International Symposium on Computational Operations Research and Algorithmic Game Theory

(ISORAGT)

March 29-31, 2021

Abstract of the papers & Programme Schedule

Organized by

Indian Statistical Institute,

7, S. J. S Sansanwal Marg, New Delhi-110 016

International Symposium on Computational Operations Research and Algorithmic Game Theory

ISORAGT

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Indian Statistical Institute, Delhi Centre

Contents

Welcome……2

Committees……3

Overview of Program……4

Abstract of the papers ……9

Welcome to ISORAGT

On behalf of the organizers of ISORAGT, I welcome you all in the Online International Symposium on Computational Operations Research and Algorithmic Game Theory organized during March 29-31, 2021 at Indian Statistical Institute, Delhi Centre.

The International Symposium on Computational Operations Research and Algorithmic Game Theory aims at discussing new developments in the methods of decision making and promises to build an interaction between the users and the academic model developers by bringing them together. There have been important new developments in the computational techniques of Operations Research and game problems. ISORAGT intends to present the state-of-the-art results and recent advances in these areas with a view to highlight possible future course of research in these areas. This symposium 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)

This symposium also intends to bring out a publication of selected and refereed papers in the Special issue of the Journal *International Game Theory Review*. Topics include (but not restricted to)

- Game Theoretical applications of Operations Research
- Static and Dynamic games
- Algorithmic Game Theory
- Graph Theory in Operations Research
- Complementarity and Variational inequalities model in Game Theory
- Operations Research problems in Statistics and Game Theory
- Portfolio Optimization
- Inventory Theory
- Stochastic Optimization
- Operations Research Problems in Reliability
- Financial Optimization

S. K. Neogy
Organizing Committee Chair

Committees

Organizing Committee

S. K. Neogy (Chair), R.B. Bapat, Arunava Sen, Prabal Roy Chowdhury, K. Manjunatha Prasad.

Programme Co-ordinating Committee

R. B. Bapat, K. Manjunatha Prasad, R. Chakraborty

Facilities Committee

R. Chakraborty, Simmi Marwah, Praveen Pandey, Parama Gogoi and Srinivas

International Symposium on Computational Operations Research and Algorithmic Game Theory

Program Overview

Inaugural Session Details

March 29, 2021 Time: 13:30 -14:00

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

Invited Sessions Details

March 29, 2021 Time: 14:00 -16:15 (IST)

Invited Session I
Chairman : S K Neogy, Indian Statistical Institute New Delhi.

1.	**Max Klimm (Technische Universität Berlin, Institut für Mathematik, Germany)** , Parametric Flow Algorithms,
2	**Bo Chen (The University of Warwick, UK)** Atomic Dynamic Flows: Adaptive versus Non-adaptive Agents
2.	**Michal Feldman (Blavatnik School of Computer Science at Tel-Aviv University, Israel)** Prophet and Secretary Online Algorithms for Matching in General Graphs

Tea Break: 16:15-16:30

March 29, 2021 Time: 16:30 -18:00 (IST)

Invited Session II
Chairman : R B Bapat, Indian Statistical Institute New Delhi.

1.	**Agnieszka Wiszniewska-Matyszkiel (Institute of Applied Mathematics and Mechanics, University of Warsaw)**"The Tragedy of the Commons" in the dynamic context
2.	**Reinoud Joosten & Rogier Harmelink (University of Twente, The Netherlands)** Tipping and strong rarity value in a stochastic fishery game

Tea Break: 18:00-18:10

March 29, 2021 Technical Session I 18:10-19:00

Chairman : S K Neogy, Indian Statistical Institute New Delhi.

1.	**Gambheer Singh** (University of Delhi) On classes of N-matrices and Nbar-matrices with Q-property
2.	**Sushmitha P (Indian Institute of Technology, Madras)** Some extensions of the Q-matrix class
3.	**Vatsalkumar N. Mer (Indian Statistical Institute New Delhi)** Linear preservers of semipositive matrices

March 30, 2021 Time: 10:00 -11:30 (IST)

Invited Session III

Chairman : S K Neogy,, Indian Statistical Institute New Delhi.

1.	**KS Mallikarjuna Rao, (Indian Institute of Technology Bombay)** Combined Lifting and Penalization Approach to Mathematical Programs with Complementarity Constraints
2.	**Yasunori Kimura (Toho University, Japan)** Fixed point problems and approximation techniques of its solutions on geodesic spaces

Tea Break: 11:30-11:45

March 30, 2021 Time: 11:45 -13:15 (IST)

Invited Session IV

Chairman : R.B. Bapat, Indian Statistical Institute New Delhi.

1.	**T. Parthasarathy (Chennai Mathematical Institute, Chennai, India)** Bimatrix bistochastic games with completely mixes equilibrium
2.	**Sandeep Juneja (Tata Institute of Fundamental Research, Mumbai, India)** Shift and Scale Approach to Speed up Epidemiological Agent Based Simulation Models

Lunch Break: 13:15 -14:00

March 30, 2021 Time: 14:00 -16:15 (IST)

Invited Session V

Chairman : S K Neogy, Indian Statistical Institute New Delhi.

1.	**Martin Hoefer, (Goethe-Universität Frankfurt am MainInstitut für Informatik, Germany),** Algorithms for Recommendation Problems
2.	**K.C. Sivakumar (Indian Institute of Technology Madras, India)** Tucker's theorem for almost skew-symmetric matrices.
2	**J Dutta, (Indian Institute of Technology Kanpur)** A Proximal Gradient Method for Multi-objective Optimization Problems using Bregman Functions**.**

Tea Break: 16:15-16:30

March 30, 2021 Time: 16:30 -18:00 (IST)

Invited Session VI
Chairman : R B Bapat, Indian Statistical Institute New Delhi.

1.	**S Dharmaraja (Indian Institute of Technology Delhi)** Markov Regenerative Credit Rating Model
2.	**S K Mishra (Institute of Science, Banaras Hindu University)** On q-Steepest Descent Algorithm for Unconstrained Multiobjective Optimization Problems

March 30, 2021 Technical Session II 18:00-19:00 (IST)
Chairman : S K Neogy, Indian Statistical Institute New Delhi.

1.	**G. Ganesan (Institute of Mathematical Sciences, Chennai)** Computing Prices for Target Profits in Contracts
2.	**Ankur Garg,** Y. Agarwal, R. K. Srivastava, S. K. Jakhar (Indian Institute of Management Lucknow) Application of Benders Decomposition for solving an Integrated Model for Schedule Design, Aircraft Rotation and Crew Scheduling in Airlines.
3.	**Lokesh Kumar Bhuranda**, Mohd. Rizwanullah (Manipal University Jaipur) Stochastic Optimization of Multi-Capacitated Vehicle Routing Problem with Pickup and Delivery using Saving Matrix Algorithm

March 31, 2021 Time: 10:00 -11:30 (IST)

Invited Session VII
Chairman : R.B.Bapat,, Indian Statistical Institute New Delhi.

1.	**Masahiro Hachimori** and Yumi Yamada **(University of Tsukuba, Japan)** On the distribution of the roots of Ehrhart polynomials for dual pairs of polytopes
2.	Shinya Fujita , Boram Park**, Tadashi SAKUMA, (Yamagata University, Japan)** Network majority and the connected safe set problem

Tea Break: 11:30-11:45

March 31, 2021 Technical Session III Time: 11:45 -13:15 (IST)

Chairman : K.M. Prasad, Centre for Advanced Research in Applied Mathematics and Statistics, MAHE

1.	**Bhawna Kohli** (P.G.D.A.V. College, University of Delhi) Some calculus rules,generalized convexity via convexifactors and their applications to optimization" for presentation
2.	**Monu,** L.N. Das, (Delhi Technological University, New Delhi) Selected Delhi Transportation Routing Bus Scheduling
3	**Akash Jain**, Anjana Gupta (Delhi Technological University, New Delhi) Solving Game Theory problem with the help of newly proposed Mayfly Algorithm
4	**Rajesh Kumar Mishra,** Vinod Kumar Mishra (Madan Mohan Malaviya University of Technology Gorakhpur, UP, India) Inventory decisions within an inventory model for joint complementary and substitutable items with substitution cost.
5	**M. Sathya (Meenakshi College for women)** Time Table scheduling using graph coloring
6	K, Sridevi, **Thiruchinapalli Srinivas (Dr.B R Ambedkar Open University, Telangana, India)** Cryptographic Coding Reciprocal Pythagorean Triples

Lunch Break: 13:15 -14:00

March 31, 2021 Time: 14:00 -16:00 (IST)

Invited Session VIII

Chairman : S K Neogy, Indian Statistical Institute New Delhi.

1.	**Pankaj Gupta (University of Delhi, India)** Impact of COVID-19 on Supply Chain Operations in India: An NLP Approach
	S.C. Malik (M.D. University, Rohtak) A New Approach for Reliability Analysis of Transformed Systems with Different Structures
2	**Dipti Dubey (Shiv Nadar University)** On Hilbert Basis and Integral Solutions of Linear Complementarity Problem

Tea Break: 16:00-16:15

March 31, 2021 Time: 16:15 -17:15 (IST) Technical Session IV

Chairman : , K.M. Prasad, Centre for Advanced Research in Applied Mathematics and Statistics, MAHE .

1.	**Nomita Pachar**, Anshu Gupta, P.C. Jha,(Department of Operational Research, University of Delhi), Integrated Centralised Decentralised Resource Reallocation Strategy based on DEA for Improving Sustainable Performance: A Case Study of Supermarket Retail Firm
2.	**Akansha Jain,** Jyoti Dhingra Darbari, P. C. Jha,(Department of Operational Research, University of Delhi), Supply Chain Restructuring for Omni-Channel Retailing: A Procurement-Distribution Planning Framework
3	Jyoti Dhingra Darbari**, Shiwani Sharma,** P. C**.** Jha (Department of Operational Research, University of Delhi), Multi-objective Modelling approach for Sustainable Reverse Supply Chain Network Planning and 3PRLP Selection
4	**Aditi,** Jyoti Dhingra Darbari, P.C. Jha (Department of Operational Research, University of Delhi, India), Bi-Objective Optimization Model for Sustainable Supplier Selection considering Trade-off between Supplier Development and Supplier Switching

Tea Break: 17:15-17:30

March 31, 2021 Time: 17:30 -18:30 (IST) Technical Session V

Chairman : , S. K. Neogy, Indian Statistical Institute New Delhi.

1	**Rashi Sharma,** Jyoti Dhingra Darbari, P.C. Jha (Department of Operational Research, University of Delhi, India), Group Consensus Reaching Model for Sustainable Tier I Supplier Evaluation and Selection in a Multi-Tier Food Supply Chain
2.	**Pankaj ,** Aditi, Arshia Kaul, Rubina Mittal(Department of Operational Research, University of Delhi, India) Identification of Challenges to Implement Industry 4.0 and Circular Economy: A Case of an Indian MSME
3	**Ranu Singh,** Vinod Kumar Mishra (Madan Mohan Malaviya University of Technology, Gorakhpur, U.P, India)Joint Optimal ordering policies for non-instantaneous substitutable deterioration products with carbon emission and cost of substitution
4	Pratiksha Saxena, Chaman Singh, **Kamna Sharma (**Gautam Buddha University, Greater Noida, Uttar Pradesh, India) Green Design and product stewardship approach for two warehouse inventory model.
5.	**Mahendra Kumar Gupta** (National Institute of Technology Jamshedpur), N. K. Tomar, A, Kumar, Index one generalized observer design for linear descriptor systems with unknown inputs

ABSTRACT OF THE PAPERS

Parametric Flow Algorithms

Max Klimm

Technische Universität Berlin, Institut für Mathematik, Germany.

:

We develop algorithms solving parametric flow problems with separable, continuous, piecewise quadratic, and strictly convex cost functions. The parameter to be considered is a common multiplier on the demand of all nodes. Our algorithms compute a family of flows that are each feasible for the respective demand and minimize the costs among the feasible flows for that demand. For single commodity networks with homogenous cost functions our algorithm requires one matrix multiplication for the initialization, a rank-1 update for each non-degenerate step, and the solution of a convex quadratic program for each degenerate step. For non-homogeneous cost functions, the initialization requires the solution of a convex quadratic program instead. For multi-commodity networks, both the initialization and every step of the algorithm require the solution of a convex program. As each step is mirrored by a breakpoint in the output this yields output-polynomial algorithms in every case.

Atomic Dynamic Flows: Adaptive versus Non-adaptive Agents

Bo Chen

The University of Warwick, UK.

We propose a game model for selfish routing of atomic agents, who compete for use of a network to travel from their origins to a common destination as fast as possible. We follow a frequently used rule that the latency an agent experiences on each edge is a constant transit time plus a variable waiting time in a queue. A key feature that differentiates our model from related ones is an edge-based tie-breaking rule for prioritizing agents in queueing when they reach an edge at the same time. We study

both non-adaptive agents (each choosing a one-off origin-destination path simultaneously at the very beginning) and adaptive ones (each making an online decision at every non-terminal vertex they reach as to which next edge to take). On the one hand, we constructively prove that a (pure) Nash equilibrium (NE) always exists for non-adaptive agents, and show that every NE is weakly Pareto optimal and globally first-in-first-out. We present efficient algorithms for finding an NE and best responses of non-adaptive agents. On the other hand, we are among the first to consider adaptive atomic agents, for which we show that a subgame perfect equilibrium (SPE) always exists, and that each NE outcome for non-adaptive agents is an SPE outcome for adaptive agents, but not vice versa.

Prophet and Secretary Online Algorithms for Matching in General Graphs

Michal Feldman,

Blavatnik School of Computer Science at Tel-Aviv University, Israel.

A common tension in market scenarios is choosing the right timing to commit to a decision. This tension is captured by the mathematical literature of optimal stopping theory, within two models that have become to be known as the secretary problem and the prophet inequality. In these models, a sequence of originally-unknown values arrive one by one. Upon arrival, the online algorithm observes the value and should decide whether or not to accept it. In secretary settings, the value sequence is arbitrary, but the values arrive in a uniformly random order. In prophet settings, every value is drawn from a known probability distribution, but the arrival order is arbitrary.

In this talk I will review the basic settings of secretary and prophet, as well as previous extensions to matching in bipartite graphs with 1-sided vertex arrival. I will then present our recent work, which studies online algorithms (in both secretary and prophet settings) for matching in *general* graphs. We provide tight competitive ratios for both secretary and prophet matching scenarios under vertex arrival. Under edge arrival, we provide competitive ratios that improve upon the state of the art.

Based on joint work with Tomer Ezra, Nick Gravin and Zhihao Tang.

"The Tragedy of the Commons" in the dynamic context

Agnieszka Wiszniewska-Matyszkiel

Institute of Applied Mathematics and Mechanics, University of Warsaw

The term "the tragedy of the commons" describes a situation in which many individuals use common or interrelated resources, each of them pursuing its own objective, and this rationality leads to inefficiency in use of the resource. Mathematically, it is modelled by a class of games, and in any ecological context, dynamic games. "The tragedy of the commons" encompasses a variety of problems, e.g. overexploitation of fisheries, spread of epidemics in presence of individual means decreasing spreading the virus, the greenhouse effect, appearance and spread of bacteria resistant to antibiotics, overuse of available frequencies, air and water pollution and space debris. With a simple example of a linear quadratic model of exploitation of common marine fishery divided into Exclusive Economic Zones, I will show what mathematical tools are needed to analyse such phenomena and what kind of surprises can be expected by mathematicians modelling them. Some focus will be on the consequences of the most inherent constraints inevitable to make any resource extraction problems at least slightly realistic. And, last but not least, how to avoid "the tragedy".

Tipping and strong rarity value in a stochastic fishery game

Reinoud Joosten & Rogier Harmelink

University of Twente, The Netherlands

Strong rarity value is the phenomenon that an increase in scarcity of a species leads to a price increase which more than compensates increased search costs and decreased landings. Tipping here is a regime shift in which overfishing moves the system into a low resource-level state from which it is impossible to escape unless measures to restore the resource are taken for a long period of time.

We engineer a model in which agents wishing to maximize their limiting average rewards have two choices at every stage of the play, restraint or no-restraint (‘overfish’). Overfishing damages the resource and causes tipping. The former induces scarcity which in turn creates rarity value, and after the tipping recovery of the resource takes a long period of time. Results show that Pareto efficient equilibrium outcomes for very patient agents may require substantial overexploitation of the resource which induces serious threats to the sustainability of the resource. Incentives of patient agents and very impatient ones (not modeled here) may point in the same direction, namely ruthless exploitation, which requires a careful long term management.

Combined Lifting and Penalization Approach to Mathematical Programs with Complementarity Constraints

KS Mallikarjuna Rao

Indian Institute of Technology Bombay, India.

We prosent a new method to study mathematical programs with complementarity constraints. By enlarging the dimension, we propose a parametrized nonlinear program with penalization. The feasible set of our nonlinear program is independent of the penalization parameter. Irrespective of constraint qualifications, we show that any local minima of MPCC can be obtained as a limit of local minima of the parametrized nonlinear program. Under suitable constraint qualification conditions, we will also show that the local minima of the parametrized nonlinear program will satisfy the respective constraint qualifications. This method will also allow us to establish the (well-known) strong stationarity of local minima of MPCC under the constraint qualification MPCC-LICQ. We also present some encouraging numerical experiments. This is a joint work with Prof. Joydeep Dutta.

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.

Bimatrix bistochastic games with completely mixes equilibrium

T. Parthasarathy

Chennai Mathematical Institute, Chennai, India

Shift and Scale Approach to Speed up Epidemiological Agent Based Simulation Models

Sandeep Juneja

Tata Institute of Fundamental Research, Mumbai, India.

Agent-based simulators are a popular epidemiological modelling tool to study the impact of various non-pharmaceutical interventions to manage an evolving pandemic. They provide the flexibility to accurately model heterogeneous population with time and location varying, person specific interactions. An important drawback of agent based simulation models (ABSM) is that each person in the region considered is separately modelled, making the computational time prohibitive when the region population is large. Simply considering a smaller aggregate model and scaling up the output leads to inaccuracies. In this paper we primarily focus on the COVID-19 pandemic and dig deeper into the underlying probabilistic structure of an associated ABSM. The infection evolution process typically involves an initial disease spread phase, where each of the starting infections create a family tree more-or-less independent of the other trees. Once enough people have been infected, the future of the number infected closely follows a deterministic process. We build upon these insights to develop a shifted and scaled version and some close variants of the simulator that accurately evaluates the ABSM's performance using a much smaller model while carefully reducing the bias and the variance that otherwise arises from smaller models. We also introduce conditioning based variance reduction techniques that substantially speed up the model calibration process.

(joint work with Shubhada Agarwal and Daksh Mittal)

Algorithms for Recommendation Problems

Martin Hoefer,

Goethe-Universität Frankfurt am MainInstitut für Informatik, Germany.

Recommendations play a crucial role in modern online markets for goods and services (hotel rooms, restaurants, etc.). Strategic aspects of information disclosure are studied prominently in the area of Bayesian persuasion. In the standard setting, an expert with knowledge about the state of the world (e.g., an online retailer) tries to influence the choice of a decision maker (e.g., a customer) by strategically revealing pieces of information about the product. In this talk, I discuss our recent work on algorithmic aspects of Bayesian persuasion. In particular, we consider incomplete information and restricted communication possibilities of the expert and their impact on (algorithms for) near-optimal persuasion.

Tucker's theorem for almost skew-symmetric matrices.

K.C.Sivakumar

Department of Mathematics

Indian Institute of Technology Madras

A real square matrix A is said to be almost skew-symmetric if its symmetric part has rank one. In this talk, I will present some recent results on this class of matrices. An interesting analogue of Tucker's theorem (known for skew-symmetric matrices) will be presented for almost skew-symmetric matrices. This result, in turn, leads to a proof of the Farkas' alternative.

*(This is a joint work with Projesh Nath Choudhury).

A Proximal Gradient Method for Multi-objective Optimization Problems using Bregman Functions*

J. Dutta,

Indian Institute of Technology Kanpur, India..

In this paper, a globally convergent proximal gradient method is developed for convex multi-objective optimization problems using Bregman distance. The proposed method is free from any kind of a priori chosen parameters or ordering information of objective functions. At every iteration of the proposed method, a sub-problem is solved to find a descent direction. This sub-problem uses a Bregman distance induced by a strongly convex function. An Armijo type line search is conducted to find a suitable step length. A sequence is generated using the descent direction and step length. It is justified that this sequence converges to a weak efficient solution under some mild assumptions. The method is verified and compared with one existing method using a set of test problems.

*Joint work with M. A. T. Ansary

Markov Regenerative Credit Rating Model

S Dharmaraja

Department of Mathematics

Indian Institute of Technology Delhi

Credit rating serves as an important input in the risk management of the financial firms. The level of credit rating changes from time to time because of random credit risk and, thus, can be modelled by an appropriate stochastic process. Markov chain models have been widely used in the literature to

generate credit migration matrices; however, emergent empirical evidences suggest that the Markov property is not appropriate for credit rating dynamics. The purpose of this talk is to address the non-Markov behavior of the rating dynamics alone with big data and optimization issues. A model is proposed based on Markov regenerative process (MRGP) with subordinated semi-Markov process (SMP) to obtain the estimates of rating migration probability matrices and default probabilities. Further, the applicability of the MRGP model with the help of historical credit rating data is numerically illustrated.

On q-Steepest Descent Algorithm for Unconstrained Multiobjective Optimization Problems

S. K. Mishra

Department of Mathematics, Institute of Science,

Banaras Hindu University, Varanasi-221005, India

The most basic version of the descent method is the steepest descent method. The q-version of the steepest descent method for unconstrained multiobjective optimization problems is constructed and recovered to the classical one as q approaches 1. The proposed algorithm is implemented by applying an independent parameter q in the Armijo-Wolfe conditions to compute the step-length. Further, numerical problems are solved to get the critical points and show the efficiency of the method.

Keywords: unconstrained optimization, steepest descent method, q-calculus, global convergence

On the distribution of the roots of Ehrhart polynomials for dual pairs of polytopes

Masahiro Hachimori and Yumi Yamada

University of Tsukuba, Japan.

Polytopes and lattice points in them are important in the optimization theory in Operations Research. In this talk, we are interested in polynomials related to the number of lattice points in a polytope. When all the vertices of a polytope are lattice points, the polytope is called an integral polytope. For an integral polytope P of dimension d, the number of lattice points contained in the n-th dilate nP is given by a polynomial of degree at most d, which is called the Ehrhart polynomial. Our concern is in the distribution of the roots of the Ehrhart polynomials on the complex plane.

When an integral polytope contains the origin as its unique interior lattice point and its polar dual polytope is also integral, such a polytope is called reflexive. The symmetric feature of reflexive polytopes is reflected so that the roots of the Ehrhart polynomials of reflexive polytopes are symmetric with respect to the

line of Re(z)=-1/2. Further details about the distribution of the roots of the Ehrhart polynomials are studied by several researchers. Among these, we are interested in the cases when all the roots are distributed on the line of Re(z)=-1/2, in which case the polytope is called CL, and when all the roots are distributed on Im(z)=0, in which case the polytope is called real.

In this talk, we will report the relation of the root distributions of the reflexive polytope P and its polar dual P^* , for the cases of low-dimensional reflexive polytopes, the class of root polytopes, and the polytopes related to graded partially ordered sets. The results contain both theoretical and computational observations.

Network majority and the connected safe set problem

Shinya Fujita (Yokohama City University, Japan), Boram Park (Ajou University, Republic of Korea)

Tadashi SAKUMA,

Yamagata University, Japan

Abstract. Let G be a graph, and let w be a non-negative real-valued weight function on $V(G)$. For every subset X of $V(G)$, let $w(X) = \sum_{v \in X} w(v)$. A non-empty subset $S \subset V(G)$ is a *weighted safe set* of (G, w) if for every component C of the subgraph induced by S and every component D of $G - S$, we have $w(C) \geq w(D)$ whenever there is an edge between C and D. If the subgraph of G induced by a weighted safe set S is connected, then the set S is called a *connected weighted safe set* of (G, w). The *weighted safe number* $\mathrm{s}(G, w)$ and *connected weighted safe number* $\mathrm{cs}(G, w)$ of (G, w) are the minimum weights $w(S)$ among all weighted safe sets and all connected weighted safe sets of (G, w), respectively. In this talk, we present some recent progress on the minimum connected safe set problem. Among others, we show that for any tree T and for any weight function w' on $V(T)$, there exists an FPTAS for calculating a minimum connected safe set of (T, w'). This gives a complete answer to a question posed by Bapat et al. [*Networks*, **71**:82-92, 2018] and disproves a conjecture by Ehard and Rautenbach [*Discrete Applied Mathematics*, **281**:216-223, 2020].

Keywords: Safe set; Connected safe set; Vertex-weight function; Network majority; Network vulnerability

Impact of COVID-19 on Supply Chain Operations in India: An NLP Approach

Pankaj Gupta

Department of Operational Research, University of Delhi, Delhi-110007

COVID-19 has clearly impacted the supply-chains of most industries. Nationwide lockdown has resulted in companies struggling to maintain a steady flow of goods and services. It has brought to light the criticality of having proper supply-chain models and strategies, especially in cases of disruption. To be better prepared in future, the following need to be done: (i) Identification, tracing and elimination of factors responsible for failing supply-chain operations; (ii) Development of highly robust and resilient supply-chain models, and (iii) Implementation (or improvement) of technologically-driven solutions.

A New Approach for Reliability Analysis of Transformed Systems with Different Structures

S.C. Malik

Department of Statistics, M.D. University, Rohtak-124001 (Haryana)

In the recent few years several reliability improvement techniques for the non-repairable systems have been suggested by the scholars and system designers. The provision of redundancy has been considered as the best one in this direction. But sometimes it becomes very difficult for keeping a spare unit high costs with the system and in that situation some other options are required to be identified. The structural design of the components is nowadays being considered for improving the performance of the systems. Today we have some well known structures like series, parallel, series-parallel and parallel-series which enable to develop systems with a considerable reliability. The researchers pointed out that the systems with parallel structure of the components have more reliability than that of the others. On the other hand any change in structural design of a system invites lot of manipulations in terms of space and costs. But sometimes we need to reduce or increase the size of the components in a particular structure and in that situation it becomes very difficult to determine the reliability of the transformed systems that involves lot of computational efforts and costs. Therefore, in the present talk, a new approach for evaluation of reliability of the transformed systems is suggested in terms of reliability of the original system and variation in reliability due to alteration in the structure. Here, the reliability of the transformed system obtained from the series and parallel-series system is discussed as an illustration. And, the effect of failure rate of the components, number of parallel paths (with addition or removal of components) and number of components added (or removed) to (or from) the original system on variation in reliability has been examined using regression approach. The goodness of fit of the model

has been checked on the basis of values of R^2 and adjusted R^2. The results are shown graphically and practical application of the work has been highlighted.

On Hilbert Basis and Integral Solutions of Linear Complementarity Problem

Dipti Dubey

Department of Mathematics, Shiv Nadar University

In this talk, we interconnect the concept of Hilbert basis with principal unimodularity of a matrix and the corresponding complementary cones. We also discuss the role of these concepts to obtain a necessary and sufficient condition for existence of an integer solution to a linear complementarity problem.

On classes of N-matrices and Nbar-matrices with Q-property

Gambheer Singh

Department of Mathematics, University of Delhi, India

In this talk the properties of N-matrices of exact order 1 and 2 and some results of N-matrices of exact order 1 and 2 that hold Q-property are discussed. A limiting class of matrices, namely Nbar -matrices exact order 1 and 2 is presented and sufficient conditions for these classes to satisfy Q-property are given.

References

[1] S. R. Mohan, T. Parthasarathy and R. Sridhar, The linear complemen- tarity problem with exact order matrices, Mathematics of Operations Research, 19(3) (1994), 618{644.

[2] S. K. Neogy and A. K. Das, On almost type classes of matrices with Q-property, Linear and Multilinear Algebra, 53(4) (2005),243{257.

Some extensions of the Q-matrix class 1

Sushmitha P

Indian Institute of Technology, Madras, Chennai-600036, India.

A real square matrix A is called a Q-matrix if LCP(A, q) has a solution for all $q \in \mathbb{R}^n$, i.e., for every vector q, there exists an $x \in \mathbb{R}^n$ such that $x \geq 0$, $Ax + q \geq 0$ and $x^T(Ax + q) = 0$. A well known result states that a Q-matrix with nonpositive off-diagonal entries is inverse nonnegative. In this talk, we shall look at properties of two classes of matrices that extend the inverse nonnegativity of the Q-matrices to the generalized inverse of a matrix. We shall also look at a new result for the class of Q-matrices.

Linear preservers of semipositive matrices

Vatsalkumar N. Mer

Indian Statistical Institute,Delhi Center, India

An $m \times n$ matrix A with real entries is said to be semipositive if there exists a $x > 0$ such that $Ax > 0$, where the inequalities are understood componentwise. This set is denoted by $S(\mathbb{R}^n_+, \mathbb{R}^m_+)$. In this presentation, I will talk about: (1) a conjecture on the structure of into linear preservers of the set $S(\mathbb{R}^n_+, \mathbb{R}^m_+)$ and (2) to determine linear preservers of the set $S(K_1, K_2)$ for proper cones K_1 and K_2, where $S(K_1, K_2)$ is the set of all semipositive matrices relative to K_1 and K_2.

Computing Prices for Target Profits in Contracts

Ghurumuruhan Ganesan

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Price discrimination for maximizing expected profit is a well-studied concept in economics and there are various methods that achieve the maximum given the user type distribution and the budget constraints. In many applications, particularly with regards to engineering and computing, it is often the case than the user type distribution is unknown or not accurately known. In this paper, we therefore propose and study a mathematical framework for price discrimination with target profits under the contract-theoretic model. We first consider service providers with a given user type profile and determine sufficient conditions for achieving a target profit. Our proof is constructive in that it also provides a method to compute the quality-price tag menu. Next we consider a dual scenario where the offered service qualities are predetermined and describe an iterative method to obtain nominal demand values that best match the qualities offered by the service provider while achieving a target profit-user satisfaction margin. We also illustrate our methods with design examples in both cases.

Application of Benders Decomposition for solving an Integrated Model for Schedule Design, Aircraft Rotation and Crew Scheduling in Airlines

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The commercial and operations planning process in airlines has traditionally been a hierarchical process starting with flight schedule design, followed by fleet assignment, aircraft rotation planning and finally the crew scheduling. Each of these planning phases, solved individually, have benefited from application of optimization models which are large-scale mixed integer programming (MIP) models with thousands

of constraints and millions of binary decision variables for even mid-size airlines. The hierarchical planning approach however has meant that the optimal solution for a planning phase higher in the hierarchy may either be infeasible for the subsequent planning phase or may lead to a sub-optimal combined planning.

In this study, we formulate and solve an integrated model for schedule design, aircraft rotation and crew scheduling for a (fictitious) Low Cost Carrier. This airline operates in an emerging aviation market and makes frequent changes to its flight schedule due to continuous fleet growth and evolving market maturity. Every time it has to go for a change in its flight schedule, the airline would like to choose a flight schedule which does not necessarily earn the maximum revenue (flight-leg and through revenues) but is the most profitable after accounting for the crew costs incurred to cover the flight schedule. Due to emerging nature of the aviation market, the airline has high emphasis on connecting different stations through via-flights if nonstop service is not possible. Hence, the aircraft rotation is important in our context to maximize the opportunity to earn through-revenue by creating more and more via-flight opportunities in the flight schedule. We formulate an integrated schedule design, aircraft rotation and crew scheduling problem to meet these business objectives. Such an integrated problem is practically insolvable to optimality due to millions of binary decision variables and hundreds of thousands of constraints. Consequently, we solve the integrated model using Benders Decomposition where we decompose the problem into a schedule design and aircraft rotation restricted master problem and crew scheduling sub-problem.

A particular complexity in solving the problem is it is not practically feasible to enumerate all hundreds of thousands of crew schedules (or crew pairings, as known) that possibly exist for even a mid-size airline. We therefore use column generation to generate only such crew pairings which are likely to reduce the crew cost. The column generation for crew scheduling is non-trivial due to complex regulatory constraints and cost structure. While past literature suggests using multi-label shortest path for column generation, another key contribution of our research is mathematical programming formulation and development of a LP relaxation heuristic to generate good quality columns within low computing times. Once the column generation has been terminated, the integer solution of least cost crew pairings has been traditionally found using branch-and-price approach. Since our problem involves solving crew cost minimization problem a few times, we propose a faster greedy branching and dynamic column generation heuristic.

We test our proposed solution methodology using dummy and random (but representative of practical situation) data set on different cases by varying the scale of operations and maximum length of crew pairing. For all the cases tested, our computational results show that our integrated model and the

solution methodology is successful in finding solutions which have a profit higher by 1% - 5% than that of traditional hierarchical approach. Since the emphasis is on finding solutions better than that of traditional hierarchical approach within practical solution times, we do not solve Benders iterations to optimality but terminate the iterations once a satisfactory solution has been found within a reasonable optimality gap. Given that airlines typically operate at razor-thin margins, a 2-3% improvement in profits is significant and for an airline of 20-25 aircraft it could mean an additional US$1-2 mn to the annual bottom-line.

The research is able to successfully contribute in the area of integrated commercial and operations planning in airlines and has the potential to improve the profit margins for the airlines. The solution methodologies developed in this research can be easily extended to similar large-scale networks with multiple constraints or to complex scheduling problems requiring column generation.

Stochastic Optimization of Multi-Capacitated Vehicle Routing Problem with Pickup and Delivery using Saving Matrix Algorithm

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The Multi-Capacitated Vehicle Routing Problem with Pickup and Delivery (MCVRPPD) is a combinatorial optimization issue. Before all routes are visited, information about all routes of the MVRP is known. The MCVRPPD looks for vehicle routes to connect all customers to a storage facility, so that the total distance is minimized. In this article, we propose an extended VRP considering a stochastic environment with multi-capacitor using saving matrix approach. Stochastic customers are the key elements of the problem. A real-life problem has been solved in a particular city with the optimum results. Computational analysis is also supports the proposed method to get the optimum rout. The same problem can be further extended to other areas under the particular constraints. We can use the concept of this work to solve the other optimization problems like Chinese Postman Problem (CPP) and Traveling Salesman Problem (TSP) in polynomial time. We will take the place location as a random variable to optimize the VRP in a certain polynomial time.

Some calculus rules,generalized convexity via convexifactors and their applications to optimization"

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In this paper, convexifactors of product, sum and quotient of two functions are computed. Generalized convexity of these functions in terms of convexifactors is studied. These results are then applied to optimization problems.

Keywords. Convexifactors, Calculus rules, Generalized convexity, Optimality conditions.

Selected Delhi Transportation Routing Bus Scheduling

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In this paper, we present a model for solving real daily scheduling problem of Delhi Transport Corporation in crew planning and bus scheduling in selected route with considering proper allotment of bus in the different mode such as early,afternoon,evening and late mode. An model is designed for improve the efficiency to minimize the idle time length, which improve the budget of Delhi Transport Corporation to minimize the cost of crew and efficiently allot the crew as well as maximize the earning of Delhi Transport Corporation by joining the inter route of the bus according to waiting ratio of passengers by 0-1 integer programming problem solution model with the help of Computer Assisted Software. At last system database management is also comprehensible designed.

Solving Game Theory problem with the help of newly proposed Mayfly Algorithm

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In nature, every well-framed problem has a solution at its core. So it is very interesting to note that in recent times researchers inclined themselves to nature’s intelligence. By mimicking the behavior of nature they can reduce their hard complexity problems into simplified ones. In view of this Mayfly Algorithm (MA) was recently proposed in 2020 based on the flight pattern and mat-ing scheme of mayflies. In this paper, we will take a classical game theory problem and solve it with the help of this newly proposed stochastic-based na-ture-inspired optimization technique. With the help of this stochastic optimiza-tion we can introduce more dynamism in the games which is based on real-time simulations. We can easily find the fitness function for our algorithm as there is well-known relationship between classical game problem and linear program-ming problem. By imbibing evolutionary computing we can also locate optimal solution strategies of non-linear game problems. The reason behind choosing Mayfly Algorithm to solve our game problem is that it combines the goodness of three major evolutionary algorithms which

are firefly Algorithm (FA), PSO (Particle Swarm Optimization) and Genetic Algorithm (GA). Lastly we will compare the results with traditional methods and Genetic Algorithm (GA) and then we will see our approach via this newly proposed technique has better convergence to the optimal solution.

Keywords: Game Theory, Mayfly Algorithm (MA), Bio-Inspired Optimization, Stochastic Optimization.

Inventory decisions within an inventory model for joint complementary and substitutable items with substitution cost

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For any business industry to make all-round profit from different aspects, a combination of substitutable and complementary item is very important. The purpose of this article is to study the inventory decisions model for two substitutable items under full substitution, where one item is also composed with two complementary components. Both items are replenished jointly. Due to substitution between two items, the substitution cost is incurred. This model is developed for two practical cases: case of depleting of item 1 before item 2 and case of depleting of item 2 before item 1. This model aims to determine order quantity for each item which maximizes the total profit. Furthermore, the nature of pseudo-concavity of the total profit is derived, and then a solution procedure is presented. The advantage of this model is that it enhances the availability of items, the total profit, and the goodwill opposed to the model with no substitution. Lastly, this model is illustrated through a numerical example after which a sensitivity analysis with respect to key parameters is conducted.

Keywords: Inventory decisions, Complementary items; Substitutable items; full substitution; Substitution cost.

Time Table scheduling using graph coloring

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Effective timetable is vital to the performance of any educational institute. It impacts their ability to meet changing and evolving subject demands and their combinations in a cost-effective manner satisfying various constraints. In this paper, we have focused our work into Course Timetable Scheduling.

Keywords: Graph Coloring, Course Timetable Scheduling, Hard Constraints, Soft Constraints, Course Conflict Graph

Cryptographic Coding Reciprocal Pythagorean Triples

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In this paper we are revisits well Known Problem in Number Theory " Reciprocal Pythagorean Theorem" in new perspective way to generate Reciprocal Pythagorean Triples.

KEYWORDS: Pythagorean Theorem, Reciprocal Pythagorean Theorem, Rpt0(Reciprocal Pythagorean Triple for Odd numbers), Rpte (Reciprocal Pythagorean Triple for Even numbers).

Integrated Centralised Decentralised Resource Reallocation Strategy based on DEA for Improving Sustainable Performance: A Case Study of Supermarket Retail Firm

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In the present times sustainability is increasingly recognised among the retail businesses as an approach to creating long-term value for its customer. An organisation can enhance its business model with the incorporation of sustainability for meeting the market demand and simultaneously achieve the environmental and social sector objectives. A firm's level of sustainability is defined in terms of how it operates in the ecological, social and economic environment. For a sustainable retail business it is imperative to focus on optimal deployment of its resources while planning their business strategies. Optimal resource deployment keeping the interests of a firm's internal customers in mind helps improve its economic, social and environmental efficiency and, overall sustainability. Often retail firms operate several stores at different geographical areas with similar operations, sustainable functions and product lines. These stores are governed by a centralized authority, responsible for making business strategies and allocating resources among stores through the central pool. This calls for scientific approach for (re)allocating available resources among subordinate retail stores such that resources are utilised in best possible ways, enriching firms overall sustainable performance. This study proposes a data envelopment analysis (DEA) based mathematical model for optimal reallocation of resources considering measures of all three dimensions of sustainability. The proposed model is formulated considering a supermarket retail chain as the unit of analysis. A retail store depends on several resources for its operations including human resource and monetary resources for store operations, inventory management, energy, store space and welfare practices of employees. While the resources such as operating expenses, energy expenses may be optimized at the central level, deployment of inventory and

human resources have additional requirements. Often retail chains manage inventory requirement of its stores through regional distribution centres (DCs) to simultaneously realize efficiency and responsiveness objectives. Each DC cater to the inventory requirement of a cluster of stores wherein store clusters are formed according to the location vicinity and DC capacities. Inventory management through DCs calls for reallocation decisions to restrict inventory reallocations at the level of clusters. Similarly optimization of human resource deployment among stores would involve employee transfer from one store to another that may negatively affect the employees' productivity and work morale. In this case the firm need to also consider human resource employee reallocation strategies within store clusters. The existing DEA based resource reallocation optimization models in the literature mostly considers reallocation decisions at the business level and ignores the additional requirements of decentralization. In this direction, the study proposes integrated centralised to decentralised resource reallocation model based on DEA to optimize distribution of centralised resources among a set of homogeneous business units (retails stores in this case) with the objective of maximizing the firm's sustainable efficiency. Application of the proposed model is validated and presented with a case study of a supermarket retail chain.

Supply Chain Restructuring for Omni-Channel Retailing: A Procurement-Distribution Planning Framework

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In recent years there has been a shift in the way customers purchase products. They no longer consider online and offline channels of the same firm to be separate. Customers want to buy products through the channel most suitable to them and wish to choose from delivery or self-picking up options according to their convenience. Under this situation, it becomes imperative for retailers to restructure their supply chains to best serve the customers in an efficient, timely and least costly manner. With customers wanting to simultaneously use the online and offline channels, the concept of omni-channel retailing has come into being. In omni-channel retailing, both the channels of a firm are fully or partially integrated. Customers can either buy a product online or pick it up in retail store or vice-a-versa. For ensuring a seamless integration of the two channels, firms are restructuring their supply chain and are developing new logistics models. Reconfiguration of the supply chain to adopt omni-channel retailing is a challenging task. This is so because each channel has its unique characteristics and they differ significantly in terms of information delivery and demand fulfilment. Restructuring the supply chain to manage these channels in an integrated manner and providing a seamless shopping experience to the customers requires a holistic transformation of the supply chain. Thus, new and updated supply chain

management policies for procurement of goods, distribution of goods and warehousing have to be developed incorporating the new paradigms of omni-channel retailing. An effective integration of the procurement and distribution processes is necessary for the efficient functioning of a supply chain. Procurement planning incorporates development of a purchasing plan of products from a supplier (manufacturer) for the time horizon considered, based on the demand. Various factors like transportation cost, quantity discounts, delivery lead times, etc. are considered while developing such a plan. Whereas, distribution planning involves the delivery of goods in a timely manner to their destination. Therefore, integrating procurement and distribution planning helps the firm in satisfying customers' demand in a cost-effective manner. The proposed research hence focuses on the development of a procurement distribution planning model as a part of supply chain restructuring for omni-channel adoption. A non-linear programming model has been proposed for this situation with the objective of maximizing the profit of procurement and distribution which includes various revenue generated by serving three types of demands, namely, online, offline and Buy-Online-Pickup-in-Store (BOPS) and various costs like purchasing cost, fixed ordering cost and transportation cost. The objective is obtained under constraints for inventory balancing, demand satisfaction, freight discount and quantity discounts. The model is validated with the help of a case study of an omni-channel retail chain in India having a well-established online, offline and BOPS

fulfilment options. It is solved using Lingo 11.0 software. The results obtained by solving the model indicate that the model is robust in nature.

Multi-objective Modelling approach for SustainableReverse Supply Chain Network Planning and 3PRLP Selection

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In order to successfully implement an effective Reverse Logistics (RL) network, electronic manufacturers are looking for better analytical solutions for choosing effective recovery strategies for products which reach their end-of-life/ end-of-use stage. Since many Electronic Manufacturing Companies (EMCs) lack the necessary requirements for effective recovery channel, they prefer completely outsourcing these activities to qualified and experienced Third-Party Reverse Logistics Providers (3PRLPs). Significantly, most of the EMCs are exploring the possibility of seeking alliances with 3PRLPs for managing their returned products sustainably. The collaborative alliance facilitates higher performance between the EMCs and 3PRLPs. Hence, it is important for EMCs to anticipate the tangible and intangible capabilities of the 3PRLP before venturing into a collaborative alliance on the basis of economic, environmental and

social attributes. Therefore it becomes crucial to present a mathematical model to determine the most preferred 3PRLP for collaborative alliance based on economic, environmental and social incentives. The key decisions taken by the model include selection of 3PRLPs as collaborative partners, determining the number of skilled technicians required for collaboration and the amount of returns to be processed at each echelon of the network. The proposed bi-objective fuzzy mathematical model optimises the RL network while capturing a trade-off between the profit earned by the EMC from the network and choosing 3PRLPs with high sustainable performance. Further, the bi-objective mathematical model developed in the study is validated for case of Indian EMC dealing with returned electronic equipments. Fuzzy programming approach is utilized to attain a satisfying solution to the mathematical problems. The proposed model aims to aid the decision makers of EMC in understanding the short as well as long term benefits that the company will endure under collaborative mode of operation for the Indian electronic industry. The result of the study suggests that by forming a strategic collaborative partnership, the EMC can improve the sustainability of the business operations. The collaborative alliance will help the EMC in identifying and capitalizing on optimum resource utilization thereby increasing the profitability of the network. The findings of the study demonstrate potential for the growth of collaborative alliance in the Indian electronics industry. The research focuses on the practical applicability of the collaborative alliance between the EMC and 3PRLPs for taking joint responsibility for proper channelization of the returned products.

Bi-Objective Optimization Model for Sustainable Supplier Selection considering Trade-off between Supplier Development and Supplier Switching

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In the current highly competitive market environment, there is a notable stakeholder pressure on companies to push sustainability into the supply chain. Hence, in order to gain competitive edge, adoption of sustainable practices is now central to core business objectives for manufacturing companies. For effective implementation of sustainable business strategies in supply chain, close coordination among all the supply chain partners is required. In this direction, an early step is to develop a strategic framework for identifying supplier base line, for engagement with suppliers for building shared mindset and for prioritizing sustainable efforts with suppliers as they play a crucial role in attaining the sustainable goals of the company. Further, companies can focus on developing effective performance monitoring systems for assessing the suppliers' performance to ensure sustainable compliance and continuous improvement. It can also aid in suggesting remediation efforts for non-performing and non-compliant suppliers. In this regard, the company needs to choose between the option of termination of

poor performing suppliers and/or investment in sustainable supplier partnerships for building suppliers' management capabilities. Moreover, the decision of supplier switching or supplier development is highly dependent on its economic impact on the supply chain. Therefore, the aim of this research is to develop a decision making model for sustainable supplier selection which aids in achieving cost effective trade-off between sourcing decision of supplier development and supplier switching. The methodological framework for developing the model involves four stages. In the first stage, a decision making team is formed that consists of experienced supply chain managers of the company and the potential sets of incumbent suppliers and new suppliers are selected.. Next, identification of sustainable evaluation criteria is done through extensive literature review and deliberation with the decision making team for performance assessment of suppliers. In the second stage, Best Worst Method (BWM) is utilized to compute the weights of the sustainable criteria for supplier performance evaluation. The results of the second stage are used in the third stage for evaluation of incumbent suppliers and new suppliers using Measurement Alternatives and Ranking according to the Compromise Solution (MARCOS). In the final stage, a bi-objective optimization model is developed to select the best performing suppliers and simultaneously optimize the supply chain cost and the weighted allocation to the selected suppliers. Epsilon-constraint method is used to solve the proposed optimization model. The proposed model is applied in real life case problem of home appliances manufacturing company to demonstrate the effectiveness of the framework.

Group Consensus Reaching Model for Sustainable Tier I Supplier Evaluation and Selection in a Multi-Tier Food Supply Chain

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In the present era, consumers are fully cognizant about the products that they consume as well as the impact generated by production of that product on the planet and people. This is especially true in case of agro-food products. This consciousness among consumers as well as binding government regulations is putting the agro-food industry of India under a lot of pressure. Thus, players of the industry are under constant radar to follow sustainable agricultural techniques, ensure food safety and maintain traceability. However, observance of sustainability practices is very difficult owing to the existing complex multi-tier structure of the Food Supply Chain (FSC). Hence, for an agro-food manufacturing firm, the need is to resolve consumer concerns regarding food safety and ensure that sustainability is embraced across all tiers of its suppliers. Within the context of India agri-food industry, farmers are typically the root tier suppliers of FSC who are not aware and inclined towards the sustainable goals of the firms. Hence, it is

imperative for Indian food manufacturing and processing firms to ensure that sustainability transmission happens right from Tier I suppliers till last tier suppliers. Thus, the pressing priority for the firm is to adopt those sustainable practices which can create sustainable impact not only on immediate suppliers but also on sub-suppliers. In general, the firm is in direct contact with only its Tier I suppliers and there is lack of communication and information sharing between the firm and its entire supplier network. This brings forward the crucial role which can be played by Tier I suppliers by acting as missing link between firm and lower tier suppliers. Sustainable accounting of Tier I suppliers become essential for extending the reach of sustainability facilities and measures provided by firm till its sub-suppliers. This can also aid in understanding the hindrances faced by sub-suppliers and identifying the causes of the non-compliance and underperformance of farmers with regard to sustainability. Consequently, these can then be addressed and resolved by the firm managers. In this regard, the current research work proposes to construct a strategic framework for sustainable accountability of Tier I suppliers based on the application of a group consensus reaching model. It is executed in three stages. Stage I involves analysis of a Field Survey which captures response of suppliers at all the tiers to i) understand their sustainability constraints and ii) to assess their sustainable conduct. In the subsequent stage, performance of Tier I suppliers is monitored through prior records available at the firm's data bank. In the final stage, a group consensus reaching model is developed in order to evaluate and select Tier I suppliers who can act as sustainability 'supervisors' and 'conductors' for the firm and contribute in their as well as firm's sustainable enhancement. A real-life case problem of an Indian flour milling company is considered to illustrate the usefulness of the proposed model.

Identification of Challenges to Implement Industry 4.0 and Circular Economy: A Case of an Indian MSME

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In the current competitive era, organizations are struggling to handle the adverse effects of unsustainable consumption. The basic idea of the linear economy of 'take-make-use-dispose' also contributes to sustainable issues. It has created a need for significant enhancement in resource performance around the global economy. Due to this, many organizations are exploring ways to reuse material/ components/ products and restore their value in the long run, paving way for the evolution of a new theory called Circular Economy (CE). CE enables the restorative and regenerative perspective for organizations and improves resource efficiency and sustainable performance of the supply chain. But the transformation of the linear economy to CE is constrained due to data discrepancies that hinder the attainment of

sustainability. To overcome these hurdles, organizations have moved towards an emerging technology called Industry 4.0. Industry 4.0 enables a higher level of efficiencies and also has the potential to majorly influence sustainable development across the organization. Hence, Integration of Industry 4.0 and CE can aid the organizations in the incorporation of better ecological control initiatives, process safety measures and sustainability aspects into their supply chains as well as gain a competitive edge in the market. In developing economies such as India, this is, however, a new concept since most organizations have insufficient knowledge to implement and adopt Industry 4.0 and CE in their system for improving current industrial system sustainability. Being the backbone of the economy of India, Micro, Small and Medium Enterprises (MSMEs) play a crucial role as a main wholesale and retail industry, distribution channel, raw material providers for large industries and contribute to a large extent to the GDP.

Hence, this paper aims to identify the major barriers that hinder the implementation of Industry 4.0 and CE in Indian MSMEs. Major challenges were identified by integrating the opinions of the decision body, industry experts and literature review. An integrated methodology of Importance Performance Analysis (IPA) and DEMATEL approach is proposed. IPA is adopted to understand the satisfaction of the customer in the MSMEs industry, and DEMATEL is adopted for the identification of cause and effect relationship among these challenges to aid the decision-makers in the proper implementation of Industry 4.0 and CE. The results of the study will aid the various stakeholders, such as the industry practitioners, policymakers and regulatory bodies to have a detailed understanding of the problems and eradicate the potential challenges in adopting Industry 4.0 and CEs for supply chain sustainability.

Joint Optimal ordering policies for noninstantaneous substitutable deterioration products with carbon emission and cost of substitution

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Carbon emissions are a big concern for both the businesses and global warming. Most organizations have concentrated on reducing the environmental impacts of business with sustainable financial benefits. This model demonstrates an inventory model for non-instantaneous substitutable deteriorating products under joint ordering policy with carbon emission. In this study, when a product is completely consumed due to demand and deterioration, the demand of that product is partially satisfied by other product and all unmet demand is lost sale. In this model deterioration rate and demand rate are assumed as deterministic, constant and triangular fuzzy numbers. The objective of this study is to determine the optimal ordering quantity and optimize the total cost function with carbon emission. This study introduces the solution

method and contains a numerical experiment to illustrate the application of the model. Sensitivity analysis is provided to get the impact of parameters and validity of the model.

Keywords: Green inventory model; Substitutable items; Carbon emission; Non-instantaneous deterioration

Green Design and product stewardship approach for two warehouse inventory model.

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Background/Objectives To trim down the recycling cost of any manufactured goods with the help of green design and product stewardship.

Methods/Statistical analysis: For the planned EPQ(economic production quantity model) model, all costs are calculated to find total cost and this total cost is optimized with the help of the Hessian matrix. Sensitivity analysis is also carried w.r.t. different parameters, to illustrate the impact of these parameters on the proposed model. The convexity of the total cost function is also checked with the help of mathematical software Mathematica 9.0.

Findings: Major finding of the proposed model are as follows (i) Increase in the number of recycles results in the reduction of the total cost. (ii) Product stewardship parameter has a negative effect on total cost as the PS increases from 1 to 4 units, total cost decreases from 5926.00 to 5918.96 units (see table 9). (similar findings can be written for numeric example 1 after correcting it). (iii) Green design costs have a positive effect on total cost, as the green design cost increases from 3 to 6 units, total cost also increases from 5918.49 to 5920.37 units (see table (10). (iv) increase in the number of recycles results in the reduction of the total cost, as the number of recycles increases from 20 to 50 units total cost decreases from 5922.87 to 5919.12 units (see table 11).

Novelty/Applications: The Study of the effects of recycling by this green design and product stewardship approach makes the proposed model distinctive from the existing methods. The proposed model applies to eco-friendly manufacturing items with green design and product stewardship.

Index one generalized observer design for linear descriptor systems with unknown inputs

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The paper considers the following linear time invariant descriptor system

$$E\dot{x} = Ax + Bu + Fv, \tag{1a}$$
$$y = Cx + Gv, \tag{1b}$$

where $x \in \mathbb{R}^n$, $u \in \mathbb{R}^k$, $v \in \mathbb{R}^q$, and $y \in \mathbb{R}^p$ are the state vector, the control input vector, the unknown input vector, and the output vector, respectively. $E \in \mathbb{R}^{m\times n}$, $A \in \mathbb{R}^{m\times n}$, $B \in \mathbb{R}^{m\times k}$, $F \in \mathbb{R}^{m\times q}$, $C \in \mathbb{R}^{p\times n}$, and $G \in \mathbb{R}^{p\times q}$ are known constant matrices.

Descriptor systems arise naturally in various real world applications as they are general enough to describe the intrinsic properties of underlying physical systems [1,2]. Contrary to state space systems, descriptor systems are very sensitive to slight input changes because higher order derivatives of inputs appear in solutions of descriptor systems [1]. This motives to consider the presence of unknown inputs in dynamic as well as in output equations of system (1). In the existing literature, various kinds of observers have been designed for systems of the type (1) see [3] and the references therein. In this work, the following sufficient conditions are given for the existence of generalized observers of index one for system (1).

$$\textbf{(H1)}\ \operatorname{rank}\begin{bmatrix} E & A & F & 0 & 0 \\ 0 & E & 0 & F & A \\ 0 & C & G & 0 & 0 \\ 0 & 0 & 0 & G & C \\ 0 & 0 & 0 & 0 & E \end{bmatrix} = \operatorname{rank}\begin{bmatrix} E & F & A \\ 0 & G & C \\ 0 & 0 & E \end{bmatrix} + n + q,$$

$$\textbf{(H2)}\ \operatorname{rank}\begin{bmatrix} A - \lambda E & F \\ C & G \end{bmatrix} = n + q\ \forall\ \lambda \in \bar{\mathbb{C}}^{+},$$

The proposed conditions are milder than the existing conditions [3, 4] required to design Luenberger observer for system (1).

Keywords

Observer design, Descriptor systems, Unknown inputs

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