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Preface

The *1st Iberian Conference on Multi-Criteria Decision Making/Analysis* (IMCDM/MCDA 2025) marks the beginning of a new series of Iberian conferences on this topic, made possible through the collaboration between the *Associação Portuguesa de Investigação Operacional* (APDIO) and the *Grupo Español de Decición Multicriterio* (GEDM). Future editions will be held alternately at Portuguese and Spanish universities, strengthening ties between these two scientific communities.

This conference provides an interdisciplinary forum for the presentation of recent developments, models, and applications in the field of Multi-Criteria Decision Making/Analysis. Its aims to disseminate innovative methods and techniques related to MCDA/MCDM, primarily (though not exclusively) involving researchers and practitioners from Portugal and Spain.

The scientific program includes nineteen oral presentations organized into five thematic sessions, complemented by a poster session showcasing seventeen additional papers. Two plenary lectures will be delivered by internationally recognized researchers in the field. Professor Ana Barbosa-Póvoa from the University of Lisbon, and Professor Francisco Ruiz de la Rúa from the University of Málaga. Their lectures are titled “Multi-objective optimization for sustainable supply chain design and planning” and “Interactive multiobjective optimization methods: Trading off and desirable properties,” respectively.

A special session will also be held in connection with the first edition of the Iberian Doctoral Theses on Multicriteria Decision Making Award, supported by ASEPUMA and the Spanish network on MCDM (Grant RED2022-134540-T). This session will highlight the work of the award recipients, who will present their doctoral theses and receive formal recognition.

This first edition has been jointly organized in Coimbra by APDIO, the *Instituto de Engenharia de Sistemas e Computadores* (INESC) of Coimbra, the *Sociedad Española de Estadística e Investigación Operativa* (SEIO) and the GEDM (Spanish network on MCDM). With the participation of over sixty researchers, the conference reflects the growing interest and strong engagement in MCDA/MCDM within the Iberian community.

Amparo Maria Marmól Conde (Universidad de Sevilla)

Maria João Alves (Universidade de Coimbra)

Antonio Jiménez Martín (Universidad Politécnica de Madrid)

Carlos Henggeler Antunes (Universidade de Coimbra)

Plenary Sessions

Multi-Objective Optimization for Sustainable Supply Chain Design and Planning

Ana Barbosa-Póvoa

Center for Management Studies (CEG-IST), Instituto Superior Técnico, University of Lisbon, Portugal

Abstract

The growing recognition of sustainability's importance is transforming supply chains, driving them toward the development of sustainable supply chain networks. These networks are complex systems of interconnected entities that manage the flow of products from suppliers to customers, including returns, while addressing economic, environmental, and social objectives simultaneously. Integrating environmental and social goals alongside traditional profit-driven objectives presents significant challenges due to the inherent complexity of supply chains. To address these challenges, multi-objective optimization models have proven to be essential tools for balancing these diverse and often conflicting goals. By utilizing optimization-based approaches, supply chain decision-makers can systematically incorporate sustainability objectives while accounting for the structural complexities and operational constraints of supply chains. This work explores the key components of these multiobjtive models, demonstrating their application in real-world base cases to support the design and planning of sustainable supply chains.

Bio

Ana Barbosa-Póvoa is a Full Professor in Operations and Logistics at the Engineering and Management Department of Instituto Superior Técnico (IST), University of Lisbon. She holds a PhD from Imperial College of Science, Technology, and Medicine.
Her research focuses on developing a deep and comprehensive understanding of complex problems in supply chains and operations management, supported by innovative engineering systems models and techniques. Key areas of her work include sustainability, resilience, uncertainty, and risk management in the design and planning of supply chains. Ana is the founder and coordinator of the Operations Management, Logistics, and Supply Chain Management (OpLog) research group at IST's Centre for Management Studies(CEGIST). She has extensive experience in supervision and has secured multiple research grants. Her contributions have been recognized with numerous national and international awards,

including twice being named the Best Researcher in Industrial Management at the University of Lisbon. Ana serves as an editor for the Computers and Chemical Engineering Journal and sits on the editorial boards of several prestigious journals, including the European Journal of Operational Research, the International Journal of Production Economics, TOP, and Operations Research Perspectives. She is also Vice President of EURO, the European Association of Operational Research Societies, and a founding member of the EURO Working Group on Sustainable Supply Chains, where she is part of the coordination team. She has also being a founding member of the EURO WISDOM Forum, where she serves on the events sub-committee. Additionally, she is a member of the EURO Working Groups on Retail and Location and Analysis.

Interactive Multiobjective Methods: Trading Off and Desirable Properties

Francisco Ruiz de la Rúa

University of Málaga, Spain

Abstract

Interactive methods have proven to be very useful tools in real decision-making processes, mainly due to two factors: the gradual incorporation of preferential information by the decision-maker and the promotion of learning processes about the problem. However, empirical studies have shown that in real applications the number of iterations performed is often excessively low. This phenomenon has often been attributed to the fact that the decision-maker must move between Pareto optimal solutions, and therefore must always lose on some objective in order to improve another. This was the motivation for developing a family of trade-off-free interactive methods: the NAUTILUS methods. These start from a poor (inferior) solution and progress to the efficient frontier, such that at each iteration improvements are obtained in all objective functions. This talk presents the different versions of the NAUTILUS methods developed so far. On the other hand, there are currently a large number of interactive methods that differ from each other, among other aspects, in the type of preferential information that the decision maker must provide in each iteration. The question therefore arises of how to choose the most appropriate method in each specific situation. Furthermore, in real decision-making processes using interactive methods, two phases are usually distinguished. A first learning phase in which the decision-maker explores different parts of the efficient set until reaching his zone of interest and a second decision phase in which the decision-maker finetunes his preferences within his zone of interest until finding his most preferred solution. It is therefore logical to wonder whether there are methods that work better at one phase or another, so that it is advisable to use a combination of methods within a decision-making process. In this talk, we present a series of studies and tests with real decision makers that attempt to determine the desirable properties of an interactive method, how to evaluate methods according to these properties, and the advantages of combining methods of different types in a single process.

Bio

Francisco Ruiz is a full professor of Quantitative Methods for Economy at the University of Málaga in Spain. He teaches at graduate courses in Economy, Business Administration and Marketing, in the Masters Course in Quantitative Methods for Economy, and in the PhD program in Economy and Business Administration. His research activities are focused on multi-objective programming methodologies, mainly in interactive methods and their applications to decision making processes in industry, development of composite indicators and sustainability assessment. He has been the Secretary of the International Society on Multiple Criteria Decision Making (www.mcdmsociety.org) and one of the coordinators of the Spanish Group on Multiple Criteria Decision Making (www.multicriterio.es). Francisco Ruiz received his BSc degree in Mathematics in 1989, and his PhD degree in Economy and Business Administration in 1994, both at the University of Málaga. He has carried out his professional activity at this institution, where he has held different positions until he became a full professor in 2009. He has stayed as visiting researcher at the University of Georgia (USA), the University of Manchester (UK) and the University of Jyväskylä (Finland). Francisco Ruiz is the (co)author of more than 90 publications (including papers in professional journals, proceedings of conferences, and book chapters) and has reviewed papers for over 40 international journals. He has participated in nearly 40 research projects, and he has held joint research activities with several Universities in Europe and North America, as well as with public and private companies. In 2024, he received the Georg Cantor Award by the International Society on Multiple Criteria Decision Making.

Oral Communications

A semivectorial bilevel optimization model to optimize energy prices at charging stations for electric vehicles

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Abstract

The growth in the number of electric vehicles in recent years has heightened the need for effective pricing strategies at charging stations to balance the demand of energy, reduce charging costs and enhance the user's experience. When deciding whether to use a given charging station or seeking an alternative, electric vehicle users consider various factors, including pricing and the total time required for charging. If prices are too high or exceed their budgets, users may opt for alternative charging options, such as home charging. Conversely, very low prices can increase demand, leading to congestion and longer waiting times, which, in the end, result in a degradation of the quality of service. Moreover, the total time required for charging depends also on the rated power of the chargers as well as on travelling times from users' locations to charging stations. Since electric vehicle users react to the prices set by the charging station operator, the system exhibits an inherent hierarchical structure; therefore, bilevel optimization provides a suitable framework for modelling this problem. At the upper level, the charging station operator determines energy prices at each station and seeks to maximize total revenue. At the lower level, users decide whether to use a charging station or not, aiming to minimize both the charging costs and the total time required for charging their vehicles. Building on these considerations, this research focuses on formulating a bilevel

optimization model for this problem, where the lower level problem has two objective functions. The solution approach proposed in this study employs a matheuristic algorithm that combines an evolutionary algorithm to explore the feasible set of the upper level decision variables with an off-the-shelf optimization solver to exactly solve the lower level problem for given values of the upper level variables.

Keywords: Electric vehicles, Charging stations, Pricing, Bilevel optimization, Multiobjective optimization

Optimal comonotonic actuarial risk redistribution

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Abstract

The optimal reinsurance problem is a classical application of Operational Research in Actuarial Science, and a very interesting overview of the state of the art may be found in Albrecher et al. (2017). This is an important actuarial problem because it provides the insurer with an efficient risk transference methodology that significantly mitigates the ruin probability. Besides, risk-sharing problems are becoming more and more studied. The reason is that in some cases a single company cannot assume all the risk that a contract may generate. Indeed, suppose that there is a need to insure events that can provoke large damages such as, for example, the costs associated with a toxic spill at sea, or the loss of a large ship or aircraft. The main notion to address risk-sharing problems is the inf-convolution (Hamm et al., 2020, Chen and Xie, 2021, etc.), which allows a certain level of risk to be assigned to each of the insurers sharing the contract. In this paper we propose a new approach allowing insurers to share risks that cannot be diversified. Instead of sharing a new risk, let us suppose that every involved insurer already has a portfolio of policies whose risks are highly correlated. For instance, the insurer is covering risks associated with catastrophic events such as floods, droughts, earthquakes, etc. Although these problems are often addressed by means of reinsurance policies, the global warming is causing this type of accident to occur much more frequently than in the past, which makes it advisable to have other coverage mechanisms in place. Consequently, instead of an allocation associated with inf-convolutions, we will consider a set of insurance companies acting simultaneously as ceding and reinsurer, that is, every company will accept a proportion of each of the other's portfolios and will cede a proportion of its own portfolio to each of the remaining companies. As usual in the optimal reinsurance literature, we will suppose that all the reinsured risks will be comonotonic (Dhaene et al., 2002, or Delbaen, 2021) in order to prevent the moral hazard. The comonotonicity will be reached by replacing the ceded risks with the marginal ceded risks as decision variables, in the line of Balbás et al. (2022) and (2023). The objective of such a plan is to minimize the risk that every company is facing without reducing its expected benefit.

The outline of the paper is as follows. The framework and some basic background will be summarized in section 2, and section 3 will be devoted to setting up the global optimization problem. This problem will be a multiobjective one, since we will have as many targets as involved insurers. Every insurer will be interested in its risk minimization, where each risk is going to be measured by a coherent risk measure (Artzner et al., 1999), an expectation bounded risk measure (Rockafellar et al., 2006) or a deviation measure (Ogryczak and Ruszczynski, 1999, or Rockafellar et al., 2006). Necessary and sufficient Pareto optimality conditions will be given. The notion of systemic risk will be introduced in section 4, as well as its existence and properties. It will be shown that insurers cannot reach the systemic risk, and consequently we will also introduce the concept of background risk per insurer, that is, the minimum risk level that each insurer might reach if the rest of participants accepted the corresponding plan (or Pareto solution). The set of background risks will generate the ideal point of the problem, which will be used to generate new optimization methods closely related to compromise programming. Section 5 will be devoted to particularizing the previous findings to the case of two insurers, and numerical illustrative examples will be developed. These examples will show how the approach of this paper may significantly reduce the risk level of every involved insurer.

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Keywords: Actuarial systemic risk, background risk, optimal co-monotonic risk-sharing.

Enhanced BPSO for Binary Optimization: A Robust Metaheuristic for Complex Problems (RRPS-PAT)

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Abstract

This work presents a variant of the *binary particle swarm optimization* (BPSO) metaheuristic that introduces a dynamic change in the sigmoid function and a repair and improvement method for infeasible solutions. This approach is applied in the decision support system for air traffic management during pandemics, RRPS-PAT (Risk Reduction in Pandemic Spread – Passenger Air Traffic Management) (Peña et al., 2025), to evaluate and optimize restriction or reopening strategies for air connections while considering multiple objectives and epidemiological, economic, and social constraints.

The RRPS-PAT system considers the following objectives: Minimization of epidemiological risk importation; Minimization of economic losses in airport influence areas (business and tourism); Fair distribution of losses among regions and airlines; Minimization of fiscal losses at airports due to landing reductions; and Minimization of social impact (loss of connectivity and affected passengers).

Additionally, the system incorporates decision-makers' preferences using the *reciprocal sum* method (Danielson *et al.*, 2014) to derive a weight vector and transform the multi-objective optimization problem into a weighted function. Finally, the enhanced BPSO variant is employed to solve the problem and obtain a compromise solution.

With the implementation of RRPS-PAT, decision-makers can evaluate different scenarios and select optimal strategies to mitigate pandemic spread without excessively compromising the economy and global air connectivity.

To demonstrate the performance and efficiency of the new BPSO metaheuristic, five main comparisons were conducted with various algorithms across three benchmark datasets. These tests assessed its ability to solve optimization problems in binary search environments using multiple performance metrics.

Five comparisons (Evural & Huseying, 2023) were conducted to evaluate the proposed method's performance and efficiency against various algorithms on three benchmark datasets.

The first comparison was performed on BD-1, where the proposed method was tested against nine binary variants of algorithms, including PSO (Particle Swarm Optimization), GHS (Global Harmony Search), AFSA (Artificial Fish Swarm Algorithm), MA (Memetic Algorithm), EHO (Elephant Herding Optimization), and RSA (Reptile Search Algorithm), under identical execution conditions. The second comparison contrasted the new BPSO with six state-of-the-art algorithms in BD-1, adapted to the binary space using the V2 transfer function. The third comparison evaluated the method against five binary variants of DE (Differential Evolution), two PSO variants, and one RSA (Reptile Search Algorithm) in BD-2, using 5000 Max-FEs and 30 runs for the KP problems in this dataset. The fourth comparison included SA (Simulated Annealing), GSA (Gravitational Search Algorithm), and IGA-SA (Improved Genetic Algorithm - Simulated Annealing) in BD-3, along with BWOA (Binary Whale Optimization Algorithm) and BMPA (Binary Moth-Pollination Algorithm), all assessed under different iteration and Max-FEs conditions. Finally, the fifth comparison tested the new BPSO against seven binary variants of state-of-the-art algorithms, adapted with different transfer functions, in BD-3.

The new BPSO variant proposed in this study has demonstrated superior performance compared to all other evaluated methodologies across the three benchmark datasets. Thanks to the integration of the dynamic change in the sigmoid function and the repair and improvement method for infeasible solutions, this optimized version achieves higher-quality solutions in fewer iterations and with greater stability across different optimization scenarios. Experimental results show that the proposed approach outperforms 26 different methods in 63 optimization problems, establishing itself as a highly efficient and robust metaheuristic. Due to its ability to solve complex problems, this methodology could be of great interest for applications in various fields, including air traffic management during health crises and decision-making in dynamic, high-uncertainty environments.

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Keywords: Metaheuristics, Decision Support Systems, binary optimization, multicriteria decision making.

How to Enhance Students Well-Being in Spain: A Multidimensional Study based on Multiobjective Optimization

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Abstract

There is a growing interest in adolescent academic performance, which is influenced by a range of factors, including student well-being. Research has shown that well-being, encompassing social, physical, and mental dimensions, is closely linked to academic success. Policies aimed at improving well-being can enhance academic outcomes and help address socioeconomic inequalities in education. The impact of globalization, technological advances, and the COVID-19 pandemic on education has made decision-making more complex, emphasizing the need for data-driven policies.

This paper addresses the multidimensional nature of the concept of student well-being from a multiple criteria decision making perspective, specifically differentiating between the social, physical and mental dimensions. The main purpose is to analyze how the well-being levels among Spanish students could be improved. Using PISA 2022 data, three indexes of student well-being are constructed: social, physical and mental. Using econometric tools, a multiobjective optimization model is developed to simultaneously maximize the three proposed indexes. To obtain solutions that balance improvements across all dimensions, the problem is solved using an achievement scalarizing function approach (Wierzbicki, 1980), an extension of the Tchebychev distance method. In this formulation, the three objective functions are equally weighted, ensuring that the social, physical, and mental perspectives of

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well-being are optimized with the same importance. This approach identifies solutions that best satisfy reference values, set as the ideal values of each well-being index.

Additionally, to account for significant correlations between students' socio-educational characteristics, bound constraints are incorporated into the model. These constraints are formulated using the confidence intervals (at 90%) of the coefficients obtained from a linear regression study performed on the independent variables, ensuring that they remain within realistic ranges according to the dataset.

Furthermore, an analysis of the ideal and anti-ideal values provides insights into the potential improvements for each well-being indicator. This analysis highlights the trade-offs between the different dimensions of well-being, demonstrating that achieving a balanced improvement across all indicators requires compromises.

The results make it possible to evaluate the real possibilities for improving the three well-being dimensions and the scenarios that would make it possible (i.e. socio-educational context for the students). This allows foreseeing the impact of the change in one of the indexes on the other two. In addition, existing correlations between students' socio-educational characteristics are introduced into the model to represent the student's context as realistically as possible. The findings indicate that students who seek to optimize their well-being from the triple perspective adopted (physical, social and mental) must make trade-offs between the indicators in order to achieve a balanced solution.

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Keywords: multiobjective optimization; econometric analysis; students´satisfaction

New insights in Evolutionary Multiobjective Optimization: Adaptive reference points and weight vectors to improve convergence and solutions distribution

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Abstract

Multiobjective optimization problems require algorithms that can efficiently approximate the Pareto optimal front while ensuring good convergence and diversity. Although there are a considerable number of algorithms that try to approximate the Pareto optimal front as well as possible, their convergence and performance depends on the shape of the front.

In this paper, we introduce and analyze two frameworks to enhance the search process in the later stages of Evolutionary Multiobjective Optimization algorithms.

Our approach leverages certain approximation of the Pareto optimal front for a multiobjective optimization problem and defines some subregions based on different reference points, and compute weight vectors to improve the algorithm' s convergence towards the true Pareto optimal front. Specifically, we propose a framework that partitions the objective space into subregions and use a dynamic adaptation of weight vector distributions based on the front's geometry. Additionally, we are working to incorporate the concept of Riesz Energy to further refine the final distribution of solutions, ensuring a more uniform and well-spread approximation of the Pareto front.

Experimental results on the WFG benchmark suite demonstrate that our approach enhances convergence, as measured by the hypervolume quality indicator, when used with the well-known evolutionary algorithm NSGA-III.

This work underscores the potential of embedding these mechanisms into Evolutionary Multiobjective Optimization algorithms, particularly for bi-objective optimization problems, paving the way for future extensions to many-objective optimization scenarios.

Keywords: multiobjective programming, evolutionary algorithms, Achievement scalarizing function, weight vectors adaptation, reference point.

WEB-MAUT-DSS. A web-based DSS based on MAUT to deal with partial/incomplete information

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Abstract

WEB-MAUT-DSS is an improved web-based version of the generic multi-attribute analysis (GMAA) system, Jiménez *et al*. (2006). It is a decision support system based on the Decision Analysis methodology (Belton, 1990) with an additive multi-attribute utility model to address complex decision-making problems with partial/incomplete information.

WEB-MAUT-DSS accounts for uncertainty about the performances of the alternatives under consideration by means of probability distributions or ordinal information, and imprecision concerning the quantification of the decision-maker (DM) preferences. A direct assignment and a combination of two gamble-based methods are provided to assess component utilities, allowing the DM to provide imprecise information, which leads to classes of utility functions.

Weights are hierarchically elicited using different weighting methods. A direct assignment and a method based on trade-offs, were originally provided in the former GMAA system. WEB-MAUT-DSS incorporates weighting methods based on ordinal information. Specifically, the *sum reciprocal* method, a surrogate weighting method in which only ordinal information on weights is demanded, Danielson *et al*. (2014), but also weighting methods accounting for additional information about the strength of the differences between the ranked criteria. Specifically,

- the *cardinal and rank ordering of criteria* method (Larsson *et al*., 2015), a two-stage distance-based method that considers cardinal information about the strength of the differences,
- the method proposed in Aguayo *et al*. (2014), which accounts for a ranking of differences and computes the centroid of a polytope delimited by constraints representing the available information on weights,

- and the *cardinal sum reciprocal* method (Danielson & Ekenberg, 2017), an extension of the *sum reciprocal* method that uses a semantic scale.

Different weighting methods could be used at the different levels and branches of the objective hierarchy, depending on the information that the DMs are willing/able to provide. This makes the systems suitable for group decision-making, especially in a multidisciplinary context. Then, each DM would participate in the weight elicitation for the criteria in which he/she specializes (Gómez-Jiménez *et al*., 2025).

An additive multi-attribute utility function is used to evaluate the alternatives under consideration. If alternative performances are represented under uncertainty by intervals, then the model is used to compute the minimum, average, and maximum overall utility for each alternative. A ranking of alternatives based on the average overall utilities is derived, whereas the overall utility intervals provide information on the robustness of such a ranking. However, if probability distributions different from the uniform or ordinal information are used to represent the alternative performances, then Monte Carlo simulation techniques are used, in which alternative performances but also component utilities and weights are randomly generated from the corresponding probability distributions or intervals, and a multiple boxplot representing the positions of the alternatives in the different rankings is output.

WEB-MAUT-DSS provides different sensitivity analysis tools that take advantage of the imprecise available information to provide further insights about the robustness of the results, including the assessment of non-dominated and potentially optimal alternatives, of weight stability intervals, and Monte Carlo simulation techniques on the attribute weights.

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Keywords: Decision Support Systems, MAUT, Partial/incomplete information.

Multiobjective stochastic optimisation for long and short-term planning of prepositioning in humanitarian logistics

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Abstract

In the context of natural disasters, response preparedness is key to saving lives and alleviating suffering. Preparedness in humanitarian logistics includes the pre-positioning of relief aid, which is especially critical in developing countries, as transport and supply chains are less reliable in the face of adverse events. Additionally, prepositioning in short-term planning is subject to long-term decisions related to warehousing.

A planning model has been developed for strategic decisions on the location of warehouses and tactical decisions on pre-positioning in the face of different seasonal disasters, taking into account the stochasticity represented by a distribution of disaster scenarios. Decisions related to warehouses concern location planning and sizing over a time horizon. Tactical decisions relate to the pre-positioned aid in the warehouses for each season. These decisions are evaluated in terms of their performance in a set of representative disasters, characterised by the quantity demanded by those affected and their location.

The model includes two objectives to assess the performance of strategic and tactical planning in operations under different scenarios: the expected deviation from the annual budget allocated, and the expected unmet demand. In Rodriguez-Martinez (2021) a scalarisation based on the weighting method was proposed to obtain the Pareto frontier and applied with data of a province in Mozambique.

However, the run times were too long to be useful in real situations. Therefore, some experiments have been developed to obtain a better approximation of the Pareto frontier with a limited runtime. These experiments include the ε-constraint methodology, the inclusion of

penalties for the most remote locations and the comparison between various formulations. This paper will present the results after these changes. Future work includes some strategies for solving the model, as Benders Decomposition, which has already been applied to a simplified version of the case study.

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Keywords: Multiobjective stochastic optimisation, humanitarian logistics, location models, scenario generation

A Bi-Objective Optimization Approach to Reducing Energy Poverty Through Biomass Gasification: The Case of Rural Colombia

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Abstract

It is well known that energy poverty hinders socio-economic development in off-grid communities. The lack of reliable, clean, and affordable electricity impacts health, economic opportunities, and social well-being, with significant effects documented in Europe, OECD countries, and Africa. Despite global efforts, 10% of the world's population still lacks electricity, and 2.4 billion people rely on polluting fuels for cooking. While governments provide subsidies to improve rural electrification, inefficient budget allocation strategies create high costs for households, limiting electrification benefits. Biomass, a clean and abundant energy source, remains underutilized and overlooked in rural energizations plans worldwide, but especially in Colombia, where it accounts for only 1.5% of off-grid energy despite a 16 GW potential.

This research develops a bi-objective optimization model to assess the feasibility of biomass gasification as an alternative to diesel-based electrification. The purpose is to explore to what extent biomass gasification can reduce energy poverty under current rural electrification budget conditions. The proposed model balances two key objectives: (1) expanding energy access and (2) reducing household overspending on energy services. To this end, we introduce two novel energy poverty indices—energy access gap (EAG) and energy service overspending (ESO)—to evaluate trade-offs between different budget allocation strategies. The model also incorporates socio-economic and technical constraints, using rural settlements´ population, density, energy demand, and biomass availability, among others, as input data.

The model is formulated as a Mixed-Integer Quadratic Programming (MIQP) problem with approximately 15,529 constraints, 6,900 binary variables, and 3,450 linear variables. The model was solved using the commercial software Lingo, and various Pareto-efficient solutions

were generated to help policymakers explore the advantages and disadvantages of different budget allocation strategies. The complete set of Pareto-efficient solutions was obtained by assigning different pairs of weight factors to the proposed energy poverty indices, EAG and ESO, as well as by testing various budget energization limits.

The case study used to test the model involved 575 off-grid settlements in Colombia, where communities rely on inefficient diesel generators despite having abundant biomass resources. The results indicate that biomass gasification could replace diesel in up to 78% of the studied rural settlements, resulting in an 89% reduction in diesel consumption while maintaining the current government budget. Additionally, testing a universal 85% energy bill subsidy policy proved effective in reducing household overspending, making energy more accessible and equitable.

Thus, this research contributes to the literature by proposing a novel bi-objective optimization model that provides a decision-support tool for optimizing subsidy distribution and electrification planning, offering actionable insights for policymakers. It underscores the importance of strategic budget allocation in ensuring long-term viability of rural electrification programs, and demonstrates that biomass gasification is a viable and underutilized electrification strategy to contribute to the achievement of sustainable energy solutions for the rural poor. By improving budget allocation decisions, this study provides a framework for enhancing energy access, reducing energy poverty, and promoting sustainable rural electrification in Colombia and other developing regions.

Keywords: Bi-objective Optimization; Energy Poverty; Off-grid Electrification; Biomass Gasification; Budget Allocation;

Leveraging MCDA for Colorectal Cancer Screening Strategies

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Abstract

Developing cancer risk models enables the integration of predictive insights into decision-support tools for personalized screening and treatment recommendations. By quantifying the impact of key medical variables on cancer risk, these tools can identify risk groups, informing the design of targeted screening and treatment programs. In this work, we present a multi-criteria decision analysis (MCDA) framework for personalized cancer screening, supporting decisions on whether to undergo screening and which method to choose. Our approach integrates a Bayesian network for cancer risk modelling with a structured decision-making process based on an influence diagram that explicitly accounts for multiple criteria. These include screening costs, potential complications, patient comfort, and the diagnostic value of each method. A multi-attribute utility model systematically aggregates these criteria, leveraging constructed attributes and information theory measures to reflect policy-level preferences while accounting for risk attitude. This approach not only enables the comparative assessment of existing screening programs but also provides a principled foundation for designing novel screening strategies and evaluating emerging screening technologies.

Keywords: Colorectal cancer screening, Influence Diagram, Utility assessment, Value of Information, Public Health Policy.

Multi-criteria decision methods for Urban Heat Island identification using Geographic Information Systems

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Abstract

Urban areas consume 78% of global energy and are responsible for up to 60% of global CO_2 emissions, even though they represent only 2% of the Earth's surface. Increasing urbanization has a direct impact on urban temperature, both surface and ambient. This phenomenon is known as Urban Heat Islands (UHI), which can be defined as *those urban areas where both surface and ambient temperatures are higher than those recorded in nearby rural areas, creating a distinct urban microclimate.* The generation of UHIs involves numerous factors with a strong local component, being closely related to the geometry and climatology of the city.

The identification of these UHIs is crucial in decision-making processes when it comes to adopting precise mitigation measures aimed at improving the city's energy performance. Recent advances in digitization and urban monitoring have allowed significant progress to be made in this regard. Specifically, two methodologies are under development:

- *Internet of Things (IoT) Monitoring:* To monitor cities in real time, this approach deploys sensors throughout the urban core. However, this methodology is cost-intensive, complex, and requires time to generate historical data to justify the different mitigating actions carried out.
- *Remote Sensing via Satellite Thermal Imaging:* This method uses satellite thermal imaging to obtain nighttime surface temperature data. However, the number of public domain satellites specialized in nighttime infrared thermal imaging is limited. Therefore, data collection is restricted in time (due to the satellite´s repetition cycle), resolution (surface area covered per pixel), and climatology (since clear skies are required at the time of image capture). Two of the most used satellites in this field are: MODIS, with 1 km resolution and 1-day repetition cycle, and ASTER, with 90 m resolution and 16-day repetition cycle.

Due to the challenges associated with acquiring and processing data to identify UHIs, the scientific community is immersed in the search of a fast, robust, and universal methodology to overcome the barriers detected in the current approaches. The objective of this work is to characterize UHIs based on surface temperature using a finite collection of parameters. In this way, a general methodology would be created to be easily applied to different urban centers sharing similar characteristics, such as belonging to the same climate zone.

This research explores the application of different Multi-Criteria Decision Methods (MCDM) and Artificial Intelligence (AI) to develop a robust and easily applicable methodology to predict surface temperature. The objective is to obtain which evaluated model performs best when predicting UHIs across different cities of Spain, classified according to the climate zones established by the Spanish Technical Building Code. After an extensive literature review, the decision variables have been reduced to five easily collectible and GIS-integrable: altitude, wind corridor, Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Sky View Factor (SFV). Among the models compared, COmplex PRoportional Assessment (COPRAS), Weighted Aggregated Sum Product Assessment (WASPAS), and the deep learning algorithm “tf.keras” stand out.

The validation of the methodologies has been performed by comparing the surface temperatures predicted from each model with a synthetic satellite image generated using ASTER and MODIS nighttime land surface temperatures. The Mean Absolute Percentage Error (MAPE) and the Root Mean Square Error (RMSE) were selected as Key Performance Indicators (KPIs). The models have been applied to four cities, each representing a different climate zone: Palencia (climate zone I), Teruel (climate zone II), Guadalajara (climate zone III), and Jaén (climate zone IV). Results shown that the mean KPIs for tf.keras (MAPE=15.5% and RMSE=3.8%) were higher than those of the MCDM models (MAPE=3.7% and RMSE= 1.5%) .

As future work, due to the promising results obtained, more quantitative and qualitative decision variables could be incorporated into MCDMs, as they offer an attractive alternative for modeling UHIs. The ultimate goal is to develop an accessible and useful GIS tool to assist stakeholders in urban planning, the implementation of mitigation measures, and the enhancement of energy efficiency in cities.

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Keywords: Urban Heat Island; Multi-Criteria Decision Method; Land Surface Temperature, Geographic Information System: Artificial Intelligence

Energy Expenditure and Ergonomic Risk in Industrial Task Assessment using TOPSIS

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Abstract

Industrial work environments expose workers to physical strain that can lead to musculoskeletal disorders (MSDs) over time. Evaluating the ergonomic risk of workers remains a significant challenge, requiring quantitative and systematic methods to identify potential hazards. The most prevalent ergonomic risk factors are the prolonged use of hand tools, exposure to mechanical pressure on the upper limbs, and awkward postures. To improve workers' health and workplace ergonomics, decision-making techniques have been increasingly used to help ergonomic professionals (Khandan et al., 2017). While different ergonomic assessment methods exist, a multi-criteria decision-making approach can provide a structured and quantitative way to prioritize tasks.

This study aims to integrate multi-criteria decision-making (MCDM) methods into ergonomic risk assessment, focusing on analyzing specific tasks based on energy expenditure and postural risks using the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method.

The Garg et al. (1978) equations were used to estimate net metabolic cost (kcal/movement) for each task, considering task type, posture, load, and motion. This is one of the most common methods used in the research of industrial to measure the energy spent by operators. To evaluate the ergonomic risk levels, the Rapid Entire Body Assessment (REBA) method was applied by dividing the body into segments regarding the movement angle (Hignett, 2000).

The results show that it is possible to rank and prioritize physically demanding tasks by quantifying the trade-offs between metabolic workload and postural risks, offering a structured method to compare tasks with varying ergonomic demands. Some tasks exhibited high energy expenditure but low ergonomic risk, suggesting metabolic demand without severe postural strain. A sensitivity analysis confirmed that the ranking remained robust across varying weight distributions.

The research shows that MCDM can assist in ergonomic interventions and workplace design improvements. By prioritizing specific movements, this approach facilitates the selection of the best occupational health promotion procedures, allowing for the optimization of movement choices to reduce ergonomic risks. The proposed ergonomic framework enables managers to allocate tasks more effectively by considering individual ergonomic constraints. By doing so, shop floor managers can make informed decisions with a structured ranking system to identify high-risk tasks, optimize job rotation, and allocate workers based on individual ergonomic needs.

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Keywords: Ergonomics; multi-criteria decision-making (MCDM); TOPSIS; manufacturing

Urban Form and Function: A Multi-Criteria Decision Analysis Approach

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Abstract

Cities are complex systems, places of increasing population concentration, wealth generation, and social and economic interactions. However, cities are also places where large amounts of energy are consumed and pollution is produced. The development and evolution of a city must consider issues of sustainability, resiliency, and equity, prioritizing the quality of life of its residents. This development is directly related to its form, i.e., its physical characteristics such as size, transportation network structure, land use, spatial arrangement, and its function, related to society, including social and economic factors and all activities that take place in its space. Form and function are essential concepts that shape the city and should enable a conscious decision-making process about the evolution of its urban space.

This research aims to contribute to the development of indicators and methodologies to quantitatively gauge the performance of the form and function of cities, analyzing and comparing real cities and concepts of ideal cities that have influenced urban planning in the last century. Different concepts of cities have been developed and put into practice, in part or in their entirety, in cities around the world. However, to the best of the author's knowledge,

there are no quantitative analyses on the comparison of the various forms and functions presented by different concepts of cities and real cities.

A quantitative analysis requires developing benchmark indicators that can be used for that purpose. Six such indicators were developed, stemming from validated literature approaches. This indicators were based on spatial characteristics and focusing on sustainability and efficiency: accessibility, active modal share, transport energy consumption, route directness, mixed land use, and pleasantness. For each indicator, Geographic Information System (GIS) based analysis of the performance of a real city (Coimbra, Portugal) was carried out and compared to spatial reconfigurations of the same city according to five ideal city concepts and an urban planning strategy (the infill).

Finally, a multicriteria analysis was conducted to compare the performance of the real city and the six city layouts based on the six developed indicators. The GIS was used for storing, managing, and spatially represent information, as well as for the implemention of analytical capabilities tailored to the analysis' needs.

The results provided quantifiable answers about the performance of each of the tested urban forms and suggest that more compact forms have an efficiency edge over the other layouts, mainly because of shorter distances. The aim of the multicriteria methodology is thus to contribute towards guidelines, urban planning strategies, and policies that can be directly applied in current urban areas. Results can be considered for application in the context of expansion programs, urban regeneration projects, and, in general, for the adaptation of urban planning policies and strategies to make cities more sustainable, resilient, and equitable.

Keywords: Urban design, accessibility, comparative analysis, GIS – Geographic Information System, TOPSIS.

A partially compensatory composite indicator based on multiple reference points. Application to the Economic Freedom Index

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Abstract

The growing amount of available data makes it complex to assess the behaviour of different units for the phenomena studied. In many occasions, a system of single indicators measuring all the different aspects of the phenomenon is built. Nevertheless, the joint consideration of a great number of indicators is troublesome and for this reason, composite indicators that aggregate all the information of the system in a single score are usually considered. One critical issue that needs to be carefully addressed when building a composite indicator is compensation. That is, to which extent do we allow bad performances in certain indicators to be compensated by good performances in others. Most of the existing methods use additive aggregation schemes that allow for full compensation, while just a few allow no compensation at all (El Gibari et al., 2019). In Ruiz et al. (2020), the Multiple Reference Point based Weak and Strong methodology (MRP-WCSI) is proposed to build composite indicators. This scheme allows the use of reference levels to identify different performance bands for the indicators. Besides, it produces a fully compensatory (weak) composite indicator and a non-compensatory (strong) composite indicator. As discussed in El Gibari et al. (2021), the joint consideration of these two composite indicators provide decision makers with valuable information. Other methods allow (like geometric mean-based ones) allow for partial compensation, but, in most of them, the compensation degree is established in a global way, that is, it is the same for all the indicators. In this communication, we present the Multiple Reference Point Partially Compensatory Indicator (MRP-PCI), introduced in Ruiz and Cabello (2021), where a different compensation index can be established for each indicator. As an example, this methodology is applied to the Index of Economic Freedom published by the Heritage Foundation. We show how the MRP-PCI scheme works and compare the results obtained with those of the original index.

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Keywords: Composite indicators, Reference Point, Partial compensation, Economic Freedom.

Ordinal Rank-based Preference Elicitation Model for Assigning Weights to Decision Criteria

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Abstract

Decision-making processes involving multiple criteria often require assigning weights to criteria to determine criteria's relative importance. In decision analysis, decision makers' (DMs) preference for each criterion must be translated into the quantitative weight. Preference elicitation techniques fill this role by extracting and refining the expressed preference to a numerical value. The extent to which those weights are truly representative of DM's preference remains an uncertain and non-trivial task.

A large strand of preference elicitation methods requires precise numerical inputs or exact verbal expressions of preference. This is challenging for DMs to provide and is beyond their cognitive capacity since the relative importance of information chunks is not shaped originally in the brain as certain numbers or explicit semantic representations. To overcome this challenge, the imprecise preference elicitation methods operate on the limited information expectation on DM's side (e.g., often simple ranking among criteria). Studies show that DMs are generally more confident and comfortable with ranking criteria than assigning direct verbal or numerical value due to our inherent cognitive limitations. This renders imprecise preference elicitation methods a more accessible and cognitively feasible approach as it does not force DMs to communicate computationally intensive forms of information within the analytically-heavy context of internal preference exploration.

This paper introduces a novel method for deriving decision criteria weights based solely on rank information and an indication of confidence level, addressing the limitations of existing approaches but remaining computationally feasible and cognitively tractable. The proposed method translates ordinal rankings into numerical weights through a structured mathematical model using a central tendency measure with an inbuilt logarithmic transformation function. Key innovations of this method are, first, allowing for the expression of the cardinality of preference for ranked criteria; second, incorporation of confidence level for application in various decision contexts based on information entropy, and its ability to handle tied ranks, where some criteria are perceived equally important—all features not being explicitly

addressed by traditional ordinal weight elicitation methods. Accordingly, the steps of the proposed model are as follows:

- Input Data: The model begins with an ordinal ranking of criteria, where each criterion is assigned a rank (d_i).
- Calculate the Mean Rank ($\bar{d}$): The mean rank is computed as the average of all given ranks.
- Compute the Central Tendency Measure ($\nu_\circ$): This step incorporates the standard deviation of ranks normalized by (n-1) and adjusted by the maximum rank value.
- Group Tied Criteria (G_j): Criteria with identical ranks are grouped together to ensure consistent weight distribution.
- Determine Intermediate Weights ($\bar{d}_i$): A logarithmic transformation and a confidence score (β) are applied to differentiate closely ranked criteria while maintaining stability
- Calculate Final Weights (w_i): Weights are normalized by summing over all group contributions and scaling to a percentage.

On this ground, the novelty of this approach lies in its integration of central tendency measures but not excluding lower-ranked criteria with non-linear transformation functions (mainly when DMs are less certain about the preferences assigned). This takes place by applying a logarithmic function adjusted by a constant factor of c — a regularization parameter to control the behavior of the natural logarithm function near zero— for the transformation of rank differences into intermediate weights. Additionally, the method incorporates a confidence score (β, allowing DMs to express their level of certainty in their rankings. When decision-makers are more confident, the model produces sharper, more exponentially expressed weights. Conversely, when the confidence level is low, the model generates more equalized, evenly distributed weights (still ordinally descending), reflecting the uncertainty in DMs' preferences. This enhances the applicability of ranking-based weighting in domains such as environmental impact assessment, risk prioritization, social vulnerability, and resource allocation, where interventions need to be prioritized based on large number of criteria in a decision context, with uncertainty and subjective rankings being common. Observing the models' application reveals that the proposed framework can produce criteria weights based on limited input validated by users' opinions after rounds of preliminary experimental tests. Furthermore, the model exhibited agility corresponding to the degree of information imperfection and performed with notable computational efficiency, thus making it a viable tool for decision-making applications.

Further research is still needed to refine the model and also explore further application of this approach. We generally recommend DMs to avoid a large number of criteria, especially with this commonly held false assumption that any method of this kind is able to provide a precise numerical representation of true weights. While ordinal weight elicitation methods are cognitively feasible, fast, and highly accessible, the information loss is too likely. Decision analysts must determine their desired trade-off, between these features and information loss, and perhaps introduce the elicitation of cardinal information to a degree that the aforementioned features remain valid.

Keywords: Rank-based Weighting, MCDM, Weight Allocation, Preference Elicitation.

Prioritising Municipal Photovoltaic Initiatives Using Multi-Criteria Decision Analysis

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Abstract

The escalating urgency of climate and energy challenges has accelerated the adoption of solar energy technologies in both the short and long term. The effective integration of photovoltaic (PV) systems demands a comprehensive evaluation of various factors, including energy resources, demand, socioeconomic contexts, and environmental impacts. Local governments and citizens play a crucial role in the energy transition, as localised emissions significantly influence broader environmental outcomes. This paper presents a decision-support approach for prioritising PV system implementations within a municipal framework, guided by decision-maker preferences. Utilising insights from an industry expert, we propose a multi-criteria decision analysis model based on the ELECTRE Tri-nC method. The model classifies PV-related actions aimed at reducing municipal emissions, taking into account different installation types, areas, sectors, and investors. Applied to the Spanish municipality of Rajadell, the model demonstrates that PV installations can reduce emissions by up to 49.11% in the residential and services sectors. From a policy perspective, the results indicate that 80% of the proposed actions should be executed by 2030 to align with the municipality's climate objectives. The robustness of the model allows for its adaptation to similar contexts. Despite technical, economic, and social constraints, the green transformation driven by PV systems can achieve significant reductions in greenhouse gas emissions, boost employment in the renewable energy sector, and decrease overall resource consumption. This model provides a valuable tool for policymakers and supports decision-makers in optimising local energy generation processes.

Keywords: Multi-criteria decision analysis, ELECTRE Tri-nC, photovoltaics, renewable energy, energy policy

Dynamic Weights and the ADRIANA Method

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Abstract

The ADRIANA method is a multicriteria decision analysis technique developed by Hein (2020). The method is inspired by Thaler's (1980) division of the utility function into acquisition utility and transaction utility. Richard Thaler found that people place a higher value on their own assets. The mental accounting phenomenon is supported by the assumption that individuals spend their money differently if the expense is labeled for a specific purpose. The endowment effect is the term coined to describe the individual tendency to value assets in a more equitable way in relation to the aversion to losing them (Kahneman & Tversky, 1979; Thaler, 1980). Loss aversion explains why people value the same asset more when they have it than when they do not have it. The endowment effect explained in terms of risk aversion is based on the assumption that individuals maximize their preferences and that they also depend on the endowment as a reference point. This is the baseline of the ADRIANA method. It involves six steps, that were maintained: (i) normalization; (ii) construction of the acquisition matrix; (iii) synthesis of the values of the acquisition matrix $\left(A_i\right)$; (iv) construction of the transaction matrix; (v) synthesis of the values of the transaction matrix $\left(T_i\right)$; and (vi) calculation of the Thaler Value $\left(VTh_i\right)$. In the synthesis of the values, in steps (ii) and (iv), weights $\left(w_j\right)$ are used that can be assigned by the decision maker or calculated according to some known technique, such as entropy, coefficient of variation, Critic, neural networks, etc. The difference in the 2020 ADRIANA method (Hein, 2020) is the weight structure. Originally, the weights were assigned to the criteria according to some technique. The weights used in the acquisition valuation were the same as those used in the transaction. The ADRIANA method underwent changes to become even more similar to Richard Thaler's Behavioral Accounting theory. In fact, in this revised model, the weight structure in the acquisition is fixed. In the second part of the model, that is, during the transaction phase, the weights change when evaluating each of the alternatives. The model assumes that during the evaluation of an alternative card, its values are not used to determine the weights of the criteria. Therefore, the analysis of each of the alternatives leads to the formation of a new set of weights. The method becomes more computationally complex, but significantly more adherent to Thaler's purposes.

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Keywords: ADRIANA Method; Multicriteria Analysis; Weight of information.

Selection of Bottleneck Detection Methods Using Multi-Criteria Decision-Making

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Abstract

The identification of production bottlenecks is crucial for optimizing manufacturing processes, yet selecting the most suitable bottleneck detection method (BDM) for different assembly line configurations remains a complex challenge. This study applies the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), a Multi-Criteria Decision-Making (MCDM) method, to rank and select the most appropriate BDM for different production environments. Unlike previous studies that focus on general industrial decision-making applications (Azhar et al., 2021; Basílio et al., 2022), this research provides a novel approach to choosing BDMs based on specific production line constraints.

Due to its characteristics, related to the idea of identifying the alternative that is closest to the ideal solution, the method TOPSIS was applied to evaluate nine BDMs: Process Time Method (PTM), Utilization Method (UM), Turning Point Method (TPM), Interdeparture Time Variance Method (ITVM), Active Period Method (APM), Bottleneck Walk Method (BWM), Arrow Method (AM), Inventory-Based Method (IBM), and Simulation Method (SM). The decision-making criteria included data availability, accuracy, adaptability, and time requirements. Each criterion was weighed differently for three distinct production lines. Performance scores for each BDM were derived from existing literature (Betterton & Silver, 2012; Roser & Nakano, 2015; Roser et al., 2017; West et al., 2022). The TOPSIS method was then applied by normalizing performance scores, weighing them, accordingly, determining ideal and anti-ideal solutions, calculating distances, and ranking the alternatives based on their closeness coefficients.

The TOPSIS rankings for each assembly line showed that for line L05C, the highest-ranked method was the PTM; For line THT2A, BWM outperformed due to its higher accuracy, making it the best choice for this scenario; For line L35, the best-ranked method was ITVM.

This study demonstrates that the TOPSIS method effectively supports decision-making in selecting BDMs tailored to specific production line constraints. While the rankings provide a structured decision-making approach, it is essential to acknowledge the influence of subjective weight assignments (Taherdoost & Madanchian, 2024). To mitigate potential biases, the study considered the top two ranked methods for each case before making a final decision. However, the analysis confirmed that the highest-ranked BDM remained the most suitable choice across all production lines. This research is the first to apply an MCDM approach to bottleneck detection method selection in industrial settings. By integrating systematic decision-making into bottleneck analysis, this study offers a replicable framework for manufacturers seeking to optimize production efficiency under various operational constraints. Future research could explore alternative MCDM techniques, such as the Analytical Hierarchy Process (AHP) or VIKOR, to validate and compare results.

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Keywords: Bottleneck Detection; TOPSIS; Multi-Criteria Decision-Making; Theory of Constraints

A collaborative dashboard-building approach combining business intelligence and socio-technical multicriteria decision analysis: a tool to assist decision-makers in health settings

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Abstract

Remote patient monitoring (RPM) holds promise for accessible and equitable care delivery, allowing professionals to monitor, assess and engage patients regardless of location. Effective RPM program implementation and operation relies on leveraging clinical, operational, and financial data for decision-making, yet navigating vast and sparse datasets poses challenges. Moreover, traditional health technology assessment (HTA) often focuses on isolated clinical outcomes or rudimentary cost-effectiveness studies, overlooking the complexity of RPM. A comprehensive approach should consider clinical, social, and economic factors, involving key stakeholders such as patients, caregivers, hospital administrators, technology providers, payers, and policymakers.

Multicriteria decision analysis (MCDA) is gaining traction in HTA for its ability to consider broader impacts and clarify their relative importance in generating added value. However, while MCDA shows potential for HTA, with increasing pressure on healthcare resource management and dynamic technological innovation, tools are needed to support decision-making in a data-rich environment. Business intelligence (BI) systems and data visualization help manage this complexity. Multidimensional management dashboards (MDDs), performance measurement systems powered by BI technology, can be an effective solution for processing data effectively and providing actionable and at-a-glance insights for continuous program management.

Within this context, this study aims to answer two research questions: (1) “What value measurement and decision support methods and tools can enable continuous monitoring and evaluation of RPM initiatives?” and (2) “What requirements and capabilities should an actionable BI tool incorporate for continuous monitoring and evaluation of RPM programs, taking into account user needs and the opinions of relevant stakeholders?”

As RPM decision-makers require practical tools to help day-to-day monitoring and evaluation of RPM programs across multiple dimensions, we propose an innovative integrative approach called Structuring, Building and Implementing a Multidimensional Dashboard with Stakeholders, BI and Multicriteria Decision-aiding (SBI-MD). SBI-MD combines decision-aiding and data visualization tools with MCDA and stakeholder participation techniques to create MMDs to assist decision-makers in managing RPM programs. Following a collaborative value modelling paradigm, SBI-MD engages stakeholders in socio-technical processes for (a) identifying key performance indicators and evaluation criteria that are aligned with producing RPM value and achieving managerial targets, (b) building a flexible multicriteria model and a classification system to help decision-makers monitoring the added value of RPM and understanding which areas need improvements, and (c) integrating information from (a) and (b) into a user-friendly MMD. Recommendations are provided for methods and tools to support modelling tasks and collaborative processes.

SBI-MD was implemented and validated in the context of an RPM program for heart failure management at Hospital de Santa Maria (HSM), in Lisbon, Portugal. The project covered the first two phases of SBI-MD, leading to the construction of a functional MMD prototype for tactical and strategic management of the HSM RPM program. In collaboration with HSM's cardiology department, the project aimed to (a) enhance the quality of care delivery by conducting continuous HTA to identify areas for improvement, and (b) transparently demonstrate the program's impacts to HSM leadership and the broader Portuguese healthcare community.

HSM project stakeholders partaken in six participatory processes to co-develop a functional MMD prototype. The MMD offers (a) a comprehensive performance overview across key program dimensions – Access, Clinical aspects, Acceptability, and Costs –, and (b) assigns achievement classifications both globally and by dimension to assess program success. These classifications are determined based on partial value scores and assignment rules in a set of stakeholder-agreed criteria. Their relative importance is represented by stakeholder-elicited weights, which reflect their collective perspectives and goals for the HF remote care program.

Obtained results revealed that involving end-users in MMD development ensures alignment but requires coordination. SBI-MD addresses stakeholder coordination challenges with a structured and methodologically sound approach to constructing MMDs, while

minimizing unnecessary interactions and cognitive load. SBI-MD is expected to advance MCDA for HTA by offering a clear, step-by-step guide that integrates practical tools and methods from BI and stakeholder engagement, supporting the development of MMD systems that automate evidence reporting, improve outcomes interpretation through intuitive visuals, and allow for real-time and interactive value measurement. These advancements help address long-standing challenges in HTA, particularly for complex health interventions like RPM.

Keywords: Dashboard development, Collaborative modelling, Business intelligence, Multicriteria decision analysis, Participatory approaches

A Transition-Centric Meta-Framework for Selecting Multi-Criteria Decision Applications in Sustainability Challenges

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Abstract

Grand challenges, such as the transition to sustainable aviation, present complex and wicked decision-making problems, requiring structured approaches to evaluate competing technological, economic, regulatory, and environmental trade-offs. While Multi-Criteria Decision Making/Analysis (MCDM/A) has been employed in various aspects of aviation sustainability—such as alternative fuel evaluation and supplier selection—existing studies often assume a predefined decision problem rather than systematically determining which dimension of a sustainability transition is optimal for the challenge and MCDM/A application. This study responds to this gap by proposing a meta-framework for identifying and prioritizing MCDA applications in sustainability transitions. While grounded in MCDA methodologies, the framework extends beyond traditional decision analysis by incorporating transition-oriented decision structuring, aligning with the broader scope of MCDM. In complex sociotechnical transitions, research method choice often depends on selecting the optimal decision frame and problem domain for MCDM/A application. The study introduces a structured selection methodology that integrates sociotechnical Matters of Concern (MoCs) and Transition Pathways analysis to systematically identify, classify, and rank important dimensions of sustainability challenges, enhancing decision-making clarity and strategic focus.

This research follows a rigorous three-stage approach to systematically select the most appropriate challenge dimension and MCDA application. Stage 1 identifies the MoCs shaping sustainability transitions, focusing on energy sources, infrastructure adaptation, emissions regulation, public acceptance, and economic viability. These challenges involve inherent paradoxes, such as balancing economic feasibility with long-term environmental impact and technological readiness with regulatory uncertainty. Stage 2 maps multiple, often competing, transition pathways within four established types: *substitution*, *transformation*, *reconfiguration*, and *de-/re-alignment*. Each pathway presents unique trade-offs and long-term

constraints within the broader sustainability transition. Additionally, key evaluation metrics and suitable MCDA models are identified for each pathway, ensuring a structured foundation. Stage 3 introduces Robust Multi-Scenario Decision Analysis (RMSDA), a flexible MCDA approach that offers two evaluation options: (1) A streamlined AHP-based method evaluates pathways using only five key decision variables—*technological readiness*, *data availability*, *policy alignment*, *computational feasibility*, and *industry adoption potential*—allowing for an efficient, structured ranking using AHP. (2) A comprehensive, scenario-driven RMSDA assessment integrates both the five key variables and five distinct transition scenarios—*short-term feasibility (2025-2035)*, *regulatory priority (2035-2050)*, *net-zero carbon priority (2050+)*, *economic feasibility*, and *total environmental sustainability*—ensuring rankings reflect both immediate feasibility and more complex long-term transition dynamics. Both approaches provide a systematic and transparent process for prioritizing pathways and selecting the most viable research focus and specific MCDA models for implementation.

Distinct from a traditional literature review, which often categorizes studies based on broad theoretical similarities rather than interrogating their underlying assumptions, this framework adopts an intentional transition phenomenon-centric approach. While general literature reviews may be effective for narrow, disciplinary-focused research, they are less suited for interdisciplinary and sociotechnical research where challenges span multiple domains and require a structured selection methodology. By shifting from a simple often opaque literature-driven selection process—often shaped by research availability rather than decision-making needs—to a transition-centric framework, this study contributes a framework that may reduce selection bias, confirmation bias, and the risk of overlooking critical challenge dimensions (e.g., unknown unknowns). Moreover, MoCs and transition pathways provide deeper insights into ongoing points of contention, trade-offs, semantic meanings, and hidden assumptions that shape trajectories and mediate sustainability transitions, ensuring that MCDA applications are systematically aligned with the most pressing and transition-relevant aspects of sustainability challenges rather than the most conventionally studied ones.

To examine this framework in practice, the study applies it to sustainable aviation as a case study, systematically evaluating five dominant pathways: Sustainable Aviation Fuels (SAFs), Hydrogen-Powered Aviation, Electrification of Aviation, Advanced Air Mobility, and Aircraft Efficiency and Fleet Optimization (AEFO). Preliminary findings, using min-max normalization, indicate that the SAF pathway emerges as the strongest MCDA candidate for the short-term transition period (2025-2035) under the robust RMSDA method, given its immediate feasibility, cost-effectiveness, and industry-wide adoption potential. Additionally, SAFs are the preferred regulatory priority candidate for the mid-term transition period (2035-2050), due to their strong policy alignment, widespread industry adoption, and compatibility with existing infrastructure. Early evidence suggests that the meta-framework incorporating RMSDA is

scalable and generalizable, providing a structured methodology for selecting MCDM/A applications across various sustainability domains, evolving future states, and complex challenges. By integrating MCDA methodology with MoCs and transition theory, this research enhances both problem framing and MCDM/A evaluation processes for decision-making in dynamic sociotechnical systems.

Keywords: Sociotechnical Transition Pathways, Matters of Concern (MoCs), Multi-Criteria Decision Analysis (MCDA), Meta-Framework, Robust Multi-Scenario Decision Analysis (RMSDA)

Posters

High-dimensional portfolio optimization with an evolutionary multi-objective algorithm implemented in Python: evMOGAportPy

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Abstract

Modern portfolio management is evolving to meet investors' needs by integrating not only additional criteria—such as sustainability, diversification, liquidity, and transaction costs—but also by considering a broader array of risk measures. While exact optimization methods are effective for simple cases, they struggle with complex, high-dimensional problems where objectives are non-linear, non-convex, or require integer constraints. Common challenges include the minimization of Value-at-Risk or Conditional Value-at-Risk, the maximization of risk-adjusted performance metrics such as the Sharpe or Sortino ratio, the integration of Environmental, Social, and Governance criteria, maximizing portfolio diversification, and minimizing transaction costs and liquidity constraints. Traditional approaches, such as the ε-constraint method, require multiple runs and careful parameter tuning, often leading to computational inefficiencies and limited solution diversity.

Evolutionary algorithms have offered several advantages over exact methods to address these challenges. They explore non-convex solution spaces, optimize multiple objectives simultaneously, and generate a diverse set of non-dominated solutions in a single run. In this work, we develop evMOGAportPy, an open-source Python package that implements an existing evolutionary multi-objective genetic algorithm (ev-MOGA) to efficiently approximate the Pareto front in portfolio selection problems with more than two objectives. Furthermore, we have tested our Python package using real-world datasets, integrating not only the generation of the Pareto front but also conducting an extensive out-of-sample performance analysis. This comprehensive approach ensures that our tool identifies optimal portfolio allocations and validates their performance under unseen market conditions. Our results show that evMOGAportPy provides computationally efficient and high-quality approximations of

Pareto optimal portfolios, making it a valuable tool for investment decision-making in high-dimensional settings.

Keywords: Evolutionary Algorithms (MOEAs); Portfolio Optimization; Multi-Objective Optimization; Python; ev-MOGA

Socially responsible investment: application to the market of renewable energy companies

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Abstract

Socially Responsible Investing (SRI) is an investment approach that integrates environmental, social, and corporate governance (ESG) factors to generate competitive long-term financial returns while also achieving a positive social impact. This strategy involves selecting companies that demonstrate strong ESG performance. Our objective is to illustrate how multi-criteria models can serve as valuable decision-making tools for investments that combine traditional financial criteria—such as expected return and risk—with social responsibility performance metrics across the three ESG pillars: environmental, social, and governance. Investing in companies that promote sustainable practices while avoiding those engaged in harmful activities has become a global trend embraced by both institutional and individual investors. However, there remains a significant gap in financial models tailored to these investors beyond the mere exclusion of assets linked to irresponsible corporate behaviors. In response to this gap, our contribution presents a multi-criteria model designed to meet the needs of socially responsible investors. Assessing the sustainability of individual investments is inherently complex, as there is no universal welfare function that accounts for all environmental, social, and governance aspects (Hallerbach et al., 2004). Moreover, the UK Social Investment Forum (UKSIF) highlights that while most individuals generally agree on ethical concerns, each investor must determine whether a particular investment aligns with their values: “Different people have different views on what is acceptable and how important a particular issue is to them”. Nonetheless, UKSIF identifies a key characteristic of effective SRI strategies: “What they have in common is a clear expression of their stance on social issues. The key is to provide and use information about investments in a way that allows investors to assess their suitability for their clients and pension funds” (UK Social Investment Forum, http://www.uksif.org/).

We propose to construct an ESG-compliant portfolio that closely resembles a conventional benchmark portfolio (the one an investor would choose if only financial objectives were considered). To achieve this, we introduce a multi-criteria methodology that incorporates fuzzy logic to account for the imprecision inherent in some elements of decision-making. Our approach is structured in two stages. In the first stage, we construct a conventional portfolio by applying prospect theory (Kahneman and Tversky, 1979) while incorporating lower risk measures. Prospect theory provides a framework for decision-making under conditions of uncertainty, capturing cognitive biases and the tendency to weight losses more than equivalent gains. This model is particularly relevant in finance as it reflects departures from classical utility theory in investment decisions. A fundamental element of Kahneman and Tversky's proposal is the S-shaped value function, which is concave (indicating risk aversion) in the gain domain and convex (indicating risk-seeking behavior) in the loss domain, both measured relative to a reference point. In this study, linguistic labels are used to model the parameters of the value function, allowing for a "soft" representation of risk and loss aversion. In the second stage, we address a multi-objective optimization problem, which is solved using an extended version of Extended Goal Programming (Romero, 2001). This approach considers the financial characteristics of the reference portfolio as aspiration levels for financial goals. We will apply our model to a market of renewable energy companies.

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Keywords: Socially Responsible Investing; Prospect Theory; Fuzzy Logic; Extended Goal Programming; renewable energy companies

Multi-Criteria Decision-Making for a Sustainable Renewable Energy Mix

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Abstract

This paper presents an optimization model for selecting a renewable energy mix using multi-criteria decision-making (MCDM) techniques. The goal is to balance economic, social, and environmental aspects, considering the preferences of different stakeholders. The study proposes a methodology based on Goal Programming with Fuzzy Hierarchy (GP-FH), the Extended Best-Worst Method (EBW), and a modified Technique for Order Preference by Similarity to Ideal Solution (R-TOPSIS). The application of this model to Spain's energy planning for 2025 and 2030 highlights the challenges in balancing different decision-making profiles and the trade-offs required between conflicting objectives.

The transition to renewable energy sources is crucial to reducing greenhouse gas emissions and fossil fuel dependency. However, selecting renewable energy technologies is not a straightforward decision, as each source has specific social and environmental impacts that need to be carefully managed. The core challenge is designing an optimal energy mix that maximizes economic benefits, minimizes environmental harm, and ensures social equity. In this context, multi-criteria decision-making (MCDM) tools provide effective solutions to tackle these challenges.

A multi-objective optimization problem is formulated to identify different combinations of renewable energies that satisfy the various criteria. A Goal Programming model with Fuzzy Hierarchy (GP-FH) is employed. This model allows decision-makers (DMs) to define flexible priority relationships between the evaluated impacts, avoiding the rigidity of strict hierarchical structures. Since the first stage generates multiple viable solutions, a final selection process is carried out based on three key steps. First, impact weights are determined using the Extended Best-Worst Method (EBW), which assigns relative importance to each criterion based on the decision profile. Second, deviations in each energy portfolio are evaluated using functions inspired by Prospect Theory, penalizing deviations in more critical criteria and third ranking alternatives through a modified TOPSIS method (R-TOPSIS), which evaluates how close each

solution is to the ideal scenario. Our approach ensures that the most balanced energy mix is selected for each decision-making profile.

The model is applied to Spain's energy planning for 2025 and 2030, based on the EU Reference Scenario 2020. Six renewable energy technologies are analyzed: Bioenergy, Solar Photovoltaic (SPV), Concentrated Solar Power (CSP), Hydropower, Onshore Wind Energy and Offshore Wind Energy. To assess the impact of each technology, six key indicators are considered: Total Employment (TEmp), Energy Return on Investment (EROI), Land-Use Footprint (LU), Levelized Cost of Electricity (LCOE), Life Cycle Greenhouse Gas Emissions (LCA), and Water Footprint (WF). Since no single energy mix is optimal across all dimensions, three decision-making profiles are defined: Economic Profile, Environmental Profile, and Social Profile.

The study confirms that energy planning cannot rely on a single criterion, as economic, social, and environmental impacts often conflict. The proposed methodology provides a structured approach that incorporates flexible decision-making preferences through Goal Programming with Fuzzy Hierarchy, reduces unfair trade-offs between impacts using valuation functions based on Prospect Theory and improves the selection process by ranking the best energy portfolios with a modified TOPSIS approach. Finally, the study emphasizes that energy policy decisions must acknowledge and accept trade-offs, as no single energy mix can be optimal for all stakeholders. The presented methodology offers a valuable tool for policymakers and planners to design more balanced and sustainable energy strategies.

Keywords: Renewable Energy Mix, Multi-Criteria Decision-Making (MCDM), Goal Programming with Fuzzy Hierarchy (GP-FH), Energy Policy Optimization, Sustainable Energy Planning.

Multicriteria Analysis of Other-Regarding Behavior in Oligopolies with Penalties

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Abstract

This work considers an extended Cournot oligopoly setting in which firms face penalties when their total production deviates from a fixed, exogenously determined quantity. Such penalties play a crucial role in real-world markets where production or resource extraction is subject to regulatory constraints. For example, in the wine sector, regulations impose maximum production limits, while in the fishing industry, the European Union's Council of Ministers of Agriculture and Fisheries annually sets fishing quotas. Exceeding these limits results in penalties that influence firms' strategic decisions and market outcomes.

We analyze situations where each firm's behavior is influenced by both its own utility and that of at least one other firm. Thus, a multicriteria game, where each firm considers the utilities of all others, provides a suitable framework to model these interactions. We represent firms' preferences through a weighted additive value function, and we explore various scenarios depending on the degree of concern each firm has for others' outcomes.

Our findings suggest that other-regarding behavior can be advantageous for firms. Under certain conditions, two key results emerge from our analysis. First, firms that exhibit greater concern achieve higher profits than those that are less concerned while also increasing consumer surplus. This suggests that a higher degree of concern leads to greater production levels and improved overall market efficiency. Second, firms with a higher degree of concern can potentially drive less concerned competitors out of the market.

Keywords: oligopoly, penalties, other-regarding preferences, vector-valued utilities, equilibria.

Measuring the enterprise competitiveness of Taiwanese listed companies: A compromise solution approach

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Abstract

As the competitiveness within the industries in Taiwan gets increasingly fierce, enterprises must be more competitive to survive and prosper. How competitive an enterprise is compared to other enterprises requires a comprehensive measure to examine. Previous studies show that fifteen indicators, under five pillars of productivity, profitability, image, stability, and growth, have been used to measure enterprise competitiveness from different aspects. How to aggregate the performances on these indicators to obtain an index that can reflect the general competitiveness of an enterprise is a multicriteria decision analysis problem. The most critical issue in aggregation is the determination of the importance, or weight, of each indicator. A compromise solution approach that determines the weight objectively reflected from the data is proposed in this paper. First, the data of every indicator are standardized by dividing by their averages. The performances of the indicators under each pillar are then aggregated by taking averages. A set of weights that produces the highest total aggregate score from the five pillars for all companies is then solved via a compromise programming model. The aggregate score of each company is obtained at the same time. Since the companies discussed in this paper are listed companies, which are more competitive than those unlisted companies, the obtained weights appropriately reflect the importance of the factors that keep a company staying long in the market. The results from the 1801 listed companies in Taiwan show that image is the most important group of indicators to reflect enterprise competitiveness. Regarding the industries, semiconductor and computers are the most competitive industries, and the world-famous semiconductor manufacturing company, Taiwan Semiconductor Manufacturing Co. (TSMC), is ranked first. This is in accordance with world's image of the industries in Taiwan that Taiwan is the Kingdom of Chips

Keywords: compromise solution, competitiveness, enterprise

A Multicriteria Methodology for Maintenance Planning of Cycling Infrastructure

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Abstract

Cycling is increasingly recognized as a sustainable, non-polluting mode of transport, offering significant benefits for urban mobility, health, and the environment. The COVID-19 pandemic further highlighted the role of cycling in mitigating the spread of infectious diseases and reducing congestion on public transportation systems. To foster cycling as a primary transport mode, it is essential for authorities to have reliable, data-driven tools to assess the condition of existing cycling infrastructure and prioritize maintenance and improvements. This research introduces a multicriteria methodology designed to assess cycling infrastructure condition, aiming at subsequent maintenance planning. The methodology employs the non-compensatory ELECTRE TRI outranking method to classify road segments (alternatives) according to predefined performance classes, considering five criteria related to cycling confort and safety from traffic. By applying engineering best practices and focusing on practical, actionable outputs, this methodology aims to support municipal authorities in their decision-making process.

The methodology was tested through a comprehensive case study in Coimbra, Portugal, involving a significant portion of the city's cycling and road network. The case study

demonstrated the methodology's scalability and effectiveness, as it only requires data whose collection is expedite. Results indicated that the main issues affecting network condition were found on main distributor roads, where inadequate cyclist safety features, such as the lack of proper segregation from motorized traffic and poorly designed intersections, were prevalent. These safety deficiencies were identified as major obstacles to cycling, reflecting broader challenges in cities that, over the years, prioritized motorized transport over cycling infrastructure.

The findings suggest that such infrastructure deficiencies may have contributed to the low modal share of cycling in Coimbra, and this is consistent with the literature, which demonstrated that safety is paramount in encouraging cycling. By focusing on infrastructure elements that can be directly influenced by municipal authorities, such as the design of intersections and the segregation of cyclists from motor vehicles, the proposed methodology provides a practical tool for identifying high-priority areas for intervention.

This research highlights the potential of this multicriteria approach as a valuable decision-aid tool for urban planners, enabling them to prioritize cycling infrastructure maintenance and upgrades effectively. In doing so, it contributes to efforts to promote cycling as a safe, accessible, and efficient transport mode, supporting broader sustainability goals and improving urban mobility for all users.

Keywords: decision making; ELECTRE-TRI; maintenance and inspection; performance measurement; town and city planning; active mobility

A cooperative game theory approach to cost sharing in capacity synthesis problems. A bi-criteria model

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Abstract

This paper considers networks in which nodes have communication needs between them, that is, any pair of agents, located at the nodes of the network, requests a connection with a certain capacity. The cost of building, maintaining or using an edge with a given capacity is the same across any pair of agents. It is known that feasibility is reached by any Maximal-Capacity Spanning Tree (MCST). The capacity that any pair of agents requires is considered their benefit if and only if, in the resulting tree, there exists a path between them such that every edge provides at least this required capacity. Hence, a *benefit capacity synthesis cooperative game* is defined, in which the worth of each coalition S is the sum of the capacities of the edges in a MCST on S. On the other hand, the agents must pay for the link of a MCST. Therefore, a *cost capacity synthesis cooperative game* is defined, in which the worth of each coalition S is the cost of the links which ensures the capacities required for the agents in S with respect to all the agents in the network. These two games have been already studied in previous works. In this paper we extend the idea of stability to a bi-dimensional framework and analyze stable allocations with respect to both games. We also relate them with some well-known solution concepts in the literature.

Keywords: capacity synthesis problem, cooperative network game, core allocations

Computing the Pareto front in Multiobjective Linear Mixed Integer Fractional Programming

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Abstract

This communication proposes and compares Branch & Bound approaches to compute all the nondominated solutions in multiobjective linear mixed integer fractional programming (MOLMIFP). The techniques provide not only supported but also unsupported nondominated solutions, that is, those that are dominated by unfeasible convex combinations of other nondominated solutions. Note that nondominated solutions associated with a weight vector are always supported. It can be observed that the nondominated solution set of a MOLMIFP problem has, in general, a significant part of unsupported solutions.

The Branch & Bound approaches share the same structure:

i) select the next nondominated region.

ii) divide this region into two sub-regions, by imposing constraints on one of the objective functions.

iii) compute the pay-off tables of the new sub-regions in order to characterize them.

The process is repeated for each sub-region until the remaining sub-regions are ‘smaller’ than a predefined error. A sub-region is ‘smaller’ than a predefined error if the range of values of each objective function in the pay-off table is smaller than the predefined error.

The several approaches differ in the way the constraints of step ii) are imposed.

The authors have published a paper (Costa and Alves, 2024) presenting a new Branch & Cut algorithm to optimize a weighted sum-of-ratios in multiobjective mixed-integer fractional programming. Now, the authors will present some extensions of the algorithm to compute all nondominated solutions in MOLMIFP.

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Keywords: Muliobjective; Fractional programming; Mixed integer programming; Pareto front.

A Comprehensive Approach to the Menu Planning Problem

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Abstract

The Menu Planning Problem (MPP) is a critical challenge in food management, balancing multiple, often conflicting objectives to create meal plans that are nutritionally adequate, cost-effective, and sustainable. Effective menu planning plays a crucial role in various settings, including schools, hospitals, restaurants, and large-scale catering, where dietary needs, budget constraints, and consumer preferences must be carefully considered. Beyond its practical implications, MPP has gained increasing attention due to its impact on public health, environmental sustainability, and food security.

A first step towards enhancing palatability, acceptability, and reliability in the Diet Problem (continuous approach) is to use the Mediterranean Diet standards as an aspiration, ensuring that meal plans incorporate culturally familiar, nutritionally balanced, and diverse ingredients that align with well-established dietary preferences and health benefits [1]. The Spanish diet serves as a key reference for understanding eating habits and cultural preferences, providing a foundation for proposing meaningful dietary adjustments that balance tradition, nutrition, and sustainability to achieve the best and most comprehensive possible results [2].

The MPP is examined through the lens of the SHARP framework, which integrates sustainability, health, affordability, reliability, and palatability. This comprehensive methodology seeks to tackle the complex nature of menu planning, fostering responsible and balanced food choices. Sustainability is addressed by designing menus that reduce environmental impact, incorporating locally sourced, seasonal, and eco-friendly ingredients. Health considerations guide the creation of nutritionally balanced meals aligned with dietary recommendations [3]. Cost-effectiveness is ensured by optimizing expenses while formulating meal plans. Reliability is maintained by guaranteeing consistent access to a diverse selection of food options, factoring in supply chain stability and availability. Finally, palatability remains

essential, ensuring that meals are both appealing and culturally relevant to support adherence to sustainable and healthy eating habits.

Our work integrates all five SHARP dimensions into the problem. A key innovation is the introduction of a novel Similarity Function to enhance palatability [4]. We propose a Multi-Objective Combinatorial Optimization model that considers three main objectives—sustainability, palatability, and cost—while incorporating constraints related to nutrition, Mediterranean diet guidelines, meal variety, balance, and scheduling. To simultaneously account for all objectives, we employ an Extended Wierzbicki Achievement Function, which enables the exploration of different regions of the Pareto Front [5].

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Keywords: Menu Planning Problem, Combinatorial Optimization, Multiobjective Optimization, Sustainability, Health

Cultural entropy in a hospital environment: a multicriterial and multilevel study

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Abstract

Entropy is a concept referring to a measure of disorder or uncertainty in a system. Since its origin in the study of thermodynamics, several scientific disciplines have applied this property in their respective fields of knowledge, which represents a great challenge, since entropy is difficult to interpret, understand or visualize, as it lacks a direct interpretation or physical measurement. Cultural entropy should be understood as a measure of the amount of energy that is consumed in carrying out unnecessary or unproductive work, generating conflict, friction and frustration in employees. According to Richard Barrett, the greatest source of cultural entropy within an organization is composed of actions and behaviors based on fear on the part of leaders, managers and supervisors, but also perceived in lower-level executives. The organizational culture, manifested in beliefs and assumptions, values, attitudes and behaviors of its members, is a valuable source of competitive advantage and helps an organization's performance. Learning occurs when any change in the organization's models maintains or improves its performance, and an organization's ability to learn refers to a skill that promotes and facilitates organizational learning. The growing complexity of this relationship between careers, the labor market, and companies has highlighted a trend to seek to understand whether organizational culture has any relationship with organizational learning capacity and performance and whether these relationships are manageable. Given the above, the following research question is presented: What is the influence of cultural entropy on the relationships between organizational culture and organizational capacity and performance in a hospital environment? In this sense, the objective is to evaluate the moderating effect of cultural entropy on the relationships between organizational culture and organizational capacity and performance in a hospital environment. To meet the objective, the research was carried out in a hospital located in the Itajaí Valley, in Santa Catarina - Brazil, through the application of questionnaires to the institution's employees. A total of 198 valid responses were obtained out of 227 possible, characterizing a non-probabilistic sample. The

questionnaire included questions on organizational culture (CO: 10 questions), cultural entropy (Ent: 10 questions), organizational learning capacity (CA: 5 questions) and organizational performance (DO: 5 questions), totaling 30 questions. A 10-point scale was used, where 0 (zero) represented 'not at all perceptible' and 10 indicated 'completely perceptible'. The data revealed that the group with low perception of cultural entropy, 56% of the sample, reached 2.38 points and the group with high perception of entropy, 44% of the sample, reached 7.58 points. The data were synthesized using the Interactive Relative Decision Analysis of Acquisition and Non-Acquisition - ADRIANA method. The method is inspired by Richard Thaler's Behavioral Accounting work, in which he divides the total utility into the sum of the acquisition and transaction utilities. The ADRIANA method is classified in the γ-type family, that is, it is part of the family of multicriteria methods that generate an ordering of the alternatives. The method has two distinct moments. In the first, the decision matrix is read from the buyer's perspective, where all the alternatives are presented and ordered. In the second moment, the method is repeated, removing one of the alternatives in each round, as if the decision maker were trying to sell the alternative, creating a value for it based on its difference from the average of the others. Finally, the two parts: acquisition and transaction are unified through the weighted average. The method is limited to numerical data and presents problems of order reversal when alternatives and/or criteria are entered or exited.The weight of each piece of information was calculated based on the coefficient of variation. After data synthesis, each respondent was classified according to their entropy (Low/High) using the k-means technique. Using Hierarchical Linear Models, two statistically significant relationships were modeled: $CA_i = \gamma_{00} + \left(\gamma_{10} + u_{1j}\right) CO_{ij} + \beta_2 Ent_j + \beta_3 CO \times Ent_{ij}$ e $DO_i = \gamma_{00} + \left(\gamma_{10} + u_{1j}\right) CO_{ij} + \beta_2 Ent_j + \beta_3 CO \times Ent_{ij}$. The first relationship resulted in: $CA = 0{,}246 + 0{,}600\, CO$ (low entropy) and $CA = 0{,}588 + 0{,}258\, CO$ (high entropy). This indicates that employees with low cultural entropy tend to transform their organizational capacity into learning capacity to a greater degree than those whose perception of cultural entropy is high $\left(\frac{\partial CA}{\partial CO_0} > \frac{\partial CA}{\partial CO_1} \therefore 0{,}600 > 0{,}258\right)$. Similarly, the second relationship: $DO = 0{,}348 + 1{,}051\, CO$ (low entropy) and $DO = 0{,}018 + 0{,}864\, CO$ (high entropy), indicates that the influence of organizational capability (OC) on organizational performance (OD) is greater in the group of employees who perceive low cultural entropy $\left(\frac{\partial DO}{\partial CO_0} > \frac{\partial DO}{\partial CO_1} \therefore 1{,}051 > 0{,}864\right)$. On the other hand, the intercepts indicate that, on average, the learning capacity of the group with high perceived cultural entropy is greater in relation to those with low perceived entropy in the first relationship studied. In the second question, the opposite occurs, that is, the average organizational performance is lower in the group subjected to high cultural entropy. It is concluded that cultural entropy is detrimental to

both scenarios, however in the first case $(CO \rightarrow CA)$ it affects more those who have a higher learning capacity, which perhaps explains the sense of perception of entropy. In the second case $(CO \rightarrow DO)$, perceived entropy harms organizational performance, especially those with lower organizational performance.

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Keywords: Cultural Entropy; Multicriteria Analysis; Multilevel Linear Models; ADRIANA Method

Using Composite Quality Indicators to Assess Population-Based Algorithms

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Abstract

The quality indicators (QIs) are essential for evaluating the performance of population-based multiobjective optimization algorithms. However, not all QIs can capture the four performance criteria: convergence, spread, uniformity, and cardinality. Moreover, it is essential to understand the limitations and challenges associated with assessing the quality of a set of solutions using each QI. Consequently, population-based algorithms may be ranked differently depending on the QIs used.

In this work, we propose to aggregate several QIs to measure the performance of population-based multiobjective optimization algorithms. To synthesize the desired QIs, we construct three composite indicators called DRP-based CQIs, based on the double reference point approach [1]. Specifically, the Weak DRP-based CQI (W-CQI) provides an overall assessment of the algorithm's performance, while the Strong DRP-based CQI (S-CQI) helps identify its weakest performance. Additionally, the Mixed DRP-based CQI (M-CQI) offers a comprehensive perspective by integrating insights from the other two indicators. The construction of DRP-based CQI is based on an aspiration point and a reservation point to be attained by the single QI, i.e., we can introduce preferences about the desirable values of the single QIs into the building process. Firstly, the single QI are normalized considering the aspiration and reservation point. In this way, the value of QIs is on the same scale, from 0 to 3. The CQI are built using the normalized QI values so the W-CQI, S-CQI, and M-CQI are also in the 0-3 range.

The combined evaluation of the W-CQI and the S-CQI offers valuable complementary insights for analysing the performance of the algorithms. This approach enables us to identify the QIs that highlight areas needing improvement in performance criteria, rather than just providing an overall performance metric. It is important to note that the S-CQI is designed to complement the W-CQI, not to be used as a standalone composite indicator. Lastly, the M-CQI is beneficial for obtaining a global ranking that incorporates the information from both the W-CQI and the S-CQI.

To validate the benefits of the proposed methodology (DRP-based CQI), we compared 18 population-based optimization algorithms on three-, five-, and eight-objective MOPs. For the aggregation, we used four QIs (ER [2], GD [3], PD [4], Spacing [5]) each one evaluating each performance criterion. Thus, the obtained DRP-based CQIs provides a comprehensive measure of the algorithms' performance. This is just a proof of concept; the approach of the methodology can change depending on the QIs aggregated.

Our experiments have shown the type of information that can be extracted with the DRP-based CQIs. With them, we have highlighted the convenience of assessing algorithms' performance using both a compensatory scenario (using the W-CQI) and a non-compensatory one (using the S-CQI). It is clear that the same algorithm does not achieve the highest value (best performance) for both indicators, W-CQI and S-CQI. Furthermore, to globally rank all the algorithms, the M-CQI is used.

As future research line, we intend to modify the calculation of DRP-based CQIs to include more than two desirable reference levels, if necessary, by utilizing the MRP-WSI. Additionally, we plan to assess the performance of CQIs on indicator-based multiobjective optimization algorithms.

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Keywords: Composite indicators, Quality performance indicators, Population-based algorithms.

A Dynamic Decision-Support Approach for the Performance Assessment of Water Utilities in Portugal

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Abstract

The need to analyze data over multiple time periods has led to the development of specific multicriteria decision-support approaches. These approaches are frequently referred to as: Dynamic Multi-Attribute Decision Analysis (DMADM/A); Multi-Period Multicriteria Decision Making (MP-MCDM); Multi-Period Multicriteria Decision Analysis (MP-MCDA); or Dynamic Multicriteria Decision Analysis (DMCDA). Regardless of the designation, the dynamic MCDA methodologies are particularly effective not only in aggregating indicators and dealing with conflicting criteria but also in integrating decision-makers' preferences, managing uncertainty, and incorporating data from different periods. Recent studies have demonstrated the applicability of MP-MCDA across various sectors, including the water sector.

In Portugal, the water industry is divided into two subsectors: bulk water supply and retail water distribution. The bulk water supply, the focus of this study, is managed by 10 public concessionaires operating multi-municipal systems. Since 2004, the Portuguese Water and Waste Services Regulatory Authority (ERSAR) has implemented a regulatory model for service quality based on the performance assessment of service providers. This model includes 14 indicators organized into three dimensions: protection of users' interests, sustainability of service providers, and environmental sustainability. For each indicator, service providers are classified, , into three performance categories: “good,” “acceptable,” or “unsatisfactory.”

For regulatory framework, we propose a multi-period MCDA model based on the Multi-Attribute Value Theory (MP-MAVT) to assess both the evolution of the water sector by indicator and the overall performance of service providers between 2018 and 2021. We used direct elicitation techniques to determine the importance of each criterion in each period. This process was conducted through structured interviews with experts appointed by ERSAR, with closed-ended questions, carried out remotely and individually. The Content Validity Ratio was used to determine the annual scaling coefficients for each criterion.

The elicitation process revealed that the criteria “Coverage of Total Costs”, “Mains Rehabilitation”, “Real Water Losses”, and “Standardized Energy Consumption” were considered essential by experts at the time the interviews took place, accounting for 43% of the total weighting across all criteria over the four years analyzed. The elicitation results also highlight the increase in scale coefficients of temporal periods over time. By assigning greater weight to the most recent year, decision-makers emphasized performance improvement, prioritizing the most current results.

The application of the MP-MAVT model revealed that most service providers were classified as having “acceptable service quality”. Only one provider was rated as having “unsatisfactory service quality”, and none achieved a “good service quality” classification. Analysis of performance over time indicates that most providers have never been classified in the “good quality of service” category, revealing a degree of stagnation in the sector.

Performance trends, by indicator, reveal positive evolution in the criteria “Safe Water”, “Coverage of Total Costs”, “Mains Failures”, and “Adequacy of Human Resources”. However, the criteria “Connection to the service”, “Non-Revenue Water”, and “Mains Rehabilitation” show negative evolution. Although they reveal distinct evolution trends, both the “Coverage of Total Costs” and “Mains Rehabilitation” criteria were deemed essential by the experts.

The empirical analysis shows that, unlike the static model currently used by the regulator, the proposed dynamic assessment framework—adaptable to other contexts—allows the identification of key sectoral challenges, such as persistent weaknesses like high water losses and insufficient investment in network rehabilitation.

As well as highlighting the importance of continuous improvement, the model allows service providers to be ranked based on overall performance, identifying both the best and worst performers, as well as the key indicators to be prioritized in each regulatory cycle. Furthermore, it underscores the need for more effective public policy instruments to ensure high-quality service provision and highlights the importance of promoting a wider debate on the regulatory model.

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Keywords: Dynamic performance assessment, Water utilities, Benchmarking regulation, Multi-period multi-attribute value theory

Optimizing Financial Education for Portuguese Youth: An AHP-Based Analysis

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Abstract

In recent years, financial literacy has gained significant attention due to its impact on economic development and well-being [1]. It directly impacts financial and social inclusion [2] and influences financial well-being. Younger generations often struggle with basic financial concepts [5], [6], [7] leading to debt issues [8], lower stock market participation [9] , and poor retirement preparation, which is a crucial topic, especially in aging societies such as those in Europe [10]. Aligned with this, recent studies suggest that Portugal has alarmingly low levels of financial literacy, ranking among the worst-performing countries in Europe in this regard [12], [13].

To this end, 172 responses were collected from first-year students at the Escola Superior de Tecnologia e Gestão de Viseu. Whenever possible, a comparison will be made between the results obtained in this study and those from a survey conducted in 2022, with the same questions about financial literacy. This will allow for some conclusions to be drawn regarding recent efforts by the Portuguese government to introduce financial literacy topics in compulsory education (e.g., [14]). The sample consists of 58.7% male and 41.3% female participants. On a scale from 0 to 100, the average financial literacy score was 44.36, which represents a decrease compared to the 2022 score of 47.525. Specifically, men had an average score of 45.25, while women scored 43.10. In 2022, the average scores for each group were 49.87 and 43.52, respectively. In this regard, men often exhibit higher levels of financial literacy than women (e.g., [15]). Although 68% of respondents chose a course related to Management, the results indicate unsatisfactory performance in terms of financial literacy.

However, it is important to highlight that the students are fully aware of their lack of financial knowledge, demonstrating a clear relationship between self-assessment and the financial literacy indicator, which can be considered significant. Additionally, 38.8% of respondents state that they have never been exposed to financial matters during their compulsory education, while 32% report very limited exposure to these topics. These findings suggest that initiatives to integrate financial literacy into the compulsory education curriculum have not been as successful as expected. Finally, 60% of participants believe that financial literacy should undoubtedly be part of the compulsory education curriculum, emphasizing the urgent need for a more effective approach in this area. These findings indicate that current financial education initiatives need reassessment to address the issue more effectively. Financial education for youth is vital during this pivotal life transition, shaping responsible decision-making with lasting personal and economic impacts. While integrating financial literacy into compulsory schooling would ensure early knowledge acquisition, implementation challenges include teacher training needs and curriculum constraints. A phased approach through pilot programs could prove effective, with targeted interim measures serving as stopgap solutions

Financial literacy among young people represents a critical socioeconomic challenge with far-reaching implications for individual financial well-being and broader economic stability. This study employs the Analytic Hierarchy Process (AHP) to develop a systematic decision-making framework for optimizing financial education strategies. Taking into consideration a representative sample of students in college, this study evaluates different approaches to enhancing financial literacy, including in-person courses, online courses, and technology-based learning tools, based on key criteria such as accessibility and ease of use, as well as effectiveness and engagement, assessing motivation and interactivity from students. The study contributes to the field of financial education through its novel application of AHP methodology, enabling precise quantification of relative priorities across competing educational objectives and delivery mechanisms. Methodologically, it advances the use of operations research techniques in educational policy design. The findings provide valuable insights for educators, policymakers, and financial technology developers on the optimal structuring of financial literacy initiatives.

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Keywords: financial literacy, analytic hierarchy process, decision analysis, educational evaluation, college students

Machine Learning-Enhanced Sustainable Portfolio Optimization

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Abstract

Sustainable finance involves incorporating environmental, social, and governance (ESG) factors into financial decision-making within the investment sector. This approach seeks to generate financial returns while addressing long-term sustainability issues such as climate change, social inequality, and resource scarcity. By integrating ESG principles into their investment strategies, companies and investors strive to ensure their activities contribute to a more sustainable and fair global economy. In recent years, sustainable finance has experienced substantial growth as organizations increasingly acknowledge the importance of aligning financial goals with broader social and environmental objectives. This shift is largely driven by heightened awareness of the risks that environmental degradation, social disparities, and weak governance pose to financial market stability. For instance, climate change can negatively impact asset values and disrupt economies, while unethical labor practices can result in reputational damage and operational inefficiencies for businesses. This study focuses on investments aligned with the United Nations Sustainable Development Goal (SDG) 6: "Ensure access to water and sanitation for all," highlighting water's essential role in socioeconomic progress, energy production, food security, and climate change adaptation. The UN stresses the need for clean water and sanitation, particularly for women and girls, as inadequate access exacerbates public health issues and economic inequalities. Currently, one in three people lack safe drinking water, and global demand is projected to rise by 50% by 2040, with an estimated 5.7 billion people facing water scarcity by 2050. Addressing this crisis requires innovative financial solutions and investment in water-related technologies. Companies specializing in water resource management, water-efficient technologies, and wastewater treatment play a crucial role in mitigating these challenges, presenting investors with opportunities in a rapidly growing market. Investors can support firms developing sustainable water solutions, utilities committed to responsible water use, or companies focused on purification and distribution.

This research introduces an innovative methodology for optimizing financial investment decisions by integrating machine learning (ML) techniques into the Black-Litterman (BL) model, utilizing Conditional Value at Risk (CVaR) as a risk measure within a Socially Responsible

Investment (SRI) framework. The proposed approach leverages various ML models—including Long Short-Term Memory (LSTM), Random Forest, Artificial Neural Networks (ANN), Gated Recurrent Unit (GRU), and Autoregressive Integrated Moving Average (ARIMA)—to predict asset returns. These forecasts are then combined using a model that considers historical performance and incorporates it into a Black-Litterman-CVaR (BL-ML-CVaR) framework. Additionally, ESG data are employed to construct portfolios that integrate financial performance with sustainable investment practices. Findings reveal that the BL-ML-CVaR portfolio delivers superior returns with balanced risk compared to conventional models, while the ESG-integrated version maintains competitive performance while adhering to sustainability principles. This research offers valuable perspectives on how ML-driven investment strategies can enhance portfolio management in emerging sectors affected by environmental challenges, paving the way for more sustainable and responsible financial decision-making.

Keywords: CVaR; ESG; Machine Learning; Black-Litterman; Water Market

On rationalizability in weighted maxmin games

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Abstract

In this work we analyse the extension to noncooperative vector-valued games of one important concept in game theory, rationalizability. The notion of rationalizable strategies for scalar games was introduced as a relaxation of the concept of Nash equilibrium. We focus on vector-valued games with compact payoff spaces which accommodate the cases of finite games and games with closed and bounded infinite sets of strategies and continuous payoff functions. The two solution concepts considered rely upon strong Pareto optimality and weak Pareto optimality.

Several forms to represent the preferences of the players can be explored. In the literature the most commonly applied is the additive representation. Our approach is based on a maxmin representation of the preferences of the players, considering the associated weighted maxmin game. This framework is appropriate when there is no possibility of compensation between the components of the utilities and therefore, in order to achieve an improvement, the smallest weighted utility must increase.

We address both the strong version and the weak version of rationalizability (which correspond to the two versions of Pareto optimality) providing a general understanding of this notion of solution. We analyse how rationalizable strategies of weighted maxmin games are related to rationalizable strategies of the vector-valued game. Our main result shows that any rationalizable strategy in the strong sense is a rationalizable strategy in some weighted maxmin game, and that a rationalizable strategy in a maxmin game is weak rationalizable in the game with vector-valued utilities. Furthermore, as in scalar games, we have proved that if a strategy for a player is part of a strong (weak) equilibrium then it is a strong (weak) rationalizable strategy for that player.

Keywords: rationalizability, games, vector-valued utilities, maxmin value function, equilibria.