recovery.

Optimality and Duality for Nonsmooth Semidefinite Multiobjective Fractional Programming Problems Using Convexificators

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This paper deals with a class of nonsmooth semidefinite multiobjective fractional programming problems (in short, (NSMFP)). Using the properties of convexificators, we deduce Fritz John type necessary criteria of optimality for the considered problem (NSMFP). Further, we employ generalized Cottle constraint qualification to derive Karush-Kuhn-Tucker (in short, KKT) type necessary optimality criteria for (NSMFP). We establish sufficient optimality conditions for (NSMFP) using the assumptions of $\partial*$-pseudoconvexity and $\partial*$-quasiconvexity on the components of the objective function and constraints involved. Moreover, related to (NSMFP), we formulate the Mond-Weir type dual model (in short, (NSMFD)). Furthermore, we establish several duality results (namely, weak, strong, and strict converse duality) relating (NSMFP) and (NSMFD) under $\partial*$-pseudoconvex and $\partial*$-quasiconvex assumptions. To demonstrate the results derived in this paper, we provide several nontrivial examples. To the best of our knowledge, optimality criteria and duality results for (NSMFP) have not been explored before using convexificators.

Performance analysis of DRX mechanism using batch arrival vacation queueing system with N-policy in LTE-A networks

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Long Term Evolution-Advanced (LTE-A) is one of the latest mobile broadband technology, which has been initiated by the Third Generation Partnership Project (3GPP). It is designed to keep up with the today's promptly amplifying data traffic; however, it lacks in maintaining the energy efficiency of the User Equipments(UEs). In addition to energy efficiency, Quality of Service (QoS) is another emerging issue, which should also be managed simultaneously as the multiple types of data and services are handled at one point in time in UEs. Power saving and QoS are the two major significant aspects of LTE-A networks. We use a mechanism known as DRX ("Discontinuous Reception"), commonly exercised to enhance the power saving competency of an UE in LTE-A networks. Based on the kind of traffic running at the UE, we propose a new appliance to switch the DRX mechanism from the power active state to the power saving state and vice versa. We mathematically investigate this switching technique in DRX mechanism using the M[X]/G/1 vacation queue system and incorporating N-policy. Further, we obtained and examined various performance and energy metrics numerically. We find the optimal value of N as well as the maximum number of DRX cycles, to minimize the power consumption of the UE. This study concludes the selection guidelines for choosing the optimal values of N and the maximum number of DRX cycles.

Data-driven robust portfolio optimization model with an application to enhanced indexing

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Enhanced indexation [1], [5], [6], also known as enhanced index tracking, is an investment strategy that aims to track a benchmark index with higher return. In this work, we follow regression based enhanced indexation (REI) strategy [4] where alpha of a portfolio (α) is proposed to maximize while attaining the value one for portfolio beta (β). However, due to the involvement of estimation error in traditional methods of quantifying the α and β, the out-of-sample performance from the (REI) model is subject to risk. In order to obtain the robust and stable results from the (REI) model, we adopt a data-driven robust optimization (DRO) approach [7] to capture and account for the uncertainty associated with α and β. RO [2], [3] is a sub field of optimization that attempts to deal with the uncertain parameters by making the resultant robust model immune to the perturbation of its underlying parameter. The objective is to construct appropriate uncertainty sets where the uncertain parameter may vary.

In this work, we propose to employ a data-driven methodology that captures the uncertainty for α and β within a convex uncertainty set using support vector clustering in the (REI) model. Thus our proposal involves an enhanced portfolio optimization model, which takes into account the uncertainties surrounding the α and β values of portfolio for better outcomes. The entire strategy involves minimizing a convex quadratic optimization model that identifies support vectors. These support vectors aids are developing a compact and convex uncertainty set that further integrates with the enhanced indexation model to yield a robust linear PO model. Additional inclusion of re-balancing in the proposed model yields a mixed integer linear robust PO model. The proposed technique additionally offers the advantage of controlling conservatism and computational simplicity, making it a practical approach for achieving robust optimal portfolios.

We adopt rolling window approach to conduct our empirical analysis for analysing the perforfance of proposed robust model, which consists of solving and analyzing a sequence of windows incorporating dynamics of the market. In continuation of empirical analysis, the performance of the proposed robust model is tested over the constituents of S&P 500. We observe that the robust counterpart of the (REI) model outperform to its corresponding nominal model in terms several financial indices including mean return, standard deviation, conditional value-at-risk, value-at-risk, Sharpe ratio, STARR ratio, and Sortino ratio.

Two Conjectures in Complementarity Theory

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The Complementarity model provides a unifying frame-work for several optimization problems. This talk deals with two well-known conjectures in complementarity modeling theory namely Stone′s conjecture and Pang′s conjecture. The solution of this conjecture is directly linked with the computational aspects of complementarity problem using well known Lemkes algorithm. We consider the class of E_0^f-matrices introduced by Cottle and Stone and partially address Stones conjecture that $E_0^f \cap Q_0 \subseteq P_0$ by showing $E_0^f \cap D_c \subseteq P_0$ where D_c is Doverspikes class of matrices. In the context of Stones conjecture, it was shown that if $A \in R^{2\times 2} \cap C_0^f \cap Q_0$, then A is positive semidefinite and conjectured that this will be true for all $n \times n$ matrices where the class of fully copositive matrices (C_0^f) is a sub-class of fully semimonotone matrices. We provide a counterexample to settle this conjecture. Pang′s conjecture $(E_0 \cap Q \subset R_0)$ is not true even when E_0 is replaced by C_0, a sub-class of E_0. We show that Pang′s conjecture is true if E_0 is replaced by almost C_0.