

Livro de Resumos



**XXIII CONGRESSO
APDIO 2024**
ESCOLA SUPERIOR DE TECNOLOGIA E GESTÃO DE VISEU

**O Potencial da IO na Formulação e Implementação de
Políticas Públicas**

Editado por:

Paula Sarabando | Joana Fialho | Manuel Reis
Suzanne Amaro | Teresa Neto | Tiago Miguel

XXIII Congresso da Associação Portuguesa de Investigação Operacional

Livro de Resumos

Editores:

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Viseu
24 a 26 de março 2024

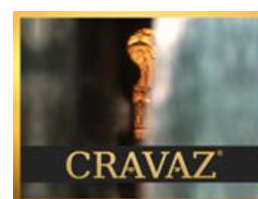
O XXIII Congresso da APDIO é organizado por:



Patrocinador principal:



Outros patrocinadores:



Conteúdo

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Mensagem do Presidente da Direção da APDIO

Caros participantes no IO 2024,

Bem vindos ao XXIII Congresso da Associação Portuguesa de Investigação Operacional - IO 2024.

O congresso da APDIO constitui o marco mais importante da vida da nossa comunidade de Investigação Operacional, mantendo o fio condutor da tradição do (re)encontro pessoal e profissional, mas sempre renovado pela chegada de novos participantes, pelo entusiasmo vivido nas atividades científicas e sociais, e pelo empenho que as comissões organizadoras colocam em todos os detalhes para que a experiência seja inolvidável.

Este congresso marca o regresso ao formato de apresentação de comunicações em sessões paralelas, nas quais a Comissão de Programa fez um bem sucedido esforço de coerência temática. O número de resumos submetidos, o interesse mais uma vez gerado pelo EstudIO, e o número de inscrições testemunham a vitalidade e a capacidade de renovação da comunidade portuguesa de Investigação Operacional.

O tema do IO 2024 é "O potencial da IO na Formulação e Implementação de Políticas Públicas". As apresentações plenárias e muitas comunicações em sessões paralelas evidenciarão o importante papel que a Investigação Operacional pode desempenhar neste domínio, ao proporcionar as formas de abordagem aos problemas e as técnicas analíticas para auxiliar na formulação, implementação e avaliação de políticas públicas eficientes e eficazes, ajudando múltiplas entidades de planeamento e de governo a tomar decisões mais informadas e mais explicáveis.

O EstudIO, que terá mais uma vez o amável patrocínio da SISCOG, permitirá divulgar os trabalhos dos nossos estudantes de licenciatura e de mestrado num fórum dedicado com o devido relevo no programa científico do congresso.

A atribuição de prémios ao trabalho realizado pelos sócios é também uma marca distintiva dos nossos congressos. Na sessão de encerramento do IO 2024 será anunciada a tese vencedora do prémio APDIO IO 2024, atribuído à melhor tese de doutoramento defendida com êxito em 2021-2023, o vencedor do prémio Augusto Queirós Novais que se destina a galardoar o melhor artigo na área de Process Systems Engineering publicado no mesmo período, bem como do prémio EstudIO.

Para tornar mais visível a parceria que a APDIO tem há vários anos com a SEIO e a SOBRAPO, associações congéneres de Espanha e do Brasil, contamos pela primeira vez na comissão de programa com representantes dessas duas associações, bem como de comunicações apresentadas pelos seus sócios, que trarão ao IO 2024 as suas experiências, ajudando a criar laços mais fortes entre nós.

O Congresso da APDIO realiza-se pela primeira vez na cidade de Viseu, materializando uma vez mais a vontade de descentralização das atividades da APDIO no território nacional, dando a conhecer os núcleos organizadores locais, e deixando as sementes para o seu desenvolvimento e afirmação.

Na qualidade de Presidente da APDIO, e em nome de todos os participantes, agradeço de forma amiga e calorosa a todas e todos que tornaram este Congresso uma feliz realidade. Os nossos agradecimentos são devidos, em especial, à Comissão Organizadora, liderada pela Prof^a. Paula Sarabando, bem como à Presidência do Instituto Politécnico de Viseu por nos acolher, à Comissão de Programa, liderada pela Prof^a. Maria Antónia Carravilla, aos membros do júri do Prémio APDIO IO2024, presidido pelo Prof. Bernardo Almada Lobo, ao júri do Prémio Augusto Queirós Novais, presidido pelo Prof. Henrique Matos, e ao Prof. Samuel Moniz, Vice-Presidente da Direção da APDIO com o pelouro dos congressos. Uma palavra especial de gratidão para todas as entidades e empresas que apoiaram materialmente a realização do IO 2024, contribuindo para o seu êxito.

Em nome da Comissão Diretiva da APDIO, expresso os votos que este congresso seja não apenas uma oportunidade para partilhar conhecimento e experiências, mas também para fortalecer os vínculos entre os participantes e impulsionar novas colaborações e iniciativas. A vossa presença e contribuição são fundamentais para o sucesso do IO 2024 e para o desenvolvimento da Investigação Operacional em Portugal.

A todas e a todos, desejo um congresso produtivo e enriquecedor.

E como diz a canção infantil “indo eu, indo eu a caminho de Viseu” para desfrutarmos em conjunto de mais um memorável congresso da APDIO.

Viseu, 24 de março de 2024

Carlos Henggeler Antunes
Presidente da Direção da APDIO

Nota do Presidente da Comissão de Programa

Caros colegas,

É com enorme prazer que vos damos as boas-vindas ao XXIII Congresso da Associação Portuguesa de Investigação Operacional (IO2024). Este evento representa sempre um marco para a comunidade de Investigação Operacional, reunindo investigadores que vão partilhar experiências e resultados dos seus trabalhos.

Durante as sessões plenárias do IO2024, teremos a oportunidade de explorar o tema central do congresso, "O Potencial da Investigação Operacional na Formulação e Implementação de Políticas Públicas". Mara Almeida, Vereadora da Câmara Municipal de Viseu e co-fundadora e CEO do Grupo ENAME, abordará na plenária de domingo a interseção entre IO e o desenvolvimento local. Na segunda-feira, Ine Steenmans, Associate Professor na University College London (UCL), discutirá metodologias de análise de políticas e futuros alternativos na tomada de decisões políticas. Na terça-feira, teremos a mesa redonda sobre dados públicos, com representantes da PORDATA, INE e e-redes, que mostrarão como a disponibilidade desses dados pode impulsionar a investigação em diversos setores.

No EstudIO, organizado pelas colegas Carina Pimentel e Elsa Silva, serão apresentados os dez trabalhos candidatos ao Prémio EstudIO, patrocinado pela SISCOG, numa sessão plenária na tarde de segunda-feira. Teremos toda a oportunidade de votar para o melhor trabalho.

A entrega dos prémios do congresso será feita na terça-feira à tarde, durante a sessão de encerramento. Serão entregues o prémio EstudIO, o prémio APDIO, que reconhece os melhores trabalhos de doutoramento em Investigação Operacional, e o prémio Augusto Queirós Novais, que galardoa os melhores artigos em Process Systems Engineering.

Foram submetidos ao congresso 83 trabalhos, organizados em cinco slots de sessões paralelas que decorrerão durante a manhã e tarde de segunda-feira e na terça-feira de manhã. Destacamos a sessão especial SEIO APDIO sobre cortes e empacotamentos, presidida pela colega Franklina Toledo, representante da SOBRAPO na comissão organizadora, que tem com a participação de dois colegas da SEIO. Teremos também vários outros participantes estrangeiros, principalmente estudantes de programas doutorais, a apresentar os seus trabalhos.

As apresentações estão organizadas em 24 sessões paralelas e, para aumentarmos os momentos de discussão entre os participantes, limitamos a duração de cada apresentação a 12 minutos. Para além disso o planeamento do congresso inclui vários momentos que permitirão reunir e discutir novas ideias de investigação e criar rede de contactos para realização conjunta de projetos.

Gostaríamos de salientar a elevada qualidade dos trabalhos apresentados, que demonstram o vigor da Investigação Operacional em Portugal. Agradecemos a todos os envolvidos na organização do IO2024, em especial à comissão de programa, pela disponibilidade para pensar nas melhores soluções para esta organização. A comissão organizadora demonstrou um empenho notável na resolução de desafios, garantindo que o congresso seja um sucesso. Agradeço também a todos os que se disponibilizaram para moderar as 24 sessões paralelas e as três sessões plenárias.

Por fim, esta experiência próxima com a direção da APDIO e com a presidente da comissão organizadora foi marcante e esperamos ter tornado em conjunto este congresso numa experiência que todos recordaremos com alegria.

Estamos ansiosos por vos receber em Viseu no IO2024!

Viseu, 24 de março de 2024

Maria Antónia Carravilla
Presidente da Comissão de Programa

Comissão Organizadora

Paula Sarabando, Escola Superior de Tecnologia e Gestão de Viseu (Presidente)

Joana Fialho, Escola Superior de Tecnologia e Gestão de Viseu

Manuel Reis, Escola Superior de Tecnologia e Gestão de Viseu

Suzanne Amaro, Escola Superior de Tecnologia e Gestão de Viseu

Teresa Neto, Escola Superior de Tecnologia e Gestão de Viseu

Tiago Miguel

Comissão de Programa

Maria Antónia Carravilla, Universidade do Porto, Faculdade de Engenharia (Presidente)

Franklina Toledo, Universidade de São Paulo (Representante da SOBRAPO)

Mercedes Landete Ruiz, Universitat Miguel Hernandez (Representante da SEIO)

Paula Sarabando, Instituto Politécnico de Viseu (Presidente da comissão organizadora)

Jorge Orestes Cerdeira, Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia (Presidente comissão de programa IO 2022)

Samuel Moniz, Universidade de Coimbra, Faculdade de Ciências e Tecnologia (APDIO VPConferências)

Carina Pimentel, Universidade do Minho, Escola de Engenharia (Organização do EstudIO)

Elsa Marília da Costa Silva, Universidade do Minho, Escola de Engenharia (Organização do EstudIO)

Agostinho Agra, Universidade de Aveiro, Departamento de Matemática

Alberto Adrego Pinto, Universidade do Porto, Faculdade de Ciências

Ana Cristina Amaro, Instituto Politécnico de Coimbra, ISCAC

Beatriz Brito Oliveira, Universidade do Porto, Faculdade de Engenharia

Carla Soares Gerales, Instituto Politécnico de Bragança

Filipe Alvelos, Universidade do Minho, Escola de Engenharia

Filipe Carvalho, Widescope

Isabel Cristina Lopes, Instituto Politécnico do Porto, ISCAP

Isabel Gomes, Universidade Nova de Lisboa, Faculdade de Ciências e Tecnologia

Luís Dias, Universidade de Coimbra, Faculdade de Economia

Maria Cândida Mourão, Universidade de Lisboa, ISEG

Maria Eugénia Captivo, Universidade de Lisboa, Faculdade de Ciências

Maria João Alves, Universidade de Coimbra, Faculdade de Economia

Mário Amorim Lopes, Universidade do Porto, Faculdade de Engenharia

Miguel Fragoso Constantino, Universidade de Lisboa, Faculdade de Ciências

Pedro Fernandes, Bullet Solutions

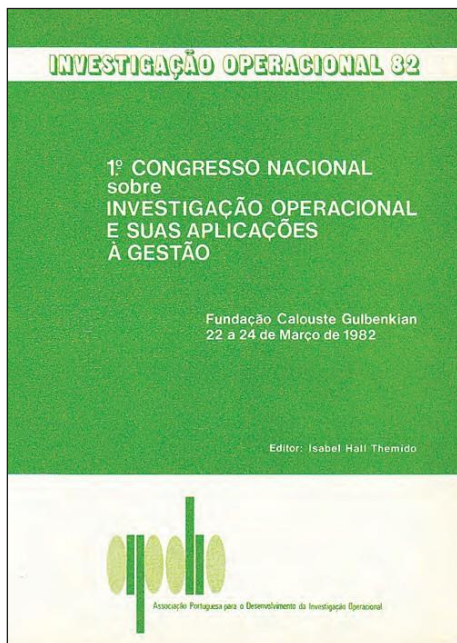
Rui Borges Lopes, Universidade de Aveiro, DEGEIT

Sara Sofia Baltazar Martins, Instituto Politécnico do Porto, ESTG

Susana Relvas, Universidade de Lisboa, Instituto Superior Técnico

Telmo Pinto, Universidade de Coimbra, Faculdade de Ciências e Tecnologia

Edições Anteriores



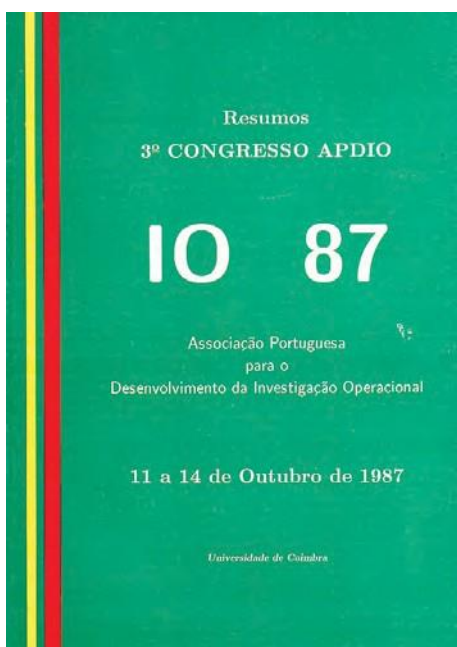
1º Congresso da APDIO

Lisboa, 22 a 24 de março de 1982
 Fundação Calouste Gulbenkian
 Presidente da Comissão Organizadora
 Aníbal Durães Santos



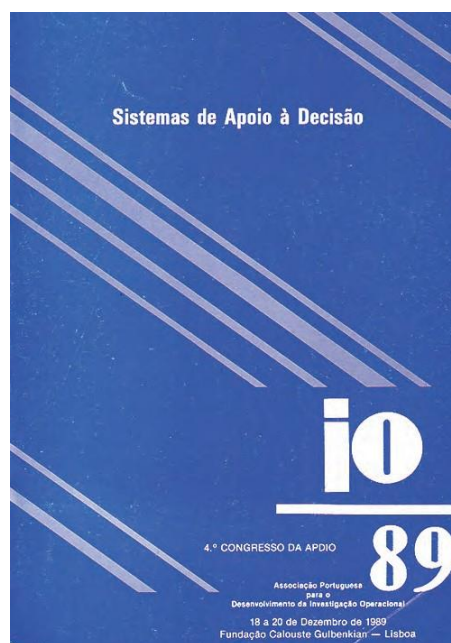
2º Congresso da APDIO

Porto, 16 a 18 de abril de 1984
 Faculdade de Economia da Universidade do Porto
 Presidente da Comissão Organizadora
 Rui Guimarães



3º Congresso da APDIO

Coimbra, 11 a 14 de outubro de 1987
 Universidade de Coimbra
 Presidente da Comissão Organizadora
 Mário da Silva Rosa



4º Congresso da APDIO

Lisboa, 18 a 20 de dezembro de 1989
 Fundação Calouste Gulbenkian
 Presidente da Comissão Organizadora
 A. J. Simões Monteiro

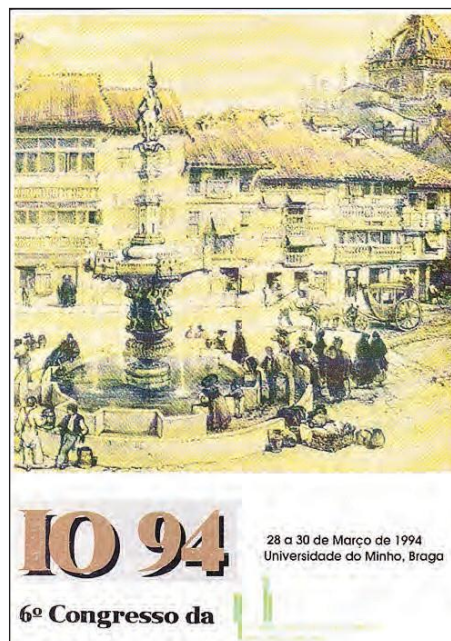


5º Congresso da APDIO

Évora, 13 a 15 de abril de 1992
Universidade de Évora

Presidente da Comissão de Programa
José Rodrigues Dias

Presidente da Comissão Organizadora
Rui Guimarães



6º Congresso da APDIO

Braga, 28 a 30 de março de 1994
Universidade do Minho

Presidente da Comissão de Programa
Jorge Pinho de Sousa

Presidente da Comissão Organizadora
A. Guimarães Rodrigues

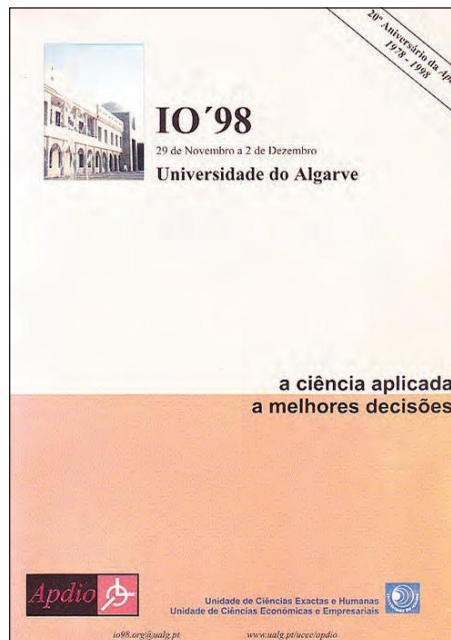


7º Congresso da APDIO

Aveiro, 1 a 3 de abril de 1996
Universidade de Aveiro

Presidente da Comissão de Programa
Carlos Bana e Costa

Presidente da Comissão Organizadora
Domingos Moreira Cardoso

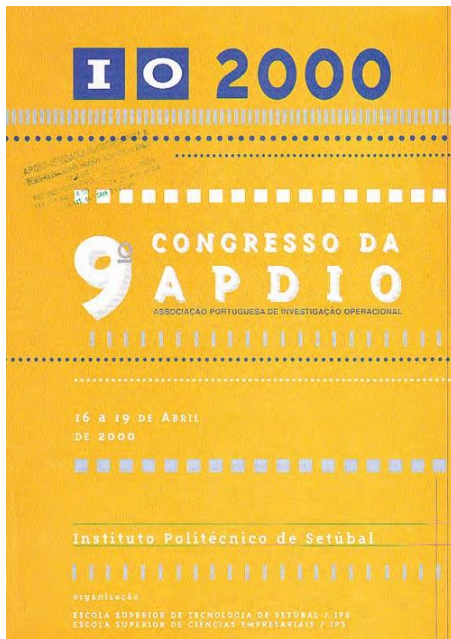


8º Congresso da APDIO

Faro, 29 de novembro a 2 de dezembro de 1998
Universidade do Algarve

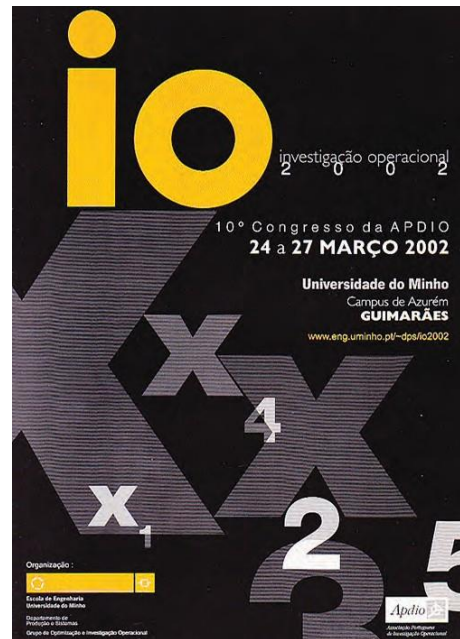
Presidente da Comissão de Programa
José Pinto Paixão

Presidente da Comissão Organizadora
Fernanda Marília Pires



9º Congresso da APDIO

Setúbal, 16 a 19 de abril de 2000
 Instituto Politécnico de Setúbal
 Presidente da Comissão de Programa
 Carlos Henggeler Antunes
 Presidente da Comissão Organizadora
 Carlos Luz



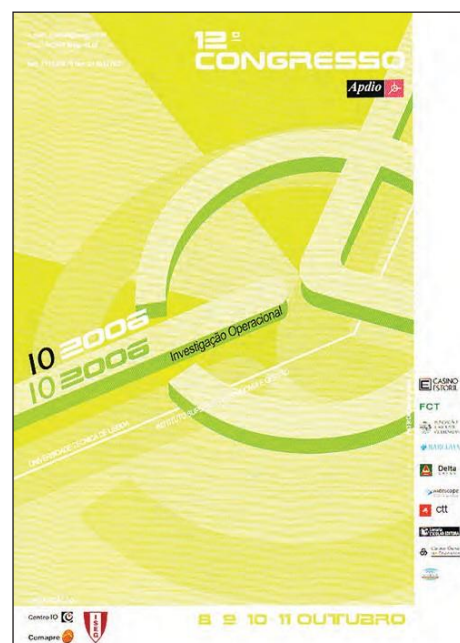
10º Congresso da APDIO

Guimarães, 24 a 27 de março de 2002
 Universidade do Minho
 Presidente da Comissão de Programa
 José Fernando Oliveira
 Presidente da Comissão Organizadora
 José Valério de Carvalho



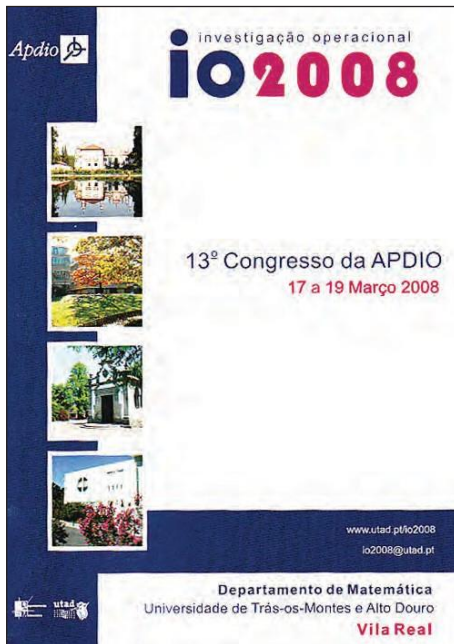
11º Congresso da APDIO

Porto, 4 a 7 de abril de 2004
 Faculdade de Engenharia da Universidade do Porto
 Presidente da Comissão de Programa
 Joaquim João Júdice
 Presidente da Comissão Organizadora
 Rui Guimarães



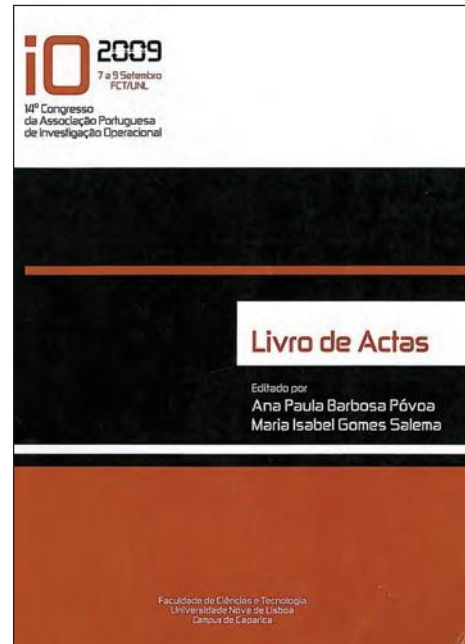
12º Congresso da APDIO

Lisboa, 8 a 11 de outubro de 2006
 ISEG - Universidade Técnica de Lisboa
 Presidente da Comissão de Programa
 Pedro Oliveira
 Presidente da Comissão Organizadora
 Margarida Vaz Pato



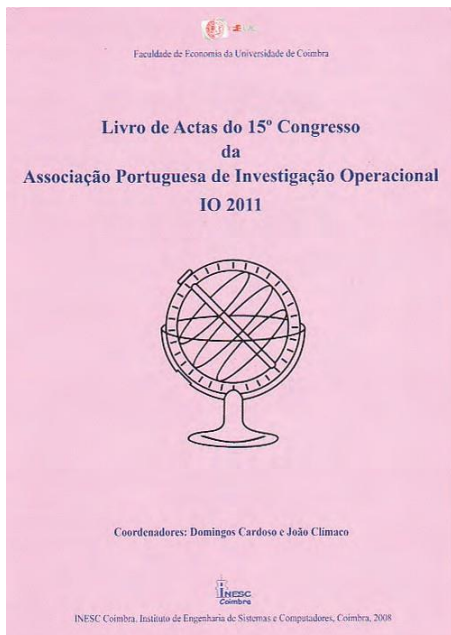
13º Congresso da APDIO

Vila Real, 17 a 19 de março de 2008
 Universidade de Trás os Montes e Alto Douro
 Presidente da Comissão de Programa
 Maria Eugénia Captivo
 Presidente da Comissão Organizadora
 Ana Paula Teixeira



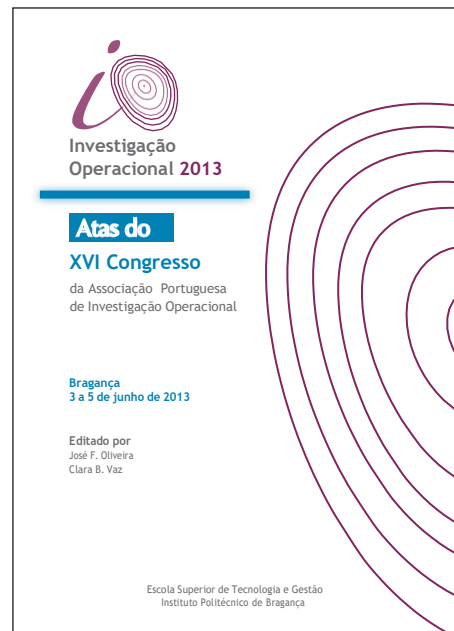
14º Congresso da APDIO

Caparica, 7 a 9 de setembro de 2009
 FCT - Universidade Nova de Lisboa
 Presidente da Comissão de Programa
 Ana Barbosa Póvoa
 Presidente da Comissão Organizadora
 Ruy Costa



15º Congresso da APDIO

Coimbra, 18 a 20 de abril de 2011
 Universidade de Coimbra
 Presidente da Comissão de Programa
 Domingos Moreira Cardoso
 Presidente da Comissão Organizadora
 João Clímaco



16º Congresso da APDIO

Bragança, 3 a 5 de junho de 2013
 Instituto Politécnico de Bragança
 Presidente da Comissão de Programa
 José Fernando Oliveira
 Presidente da Comissão Organizadora
 Clara Bento Vaz

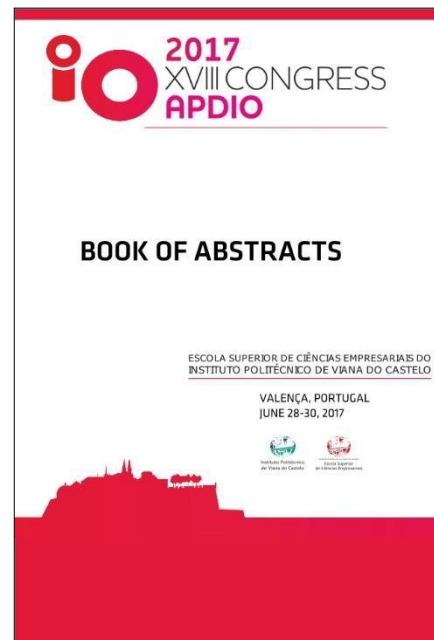


17º Congresso da APDIO

Portalegre, 7 a 9 de setembro de 2015
Instituto Politécnico de Portalegre

Presidente da Comissão de Programa
Ana Paula Barbosa-Póvoa

Presidente da Comissão Organizadora
João Luís de Miranda



18º Congresso da APDIO

Valença, 28 a 30 de junho de 2017
Instituto Politécnico de Viana do Castelo

Presidente da Comissão de Programa
António Ismael Freitas Vaz

Presidente da Comissão Organizadora
Lia Oliveira



19º Congresso da APDIO

Aveiro, 5 a 7 de setembro de 2018
Universidade de Aveiro

Presidente da Comissão de Programa
Maria João Alves

Presidentes da Comissão Organizadora
Ana Raquel Xambre
Helena Alvelos



20º Congresso da APDIO

Tomar, 22 a 24 de julho de 2019
Instituto Politécnico de Tomar

Presidente da Comissão de Programa
Susana Relvas

Presidente da Comissão Organizadora
João Patrício



21º Congresso da APDIO

Figueira da Foz,
7 e 8 de novembro de 2021

Presidente da Comissão de Programa
Samuel Moniz

Presidente da Comissão Organizadora
Samuel Moniz



22º Congresso da APDIO

Évora, 6 a 8 de novembro de 2022
Universidade de Évora

Presidente da Comissão de Programa
Jorge Orestes Cerdeira

Presidente da Comissão Organizadora
Cesaltina Pires

Programa Geral

	domingo (24/03/2024)	2ª feira (25/03/2024)	3ª feira (26/03/2024)
9h00 - 9h30		Sessões paralelas 1	
9h30 - 10h00			
10h00 - 10h30		Sessões paralelas 2	Sessões paralelas 4
10h30 - 11h00		Coffee break	Coffee break
11h00 - 11h30		Plenária 2 - Ine Steenmans	Sessões paralelas 5
11h30 - 12h00			
12h00 - 12h30		Almoço	Almoço
12h30 - 13h00			
13h00 - 13h30		Atuação	
13h30 - 14h00	Receção dos participantes		Plenária 3 - Mesa Redonda
14h00 - 14h30	Sessão de Abertura	Plenária Estúdio	Sessão de encerramento Entrega prémios
14h30 - 15h00	Plenária 1 - Mara Almeida		
15h00 - 15h30		Sessões paralelas 3	
15h30 - 16h00	Coffee break especial de boas vindas		
16h00 - 16h30		Coffee break	
16h30 - 17h00	Visita à cidade	Assembleia Geral da APDIO	
17h00 - 17h30			
17h30 - 18h00	Dão de Honra		
18h00 - 18h30			
18h30 - 19h00			
19h00 - 19h30			
19h30 - 20h00		Jantar do Congresso	
20h00 -			

Sessões Plenárias

Sessão Plenária I

Moderador: Carlos Henggeler Antunes

Das empresas às autarquias, onde a investigação operacional influencia as nossas vidas.

Mara Almeida

Vereadora da Câmara Municipal de Viseu

Nesta apresentação partilharei a minha experiência pessoal e visão sobre o impacto da Investigação Operacional na tomada de decisões. Orientada pela busca do “ótimo”, recorro frequentemente a abordagens menos formais para procurar maior eficiência e eficácia das decisões.

Através da apresentação de dilemas reais enfrentados na autarquia e na empresa, como a gestão de recursos humanos, discutirei a necessidade de modelos científicos para ultrapassar esses desafios. Destacarei a importância da Investigação Operacional em diversas áreas, desde a gestão empresarial até ao planeamento urbano, enfatizando a necessidade de difundir esse conhecimento na sociedade para promover decisões mais informadas e sustentáveis. Como autarca e empresária, deparo-me frequentemente com decisões que requerem acompanhamento científico e técnico, reconhecendo o papel fundamental da Investigação Operacional para o progresso e desenvolvimento sustentável da sociedade.

Biografia

Mara Almeida é licenciada em Contabilidade e Administração pelo Instituto Politécnico de Viseu, com Especialização em Programas de Desenvolvimento em Gestão e Liderança através da Católica Lisbon School of Business Economics, pós-graduada em Avaliação e Gestão da Atividade Imobiliária pela Coimbra Business School. Certificada como Internacional Coach pela Internacional Coaching Community e graduada em Integrative Nutrition Health Coach pelo New York Institute of Integrative Nutrition.

É vereadora na Câmara Municipal de Viseu com os pelouros de Urbanismo, Economia Investimento e Inovação, Modernização Administrativa, Saúde, Juventude, e Defesa do Consumidor.

Participa em atividades de cidadania, contribuindo ativamente junto de grupos temáticos para o desenvolvimento da atividade empresarial e aumento da atratividade das regiões para a captação de investimento empresarial; agente inspiracional para diversos públicos ligados à direção de instituições públicas para interações virtuosas ancoradas em competências e capacidades chave no âmbito do empreendedorismo e gestão empresarial.

Atividades de representatividade: na Direção da AIRV - Associação Empresarial da Região de Viseu; na Presidência do Conselho Fiscal da AIP - Associação Industrial Portuguesa/Câmara do Comércio e Indústria, entre outros.

No âmbito da temática Mulher nos Negócios, é agente dinamizadora da Rede Mulher Líder, com o IAPMEI, para criação conjunta de uma rede exclusiva, dirigida a PME de elevado desempenho em setores críticos para a competitividade nacional, que pretendam ligar-se entre pares, e com grandes empresas e entidades facilitadoras, com o objetivo de trabalhar a capacitação empresarial e acelerar o desenvolvimento dos negócios.

É Cofundadora e Presidente do Conselho de Administração de um agrupamento empresarial instalado em diversos países da Europa, a trabalhar vários setores de negócio, atuando em toda parte do mundo e no qual, continua a colaborar para um crescimento pleno e sustentável.

Dedicada e orgulhosa mãe de dois filhos, com a incondicional missão de lhes proporcionar as melhores ferramentas para se tornarem seres íntegros, autónomos, resilientes, saudáveis e felizes, seres de grande tolerância e compaixão, não só com o objetivo de poderem viver em plenitude, como também, de contribuírem para que o mundo seja um lugar melhor.

A Mara é uma pessoa rendida ao desenvolvimento pessoal, procurando sempre um equilíbrio harmonioso entre o seu estado físico, mental, emocional e espiritual, de modo a fazer face aos incessantes desafios que a vida lhe presenteia.

Como filosofia de vida, entende que não é possível controlar aquilo que nos acontece, mas temos a escolha e o domínio absoluto, sobre a forma como iremos reagir. Defende que a excelência atinge-se cooperando e não, competindo.

Sessão Plenária II

Moderador: José Fernando Oliveira

Future Policy and the Roles for Operational Research

Ine Steenmans

University College London

In today's world, it's crucial for the field of Operational Research (OR) to play a significant role in shaping future public policy. Historically, OR has been pivotal in introducing innovative scientific techniques and analytical methods to enhance policy analysis, design, and implementation. However, with public policy now facing significant challenges—such as resource scarcity, ineffective waste management, climate change, mass migration, digital divides, health crises and economic inequities—alongside shifts in public service delivery and governance models, it may seem daunting to identify specific areas where OR professionals can contribute effectively.

In my presentation, I will highlight five key drivers of change and areas of innovation in contemporary policy design and analysis that are critical in defining its future direction. I will also discuss how the unique skills and capabilities of OR professionals can provide essential and invaluable insights for creating better futures. Finally, we will discuss important areas for ongoing research and education to further empower OR's contribution to public policy development.

Biography

Dr Ine Steenmans is an Associate Professor in Futures, Analysis and Policy at the University College London (UCL). Ine's research focuses on future policy competencies and capabilities. This means her research explores questions such as: What analytical competencies do policy professionals need, and how do they develop them? How do groups develop collective analytical capabilities? And how can the development of competencies and capabilities be better aligned? She has an especial interest in the competencies for integrating knowledge across disciplines, sectors, and time horizons. This includes futures and foresight methods, systems methodologies, and evaluation. All her work takes a needs-led, transformation-oriented approach, which involves working in partnership with policy professionals. Recent projects included capability development work on the uses of systems mapping, evaluation skills, scenarios, and strategy tools – in collaboration with BEIS, Lloyds Insurance, UNDP, Policy Lab, the UAE Office of Advanced Sciences and the UAE Space Agency. Before joining UCL in 2017, Ine worked as a foresight researcher in the UK Government Office for Science.

Sessão Plenária EstudIO*Moderadoras: Carina Pimentel, Elsa Silva***Submissão #1****A storytelling dashboard for multicriteria decision-making**

André Couto, Samuel Moniz, Luís Paquete

Consultar página 65.

Keywords: multi-criteria, decision support, storytelling, visualization**Submissão #2****Programação de máquinas paralelas dedicadas com setups dependentes da sequência de famílias e recursos adicionais**

Ângelo Soares, Manuel Pereira Lopes

Consultar página 67.

Keywords: Escalonamento, Máquinas paralelas, Setups, Recursos, Tabu Search, Heurística matemática**Submissão #3****A Numerical Approach for the Aircraft Deconfliction Problem with Speed Regulation**

Antonio Iglesias, Tatiana Tchemisova

Consultar página 69.

Keywords: Air Traffic Management, Aircraft Deconfliction, Speed Control, Semi-Infinite Programming, Non-Linear Programming**Submissão #4****Sistema de Apoio à Decisão para aquisição de ração para os cães da Guarda Nacional Republicana**

Hélio Miranda, João Miranda, Paulo Ferreira

Consultar página 72.

Keywords: GNR, Ração, Canídeos, Programação Linear

Submissão #5

Reserve Crew Scheduling in Passenger Rail Transport

Inês Douradinho, Ana Wemans, Jorge Roussado, Ricardo L. Saldanha, Nelson Chibeles P. Martins

Consultar página 74.

Keywords: Reserve Crew Scheduling

Submissão #6

From data to action: transforming warehouse operations with simulation

Diogo Gonçalves, João Melo, Samuel Moniz

Consultar página 76.

Keywords: Simulation, Warehouse, Optimization, Service Level, Total Costs, Experimentation

Submissão #7

Otimização de um problema integrado de balanceamento de postos e afetação de recursos: Um caso de estudo

Leonor Gonçalves, Ana Moura, Helena Alvelos

Consultar página 78.

Keywords: Otimização, Balanceamento de linhas, Afetação de recursos

Submissão #8

Implementação de um algoritmo de análise multicritério numa empresa do ramo automóvel

Marco Silva, Helena Alvelos, Ana Raquel Xambre

Consultar página 81.

Keywords: Otimização, Análise Multicritério, TOPSIS

Submissão #9

Operational Research Models for Kitting Systems in the Warehouse of the Future

Mário Jorge Simões, Telmo Pinto, Cristóvão Silva

Consultar página 83.

Keywords: Kitting, Line Feeding, Mixed-Model Assembly, Optimization, Mixed Integer Programming

Submissão #10

Sustainability of cutting and packing problems: beyond waste minimization

Matheus Campinho, Elsa Silva, José Fernando Oliveira, Maria Antónia Carravilla

Consultar página 85.

Keywords: cutting and packing problems, mixed-integer linear programming model (MILP), complexity of the cutting patterns

Sessão Plenária III

Moderadora: Ana Barbosa-Póvoa

MESA REDONDA: Utilização de Dados Públicos para a Investigação

Francisco Lima (INE), Luísa Loura (PORDATA), Bruno Espírito-Santo (E-redes)

Os dados públicos representam uma fonte valiosa de informações para investigadores, académicos, profissionais e decisores políticos. Nesta mesa redonda, em que participarão representantes de organizações de referência no fornecimento de dados públicos em Portugal, salientaremos como a disponibilidade desses dados pode impulsionar a investigação.

Francisco Lima: Como órgão central de produção de estatísticas oficiais em Portugal, o INE (Instituto Nacional de Estatística) desempenha um papel crucial na disponibilização de dados públicos confiáveis e atualizados sobre uma ampla gama de temas. Francisco Lima irá partilhar a sua visão sobre o uso dos dados do INE na investigação e seu impacto na formulação de políticas e estratégias.

Luísa Loura: A PORDATA tem sido uma fonte crucial de estatísticas e indicadores que permitem uma análise abrangente e atualizada da sociedade portuguesa. Luísa Loura irá partilhar casos de uso dos dados da PORDATA e discutir como esses dados podem contribuir para a investigação em diferentes contextos.

Bruno Espírito-Santo: Com o crescente papel da tecnologia na gestão de infraestruturas, a e-redes desempenha um papel vital na disponibilização de dados relacionados com o setor energético em Portugal. Bruno Espírito-Santo apresentará exemplos de como os dados fornecidos pela e-redes têm sido utilizados para tomar decisões fundamentadas.

Sessões Paralelas

Sessão S1.1*Moderadora: Franklina Toledo***SEIO APDIO session on cutting and packing problems****Submissão #1****The 2-dimensional cutting stock problem with variable-sized stock**

Paula Terán-Viadero, Antonio Alonso-Ayuso, F. Javier Martín-Campo

This work is being carried out in collaboration with a Spanish company in the honeycomb cardboard sector that wants to automate its manufacturing processes. Different optimisation models have been developed to help them in their decision-making process. The company manufactures panels that need to be cut into smaller rectangular pieces. Both the production and the cutting of the panels are carried out in its own factory, so it can decide which panels to manufacture and how to cut them according to the orders received. The possibility of deciding on the size of the panels leads to a new version of the classical Cutting Stock Problem. Here the stock is considered to be of variable size. A mixed integer programming model is presented that minimises the amount of material used by defining the dimensions of the panels, how many of each type to produce and how to cut them. The model has been validated with real data obtaining results that considerably reduce the material they currently use.

Keywords: Cutting, Variable-Sized stock, Mixed Integer Linear Optimisation, 2-stage guillotine, Honeycomb cardboard industry

Submissão #2**The Floating-Cuts model: a general and flexible mixed-integer programming model for non-guillotine and guillotine rectangular cutting problems**

Elsa Silva, José Fernando Oliveira, Tiago Silveira, Leandro R. Mundim, Maria Antónia Carravilla

Cutting and packing problems are combinatorial optimization problems with many industrial applications, in which, the raw material and the cut parts have a rectangular shape. This is known in the literature as the (two-dimensional) rectangular cutting problem. Many variants of this problem may arise, led by cutting technology constraints, the most relevant of which are the guillotine cuts. The absence of the guillotine cuts makes the problem harder to solve to optimality. A general and flexible MILP model for the two-dimensional rectangular cutting problem is proposed based on the Floating-Cuts paradigm. To the best of our knowledge, it is the first MILP model in the literature for both non-guillotine and guillotine problems. The basic idea of this model is a tree search where branching occurs by successive first-order non-guillotine-type cuts. The exact position of the cuts is not fixed, but remains floating until a small rectangle is assigned to a child node. This model does not include decision variables either for the position coordinates of the items or for the coordinates of the cuts. Under this framework, many different variants of the problem were addressed. Extensive computational experiments were run and the results confirm the power of this flexible model.

Keywords: Non-guillotine and guillotine cutting and packing problems, Mixed-integer linear programming model, Tree search

Submissão #3

An optimisation model for slitting line allocation in the steel industry

F. Javier Martín-Campo, María Sierra-Paradinas, Antonio Alonso-Ayuso, Óscar Soto-Sánchez, Micael Gallego

A mathematical optimisation model is presented to address the 1.5-dimensional Cutting Stock Problem (CSP) applied in a Spanish steel manufacturing company. The model helps to fulfil orders by cutting coils from stock into smaller pieces according to customer specifications in terms of width and weight. In addition, the model determines the appropriate slitting line to process the coils, taking into account the heterogeneity in speed and specifications of the different lines. Validation of the model with real data from the company shows improvements in the current operation.

Keywords: cutting, mathematical optimisation, steel industry

Sessão S1.2

Moderador: Diana Jorge

Routing Problems 1

Submissão #4

Otimização da Recolha de Biorresíduos: Uma Abordagem Estratégica para a recolha de resíduos no Município de Paços de Ferreira

João Cunha, João Magalhães, Fábio Oliveira, Wellington Alves

Um dos maiores desafios da atualidade em termos ambientais é reverter a crescente produção de resíduos e minimizar os seus impactos negativos, procurando assim contribuir para uma minimizar os impactos ambientais e sociais deste modelo de produção. Neste sentido, no âmbito das políticas voltadas a Economia Circular, a UE estabeleceu a obrigatoriedade de recolha seletiva de biorresíduos, para todos os estados-membro. No que se refere ao caso português, essa responsabilidade foi delegada aos municípios, que por sua vez são responsáveis pelos consideráveis custos, devido à sua complexidade operacional. Neste sentido, tenho em conta a importância do desenvolvimento de estratégias que possa dar suporte a gestão de resíduos, este artigo apresenta uma proposta de rotas otimizadas para a recolha de biorresíduos no Município de Paços de Ferreira - PT. Com recurso ao NEOS Server, aplicando o solver concorde que é um solucionador TSP exato baseado em Branch and Cut foi possível obter uma rota consideravelmente mais curta e conseqüentemente com menores custos económicos e impactos ambientais. This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia through project UIDB/04728/2020.

Keywords: Biorresíduos; Branch and Cut; Economia Circular

Submissão #5

Enhancing Logistics through a new Vehicle Routing Problem with Deliveries, Pickups and Backhauls

Maria João Santos, Diana Jorge, Tânia Ramos, Ana Barbosa-Póvoa

The logistics sector currently confronts several challenges, including the need to balance efficiency and sustainability with cost reduction. To address this, a new class of the Vehicle Routing Problem with Deliveries and Pickups (VRPDP) is proposed. This approach considers two distinct customer types: those with delivery and pickup demands (mandatory to serve), and those with single pickup demands (backhaul customers) that are only visited if profitable. A mixed-integer linear programming model is formulated aimed at minimizing fuel consumption costs. This model can accommodate various problem variants, including simultaneous and separate visits for delivery and pickup services, as well as backhaul visits in different sequences. To solve this model, a hybrid Simulated Annealing Neighborhood Search (hSANS) metaheuristic is developed, which is tested and validated using instances adapted from existing literature and applied to a real case study involving a beverage distributor. Our findings indicate that allowing split visits and mixed backhaul collections results in significant savings, reaching approximately 39% in the real case study.

Keywords: Vehicle Routing Problem, Delivery-Pickup, Backhaul, Sustainability

Submissão #6

Robust Models for the Pollution Routing Problem with Uncertain Demand and Travel Time

João Martins, Telmo Pinto, Carlos Henggeler

The Vehicle Routing Problem and its numerous variants have been subject to considerable study over the years due to the various benefits brought by the efficient planning of routes. However, many routing models consider cost minimization by focusing solely on factors such as distance travelled or the number of vehicles utilized, often overlooking other considerations that affect costs and often ignoring the environmental impact of solutions. This has prompted the proposal of novel formulations aimed at better mirroring the complexities of logistic operations. Moreover, the uncertainty inherent to several factors has spurred investigation into models capable of handling uncertain data, thereby providing solutions more useful in practice. In this presentation, we study the Pollution Routing Problem, a variant of the Vehicle Routing Problem designed to account for expenses related to drivers and fuel consumption, and introduce novel models that account for uncertainties in travel times and demand. We conduct computational experiments on benchmark instances to assess the impact of hedging against uncertainty on solution quality and computation time and illustrate the positive effect of start-stop systems on operational costs.

Keywords: Pollution Routing Problem, Robust Routing, Optimization, Uncertainty

Submissão #7

Parallelization of local search heuristics for the pollution routing problem using GPU computing

Mário Leite, Telmo Pinto, Cláudio Alves

This presentation addresses the Pollution-Routing Problem (PRP), a particular concept of the Vehicle Routing Problem (VRP) accounting for minimizing fuel and driver expenses and greenhouse gas emissions. The vast majority of models for the vehicle routing problem focus simply on reducing costs based on distance travelled, often ignoring several essential elements that affect the actual cost of the routes and their impact on the environment. With other features of both vehicle and road, and even driver skills, the vehicle's load and speed in each arc travelled are crucial factors in pollution-routing issues. Since PRP is an NP-hard problem, we provide optimization techniques based on local search heuristics and meta-heuristics, applying parallel programming strategies on the Graphics Processing Unit (GPU). Combining the Central Processing Unit (CPU) and the General-Purpose GPU to take advantage of parallel programming is as challenging as promising since it can achieve better solutions by moving through the search space faster than a traditional sequential version. We provide the findings of the parallel computational experiments on benchmark instances for the PRP to assess the quality of the proposed methods by comparing them to the existing sequential approaches.

Keywords: Pollution-Routing Problem, Local search, Metaheuristics, Parallel programming, GPU

Sessão S1.3*Moderador: João Pedro Pedroso***Optimization****Submissão #8****Direções de procura ortogonais aleatórias em métodos de procura direta**

Humberto Rocha

Os métodos de procura direta têm sido amplamente usados para resolver problemas de otimização complexos quer académicos quer do mundo real. As abordagens determinísticas tipicamente usadas consideram direções de procura pertencentes a conjuntos com pelo menos $n+1$ direções (para um espaço n -dimensional), o que resulta num procedimento computacionalmente moroso em particular para funções objetivo dispendiosas em termos de tempo computacional. A utilização de estratégias aleatórias para resolver um problema numa configuração determinística está a tornar-se mais comum após o sucesso obtido na aprendizagem automática e na inteligência artificial. Em alguns domínios, as vantagens da utilização de estratégias aleatórias são conhecidas, mas a questão é saber se, para uma configuração determinística do problema de otimização em questão, os métodos aleatórios são verdadeiros concorrentes dos determinísticos – a ação COST Randomised Optimisation Algorithms Research Network (ROAR-NET) dedica-se a esta temática. A introdução da aleatoriedade em métodos de procura direta determinísticos tem demonstrado um excelente desempenho computacional, particularmente quando se considera um número reduzido (tão baixo como duas) de direções de procura aleatórias em cada iteração. Neste estudo, propõe-se o uso de direções de procura ortogonais aleatórias e comparam-se várias estratégias de procura direta aleatória, considerando diferentes conjuntos de direções de procura.

Keywords: otimização sem derivadas, procura direta, direções aleatórias

Submissão #9**Efficient Parameter Tuning in Location Systems via Direct Search Optimization**

Aldina Correia, João Matias, Pedro Mestre, Carlos Serôdio

This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia through project UIDB/04728/2020. Optimization challenges prevalent in engineering fields stem from the non-smooth nature of objective and constraint functions, often compounded by unknown derivatives. This characteristic renders derivative-based optimization methods impractical, necessitating the adoption of alternative strategies like direct search methods. In our study, we applied these methodologies to refine Fuzzy Logic parameters within location systems and optimize rule weights in the online phase of the Fingerprinting location method. The primary objective was to minimize precision discrepancies. By leveraging direct search methods, we addressed the inherent complexities of non-smooth functions and derivative ambiguity, enabling effective parameter tuning in location systems. Fuzzy Logic parameters, crucial for accurate location estimation, were systematically adjusted to enhance system performance. Additionally, optimizing rule weights in the Fingerprinting location method's online phase ensured robust and precise positioning outcomes. This approach not only circumvented the limitations posed by derivative-based techniques but also facilitated fine-grained adjustments tailored to the unique requirements of location systems. Through meticulous parameter optimization and rule weight adjustments, our study contributed to minimizing precision errors, thereby advancing the efficacy of location-based technologies in engineering applications.

Keywords: Optimization, engineering, non-smooth functions, direct search methods, Fuzzy Logic, parameter tuning, location systems, Fingerprinting method, precision minimization

Submissão #10

Instant runoff voting via integer programming

Manuel V.C. Vieira

Instant runoff voting (IRV) is an electoral system in which voters rank candidates according with their preferences. In the end, IRV aggregates the preferences of all voters returning a final rank of the candidates. From an optimization point of view IRV seems to be a heuristic method to aggregate the preferences of the voters. Regarding this, we present an integer programming model which aims to capture the features of IRV. From the literature, we know the linear ordering problem (LOP) which can also be applied to aggregate preferences; however, this problem does not capture the full nature of IRV. Thus, the model we present can be seen as a variant of the linear ordering problem and we call it linear ordering with weighted rank (LOP-WR). In this talk we explain why the linear ordering problem does not aggregate preferences as IRV and why the new model does it.

Keywords: Linear ordering problem; integer programming; instant runoff voting

Submissão #11

Maximum-expectation matching under recourse

João Pedro Pedroso

We address the problem of maximizing the expected size of a matching in the case of unreliable vertices and/or edges. The assumption is to treat edges with successfully matched vertices as fixed; but upon edge or vertex failures, the remaining vertices become eligible for reassignment. This process may be repeated a given number of times, and the objective is to end with the overall maximum number of matched vertices. An application of this problem is found in kidney exchange programs, going on in several countries, where a vertex is an incompatible patient-donor pair and an edge indicates cross-compatibility between two pairs; the objective is to match these pairs so as to maximize the number of served patients. A new scheme is proposed for matching rearrangement in case of failure, along with a prototype algorithm for computing the optimal expectation for the number of matched vertices, considering a possibly limited number of rearrangements. Computational experiments reveal the relevance and limitations of the algorithm, in general terms and for the kidney exchange application.

Keywords: Matching, Combinatorial optimization, Stochastic optimization

Sessão S1.4

*Moderador: Luís Dias***Multiple Criteria Decision Aiding 1****Submissão #12****Current research topics on MACBETH**

Miguel Fernandes, João Bana e Costa, Ricardo J. G. Mateus, Mónica D. Oliveira, Carlos A. Bana e Costa

The MACBETH approach (Measuring Attractiveness by a Categorical Based Evaluation Technique) has been widely used in complex evaluation contexts to construct quantitative value models based on qualitative judgements of difference in value elicited from a panel of evaluators. When these pairwise comparison judgements are expressed by each evaluator separately, with no group discussion to reconcile them, decision analysts face the problem of how to derive a collective value function from the evaluators' individual judgements. This study proposes an original technique, implemented in Python, to address this issue under a MACBETH multicriteria framework. For each evaluation criterion, the proposed collective value function respects the majority rule and assumes a collective constant trade-off attitude. A second research topic concerns the situation in which it is not realistic to ask from each evaluator all the possible pairwise comparison judgements. This study also examines the extent to which incomplete sets of MACBETH judgements affect the robustness of the derived value functions.

Keywords: MACBETH, MCDA, multicriteria value measurement, value functions, robustness

Submissão #13**Advancing Hospital Quality Assessment: A Comprehensive
Multidimensional Analysis of Portuguese public hospitals**

José Rui Figueira, Alexandre Vilar Ricardo, Ana Sara Costa

Recent healthcare policy reforms in Portugal have significantly influenced the quality of health care provided to citizens, particularly in public hospitals, crucial as secondary care providers within the National Health Service (NHS). Traditional multidimensional assessments fall short in distinguishing hospitals across quality dimensions, limiting benchmarking efficiency. Integrating the Electre Tri-nC method with the Multiple Criteria Hierarchy Process (MCHP) allows a nuanced evaluation of Portuguese public hospitals. Electre Tri-nC categorizes each hospital based on Timeliness, Effectiveness, Safety, and Efficiency criteria. MCHP provides a hierarchical structure for in-depth analysis, considering specific criteria subsets or a comprehensive approach. Analyzing 25 hospitals from 2019 to 2022 reveals a general decline in quality, especially in Effectiveness. A robustness analysis ensures model reliability. This study serves as a valuable framework for quality assessment and contributes significantly to hospital benchmarking. **Keywords:** Multiple Criteria Decision Aiding, Criteria hierarchy, Quality assessment, Public hospitals.

Keywords: Multiple Criteria Decision Aiding, Criteria hierarchy, Quality assessment, Public hospitals

Submissão #14

Investment portfolio: how to help individual investors?

Paula Sarabando, Joana Fialho, Manuel Reis, Tiago Miguel

There are several ways to apply savings (different assets), so it is necessary to analyze and choose the one(s) that best suit(s) investors' characteristics. The use of Mathematics and Operations Research in the financial area dates back to the 1950s with the introduction of the Markowitz model. In this theory, the most usual is to use two types of criteria: return and risk. In so-called "pure" financial decisions, these criteria guide most decisions. In "mixed" financial decisions, other criteria are also considered. Many decisions are mixed and should be treated as multicriteria decision problems. The objective of this work is to infer the importance of criteria considering an investor's characteristics, using multicriteria methods. The weight of the criteria may allow the elimination of some assets. The selected assets are then analyzed according to the defined criteria to determine the best way to apply the investor's savings. The final objective is to recommend a combination of different types of assets, giving a portfolio composition – indicating, for example, that a certain investor should allocate in stocks between 10%-20% of the available capital, in bonds between 30%-40%, etc.

Keywords: multicriteria methods, investment portfolio, investor profile, individual investor, portfolio selection

Submissão #15

An application to improve Integrated Pest Management Systems using multicriteria sustainability assessment

Luis C. Dias, Pedro Marques, Rita Garcia, Fernanda de Santo, Rita Tentúgal, Tiago Natal da Luz, Álvaro Sousa, José Paulo Sousa, Fausto Freire

This presentation reports a comparison of Integrated Pest Management Systems, in the context of the H2020 OP-TIMA project. The comparisons are based on a sustainability assessment of the current practices and alternative systems, using data from field trials, and considering multiple criteria: environmental indicators (global life cycle emissions and risk for local species), social indicators (human health risks for farmers and local inhabitants), and an economic indicator (cost for farmers). This set of criteria was developed with the help of multiple stakeholders, who also participated in rating the importance of the criteria. We developed an approach to elicit information concerning the criteria importance that could be used for different methods, asking separately to rate the importance of improving the current situation and the importance of not worsening the current situation. To contrast compensatory and non-compensatory approaches, the selected multicriteria aggregation methods were additive multiattribute value functions and ELECTRE outranking relations. Stochastic analyses were performed considering absence of preferences and also considering preferences derived from the answers to a survey to stakeholders. As no single weighting vector was fixed, results allowed observing conclusions that are robust to weighting choices, thus identifying which changes are recommended.

Keywords: Multiple Criteria Decision Aiding (MCDA), Weighting, Sustainability assessment, Agriculture

Sessão S1.5*Moderadora: Susana Relvas***Supply chains 1****Submissão #16****Global Pharmaceutical Supply Chains: How to navigate through the impact of uncertainty?**

Maria Ana Monge, Nelson Chibeles-Martins, Tânia Pinto-Varela

Pharmaceutical Supply Chains (PSCs) are very complex networks shaped by global business dynamics and rigorous regulations. Ensuring pharmaceutical products' availability in a world facing increasing uncertainty and disruptions at a reasonable cost is crucial for every company to maintain its desired performance. This work explores this challenge by assessing the intensity of the impact of uncertainties and disruptions on the supply chain network costs and its topology, in addition to understanding the way it reacts when facing variability. A decision tool based on the Simulated Annealing Algorithm (SA), including uncertainty parameters of the supply chain is developed. The structure of the algorithm allows the assessment of different uncertainties and disruptions individually or in simultaneous, as well as the different network designs generated by them in a short time frame. A case study is presented to validate the approach. Several scenarios are studied and the effect of uncertainties on the demand, production capacity, raw material supply, and disruptions on the transportation and production on a global pharmaceutical supply chain are analysed. The most significant disturbances impacting the supply chain are identified and the results reveal an increase in redundancy and consequent decentralization of the network in response to uncertainty severity, providing a useful advantage for decision makers and supply chain managers regarding strategical and tactical decisions capable of thriving in the future.

Keywords: Pharmaceutical Supply Chains, Simulated Annealing, Uncertainty**Submissão #17****Rescheduling recovery model in the Blood Supply Chain**

Maria Meneses, Daniel Santos, Ana Póvoa

The timely and efficient availability of blood products is critical in the blood supply chain, which is challenging due to the inherent uncertainty of blood donations and demand and disturbances that affect the network operations. This research proposes a reactive planning model for blood supply chain management, addressing uncertainties like demand and supply variability, delayed or canceled collection sessions, and staffing shortages affecting supply. The replanning model leverages real-time data to modify the existing master plan in response to disturbances, optimizing reactive measures, while maintaining a high operational performance. This work also addresses when to initiate a replanning action and what that action should be. The uncertainty in demand is addressed using a robust approach, and the uncertainty in supply is handled using a rolling horizon approach that integrates real-time. The proposed model considers sequence disruptions during the replanning interval and frozen decisions that cannot be altered. Frozen decisions aim to minimize the logistics challenges, costs already incurred, nervousness, and commitments made with third-party organizations, particularly those that have already scheduled temporary sessions in advance.

Keywords: Replanning, Rescheduling, Blood Supply Chain, Optimization Models, Operational Planning

Submissão #18

Exploring Symbiotic Supply Chains: A Nexus Perspective and Operations Research Framework

Mafalda Ivo de Carvalho, Vânia Veloso, Ana Carvalho, Susana Relvas, Ana Barbosa-Póvoa

In an era where the pursuit of sustainability is paramount, the role of supply chains (SC) in shaping the environmental landscape remains unparalleled. Despite efforts to manage direct greenhouse gas emissions, the importance of indirect emissions requires a comprehensive approach to emissions management. Industrial Symbiosis (IS) is attracting attention for its potential to optimise resource use and minimise waste safeguarding customer satisfaction. Given the limited research on IS applicability in Supply Chain Management, a novel definition of Symbiotic Supply Chains (SymSC) is proposed, emphasizing the pivotal role of collaboration in the share of flows under the nexus of material-energy-water in a network involving multiple supply chains. Given their complexity, SymSCs require detailed planning and management which can be facilitated by developing decision-supporting models. This study focuses on the main characteristics that should be included in these models to meet the needs and requirements of symbiotic entities in the decision-making process both at the strategic and tactical levels. An Operations Research modelling framework for the design and planning of SymSCs is proposed. A roadmap for future research is discussed to improve sustainability performance in the context of SymSC.

Keywords: Industrial Symbiosis, Supply Chains, Operations Research

Submissão #19

Integrating Environmental and Social when Designing and Planning Supply Chains: A Monetization-Based Approach

Cátia da Silva, Ana Carvalho, Ana Barbosa-Póvoa

In an era marked by escalating legal requirements and competitive market dynamics, it becomes a necessity for companies to pursue not only financial positive results but also actively get engaged in sustainable environmental and social practices. To do so designing and planning their supply chains towards sustainability goals is imperative. This work deals with this challenge and explores the integration of environmental and social impacts monetization into an optimization-based decision-supporting tool for the design and planning of supply chains. The application of the optimization tool covering economic, environmental, and social performances under uncertainty of product demand shows the possibility of increasing environmental and social performances with the retention of modest loss in economic performance. This approach results efficiently as it quantifies the environmental and social impacts in easily understandable monetary terms, thereby providing decision-makers with clear guidance on how to steer supply chains toward sustainability goals in a balanced manner.

Keywords: sustainable supply chain, monetization, optimization, decision support tool

Sessão S2.1

Moderadora: Isabel Gomes

OR with Social Impact

Submissão #20

Optimizing Tactical Planning for Home Visits in Family Interventions: The Real Case of ComDignitatis.

Ana Raquel de Aguiar, Maria Isabel Gomes, Tânia Ramos

This work addresses the challenges faced by social organizations in scheduling home visits for family interventions. We propose a bi-objective multi-period mixed integer linear programming model to simultaneously allocate home visits to technicians, and schedule them over an extended planning horizon. The model considers visit intervals, flexible worker schedules, and incorporates technicians' preferences to address work-life balance concerns. The problem's complexity concerns the matching of availabilities between a pair of technicians (amongst themselves) and families, as each visit requires two technicians. Also, time intervals between two consecutive visits are pre-established to secure the quality of intervention. The case study is solved for a three-month planning horizon, for 6 technicians and for 53 families dispersed in 3 municipalities. Service quality and efficiency are significantly improved. The number of visits increases from 56 to 203, the scheduling capacity used rises from 57% to 83%, and double visits increase by 738%, indicating improved technician's time utilization. However, the use of inconvenient slots increases, highlighting potential work-life balance issues. We introduce a tactical planning approach for family interventions, highlighting the trade-offs between increased service delivery and technician schedules. This enriches the literature by focusing on different characteristics from traditional health and social care optimization.

Keywords: Home visit scheduling, family interventions, tactical planning, mixed integer linear programming, work-life balance, service quality, efficiency

Submissão #21

Social Care Logistics: what is it?

Maria Isabel Gomes, Helena Ramalhinho

The United Nations Sustainable Development Goals (SDGs) address global challenges facing the world's population. Although many believe that these goals are primarily aimed at developing countries, the SDGs set ambitious targets for all countries. To varying degrees, social challenges such as poverty and isolation exist in developed countries as well. Providing services in this social context is challenging, as it deals with people in a situation of social fragility. Therefore, OR models that address logistics efficiency can be of utmost value, but need to be thoroughly thought through to support decision making in what we have termed Social Care Logistics. In a nutshell, Social Care Logistics refers to all logistics activities that support the provision of services to people in need of social support in their daily lives. In this presentation, we will look at two of the Social Care Logistics challenges faced by developed countries: home care support and food banks. For the former, we will show some adaptations that need to be made in order for traditional routing and scheduling models to be useful in planning the routes of caregivers providing support in patients' homes. For the latter, we will highlight the differences between a traditional and a food bank supply chain.

Keywords: Logistics, Homecare Problem, Food Bank Supply Chain

Submissão #22

Uma abordagem em duas fases para o planeamento de serviços de cuidados domiciliários

Patrícia Maduro, Joana Dias, Isabel Gomes

O planeamento das atividades diárias de um prestador de serviços de cuidados domiciliários é uma tarefa complexa, devido à exigência de visitar vários pacientes regularmente (por vezes diariamente), com necessidades específicas e que residem em diferentes locais, enquanto se gerem recursos limitados. Neste trabalho apresentamos uma nova abordagem em duas fases para o planeamento automático e ótimo de serviços de cuidados domiciliários. Destacamos especificidades importantes que esse planeamento deve considerar, nomeadamente o respeito pelo padrão de cuidados exigido por cada paciente; o respeito por todos os requisitos legais de horários dos profissionais; a correspondência entre as competências dos profissionais e as necessidades e preferências dos pacientes; a atenção explícita à continuidade dos cuidados; entre outros. Na primeira fase, é determinada a atribuição de cuidadores aos pacientes. Na segunda fase é decidida a operação diária de cada profissional, considerando a otimização do roteamento e as decisões da primeira fase. Na primeira fase, diversas restrições são adicionadas ao modelo para garantir que a solução obtida é adequada para a otimização da segunda fase. A abordagem desenvolvida demonstrou ser capaz de computar soluções de alta qualidade. Alguns exemplos e testes computacionais inspirados em problemas identificados em instituições reais de cuidados domiciliários serão apresentados.

Keywords: Atribuição de recursos, Otimização do planeamento de serviços de cuidados domiciliários, Planeamento de rotas

Submissão #23

Heterogeneous workforce management - could optimisation be part of the solution?

Mónica Gaboleiro, Isabel Nunes, Maria Isabel Gomes

People are authentic and each of us has characteristics that make us different. There are also people who are born with certain limitations and/or disabilities, but who deserve the same opportunity to live a dignified life and have decent working conditions. In addition, the world is facing some phenomena that are changing the world of work. The increase in the average life expectancy of the population, combined with a low birth rate, means that the population is ageing at a very high rate. This poses some challenges for organisations, such as an ageing workforce. With the phenomenon of globalisation, migration has been a solution for many seeking new opportunities, which means that organisations have to deal with an increasingly culturally diverse workforce. The aim is to encourage organisations that to adopt inclusive management approaches in order to contribute to the achievement of the 2030 Agenda for Sustainable Development Goals (SDGs) by showing them that with optimisation is possible to include people perceived as 'less productive' without compromising productivity and system performance. To this end, it is necessary to understand what contribution operational research has made, namely whether optimisation models incorporate issues such as human factors, how they do so, and which human factors are included, in order to understand the direction that future research should take.

Keywords: Human Factors, Optimisation Models, Overview

Sessão S2.2*Moderadora: Sara Martins***Applied Discrete Optimization****Submissão #24****Selecting Dispatching Rules on the fly for the Dynamic Job Shop Scheduling Problem**

Nuno Marques, Gonalo Figueira, Luis Guimares

Pressured by fierce competition and complex customer requests, scheduling in manufacturing contexts has become more dynamic than ever, with uncertain events occurring frequently. Dispatching rules (DRs) are particularly well suited to high uncertainty and dynamic settings, as they can be executed in a fraction of a second. Moreover, they are easy to implement and understand. However, no DR works well in varying conditions, particularly for different load and job urgency levels. Therefore, the main goal of this work is to propose systems that select the DR as conditions change in dynamic job shops. Two main approaches exist in the literature: systems that select the rule periodically (PRS) and systems that select the rule in real-time (RTRS). The former is mainly tackled with supervised learning, while the latter is mainly tackled with reinforcement learning. There is a lack of scientific works comparing PRS and RTRS for the same instances. We implement and contrast both approaches. Preliminary results show that our DR selection systems render a 20% improvement tardiness-wise over using a single DR. Moreover, PRS and RTRS performed similarly overall, but the latter appears to be more promising.

Keywords: Dynamic Scheduling, Job Shop, Dispatching Rules**Submissão #25****Solving the Dynamic and Stochastic Inventory-Routing Problem**

Francisco Maia, Gonalo Figueira, Fbio Neves-Moreira

Sequential-decision making is an active area of research in Operations Research (OR), where real-time decision-making, machine learning and data-driven approaches are stepping forward. The Dynamic and Stochastic Inventory-Routing Problem (DSIRP) is one of the most fundamental problems companies seek to optimize, given its meaningfulness at strategic and operational levels. The challenge at hand involves the integration of inventory management and vehicle routing problems while at the same time effectively handling the dynamic and stochastic nature of customer demands unveiled over time. A promising research path lies in combining Reinforcement Learning and OR to achieve novel inventory and routing policies with significant cost savings. Accordingly, Policy Function Approximation (PFA) emerges as an encouraging strategy. This research intends to give new insights into solving the single-item, single-vehicle DSIRP with a one-to-many endpoint structure, where decisions must be released periodically. Therefore, we propose novel delivery policies based on PFA, exploring two evolutionary algorithms, i.e. Genetic Programming and Genetic Algorithms. The proposed problem-solving methodology and resulting delivery policies enabled us to derive novel rules that present optimistic outcomes, overcoming several benchmarks in total costs by at least 7%, increasing the balance between overstocking and stockouts, reducing waste and decreasing the travel distances.

Keywords: Inventory-routing problem, sequential decision-making, genetic programming

Submissão #26

Dynamic pricing strategy for substitute perishable products

Mariana Sousa, Sara Martins, Maria João Santos, Pedro Amorim

Dynamic pricing is a prevailing strategy employed to adjust the prices of goods based on strict consumer behavior. In the grocery retail sector, this tactic is frequently used to prompt timely purchases of perishable products nearing the end of their shelf life. Nevertheless, current procedures often overlook the impact of sales cannibalization among similar products and do not differentiate discounts across the product portfolio. This research seeks to devise a dynamic pricing approach for multiple perishable items, focusing on optimizing retail profits and reducing food waste. We first test assumptions about substitution among similar products using historical data from a European retailer. We then construct a demand forecasting model for a subset of products and incorporate it into a proximal policy optimization algorithm. This algorithm determines the pricing strategy for the selected group of products by setting continuous discounts throughout their shelf life. Finally, we analyze the impact of considering multiple products simultaneously rather than a single product at a time to develop the pricing policy. The findings highlight the importance of concurrently considering multiple substitute products when devising pricing policies, emphasizing the impact on retailer profit while acknowledging the trade-off associated with minimizing food waste.

Keywords: Dynamic pricing, Substitution effects, Reinforcement learning

Submissão #27

Definition of the MLOR rule through a bilevel optimization model

Francesca Landolfo, Maria João Santos, Sara Martins, Pedro Amorim

The Minimum Life On Receipt (MLOR) rule is established by retailers to impose the maximum age at which a perishable product can be accepted upon reception. Such a rule tends to be rigid, but allowing the rule's flexibility may benefit both producer and retailer. The objective of this work is to investigate such benefits. The problem will be represented by a bilevel optimization model where the retailer is the leader, and the producer is the follower. In this problem, the rational response of the producer is to either comply with the fixed MLOR rule imposed by the retailer or offer a discount to the retailer's orders whenever he/she is willing to adopt a flexible rule. An instance composed of a perishable product with 3 days of shelf life and a time horizon of 3 periods is used to enumerate all possible solutions for the problem. The solutions are examined in terms of profits and waste generated. Afterwards, an exact solution method is developed through single-level reformulation to solve the general problem.

Keywords: bilevel optimization, perishable, food waste

Sessão S2.3*Moderador: Bernardo Almada-Lobo***Retail****Submissão #28****Understanding the dynamics of fairness in wholesale-retail price coordination**

Catarina Bessa, Tânia Pinto-Varela, Ana Paula Barbosa-Póvoa, Cristóvão Silva, Samuel Moniz

Motivated by the growing social sustainability concerns within supply chains, our study explores how wholesale-retail price contracts can be coordinated to provide fairness in a supply chain consisting of one supplier and one retailer, i.e., a dyadic channel. We study two widely recognized fairness models from the literature, one grounded in equity and another in reciprocity, to assess their effectiveness in a context in which the channel members jointly seek higher profit than the channel can produce. Our aim is to develop an empirical analysis of both models under identical conditions to understand their operational behavior across several parameter ranges and to evaluate to which extent they grant equitable and reciprocal outcomes. Previous studies have shown the tendency of the equity-based model to yield disadvantageous outcomes for the supplier, while the reciprocity model struggles to foster coordination with full reciprocal outcomes. Our main findings unfold three key insights: (1) the equity-based model exhibits superior efficacy in safeguarding the channel's profitability as the retailer's concept of fair share increases; (2) the reciprocity-based model excels in ensuring absolute equality as the supplier's idea of fair share intensifies; (3) we observe that higher production costs pose significant challenges in attaining fairness.

Keywords: Inequity-averse, Reciprocal channel, Channel coordination, Wholesale-price contract

Submissão #29**Learning efficient in-store picking strategies to reduce customer encounters in omnichannel retail**

Fábio Neves-Moreira

Several retailers are now using stores as supporting distribution centers to offer quicker Buy-Online-Pickup-In-Store (BOPS) and Ship-From-Store (SFS) services. They resort to in-store picking to serve online orders using existing assets. However, in-store picking operations require picker carts traveling through store aisles, competing for store space, and possibly harming the offline customer experience. To learn picking policies that acknowledge interactions between pickers and offline customers, we formalize a new problem called Dynamic In-store Picker Routing Problem (diPRP). This problem considers a picker that tries to pick online orders (seeking) while minimizing customer encounters (hiding) – preserving the offline customer experience. We model the problem as a Markov Decision Process (MDP) and solve it using a Reinforcement Learning approach. We tackled this problem in the context of a large European retailer to assess the proposed policies regarding the number of orders picked and customers encountered. Our work suggests that retailers should be able to scale the in-store picking of online orders without jeopardizing the experience of offline customers. The policies learned reduced the number of customer encounters by up to 50%, compared to policies solely focused on picking orders.

Keywords: Omnichannel retail, In-store picking, Markov decision process, Reinforcement learning, Real-world application

Submissão #30

Optimizing Order Allocation in an Online Fashion Marketplace

Sérgio Castro, Gonçalo Figueira, Bernardo Almada-Lobo

Order allocation involves optimizing the distribution of incoming orders to fulfillment nodes. We address this problem in an Online Fashion Marketplace, where orders need to be promptly assigned, upon their arrival, to fulfillment nodes owned by different vendors. This setting significantly differs from those approached so far in the literature in that it is characterized by consistently low sales volume per item across most of its portfolio and the daily movement (addition and subtraction) of inventory by vendors, contributing to increased uncertainty. Considering the dynamic and novel aspects of this problem compared to the current literature, we propose a new methodology for generating heuristic fulfillment policies. We use either Genetic Programming (GP) or Genetic Algorithms (GA), leveraging key policy information such as shipping costs, basket coverage, stock depth, load deviation, and inventory movements, which are integrated into a machine learning pipeline to generate effective policies. To assess the effectiveness of the proposed policies, we compare them against the retailer's current policy and a perfect hindsight policy, allowing to quantify the improvement achieved over the existing policy and identify any remaining potential gaps for improvement. In addition, we derive valuable managerial insights.

Keywords: Retail, Online, Fulfillment

Submissão #31

Promotional forecasting in a retail setting

Ana Margarida de Figueiredo Pereira

This dissertation focuses on promotional sales forecasting applied in a major Portuguese retailer scenario. It aims at improving the current forecasting solution by actively accounting for promotion, cannibalization and stockpiling effects in the prediction process. To achieve this a great effort was put into engineering specific features that can capture these effects at various levels. To predict promotional sales two main approaches are explored, one using regression techniques and another using machine learning algorithms. For the regression-based methods, in order to account for heterogeneity between store types and for homogeneity between similar products nine variations of the regression model are estimated. For the machine learning portion, two tree based algorithms are considered, specifically Random Forest and Gradient Boost Regressor. The multiple regression methods proved that including promotional effects' related variables has a positive impact in prediction accuracy. Furthermore, this approach yielded better results than expected, outperforming the machine learning techniques in many cases.

Keywords: promotions, forecast , cannibalization , stockpiling , retail

Sessão S2.4

*Moderador: Samuel Moniz***Interfacing with Artificial Intelligence****Submissão #32****Bacterial Detection: Harnessing Artificial Intelligence for Rapid Results**

Felipe Yamada, Flávia Barbosa, Luís Guimarães

Antimicrobial resistance (AMR) poses a significant global threat of far-reaching proportions. In the European Union, more than 33.000 people die each year due to AMR, with an economic impact of about €1,5 billion/year in healthcare costs and productivity loss. The World Health Organization (WHO) has declared AMR as one of the top 10 global public health threats facing humanity and has requested all countries to implement national action plans to prevent the indiscriminate use of antibiotics. Awareness of antimicrobial resistance (AMR) and the necessity for action has prompted the development of a comprehensive strategy. This approach involves creating AI-driven miniaturized devices for detecting AMR pathogens, genes, and antibiotic residues. This research endeavors to improve the precision of bacteria identification through advanced data analysis and artificial intelligence algorithms. A microfluidic lab-on-a-chip device custom-designed for detecting bacterial and antimicrobial resistance (AMR) genes facilitates data collection. This device employs molecular detection techniques, utilizing DNA and bacteriophage proteins as bio-recognition molecules, and interfaces seamlessly with graphene chips. It can generate distinct signals corresponding to the composition of each fluid. Our study introduces strategies for data processing and machine learning algorithms to enhance bacteria identification accuracy.

Keywords: Artificial Intelligence (AI), Machine Learning (ML), Biosensor, lab-on-a-chip

Submissão #33**Towards efficient scheduling with AI: exploring Deep Q-Learning for the flexible job-shop scheduling problem**

Alexandre Jesus, Arthur Corrêa, Catarina Marques, Miguel Vieira, Cristóvão Silva, Samuel Moniz

After dominating the realm of board and arcade games, Deep Reinforcement Learning (DRL) has been experimented on a vast set of industrial problems. However, while arcade environments present precisely controlled settings and goals, problems like production scheduling entail complex constraints and conflicting objectives. Consequently, DRL models often fall short when compared with operations research methods, such as mathematical and constraint programming models, or even metaheuristics. In this work, we conduct an extensive analysis on the design options across a Deep Q-Learning framework to solve the Flexible Job-shop Scheduling Problem (FJSP). We jointly assess the relevance of action spaces, reward functions, and state features, and the problem structure to the solutions quality. By addressing three benchmark problem datasets, the impact of different design choices on workload balance, job lead time, and makespan is measured against exact models. The experimental results provide valuable guidance for the conceptualization of centralized DRL models for the FJSP. Moreover, findings indicate that our model is capable of producing high quality solutions in a residual portion of the computing time.

Keywords: Deep Reinforcement Learning, Production Scheduling, Operations Research

Submissão #34

Performance Assessment of Deep Reinforcement Learning Extensions for Flexible Job Shop Scheduling

Arthur Corrêa, Alexandre Jesus, Cristóvão Silva, Samuel Moniz

Flexible Job Shop Scheduling (FJSP) plays an important role in production management, but due to the high computational complexity, it is difficult to obtain good quality solutions for large problems using exact optimization methods. Although Deep Reinforcement Learning (DRL) has shown good results in solving complex problems in arcade learning environments, its performance on the FJSP remains uncertain. Moreover, despite the emerging interest in DRL algorithms within scheduling research, there remains a lack of quantitative evidence of the impact of recent progress in the field of DRL. In this work, we study several DRL extensions from the literature and analyze their performance when solving FJSP instances. Our findings reveal that all the employed extensions obtained good quality solutions with very reduced computational time, while some exhibited superior performance in terms of minimizing the makespan objective. These preliminary results suggest promising opportunities to use DRL to overcome the computational burden related to FJSP and show its effectiveness in solving complex scheduling problems.

Keywords: Scheduling, job-shop, reinforcement learning

Submissão #35

Analyzing the Impact of Next Best Offer and Churn Methodologies on Customizing Promotions in the Insurance Industry

Tomás Martins Araújo

This abstract presents two systems for an insurance brokerage firm that aims to improve profitability by identifying opportunities for cross-selling and preventing churn. The systems are evaluated by selecting two groups of clients (treatment and control), which were contacted to demonstrate the effectiveness in identifying the Next Best Offer and predicting Churn. These systems were developed utilizing data management and machine learning techniques. Upon receiving data from the Insurance Brokerage, it was manipulated to extract the most relevant features. Furthermore, socio-demographic data was incorporated as external information to enrich client profiles and enhance analysis comprehensiveness. Various machine learning techniques were employed to discern the best suited models for each system, utilizing evaluation metrics like F1, F2, and F0.5 scores. Two client subsets were selected for contact: "treatment"(clients likely to buy Multi-Risk House Insurance or churn) and "control"(randomly chosen clients for Next Best Offer or with high churn probability). Before this work's delivery, only clients for the Next Best Offer system were contacted and demonstrated substantial enhancement in targeting potential Multi-Risk House Insurance buyers. Implementation of this system offers a competitive advantage, optimizing decision-making and maximizing customer relationship benefits, thereby supporting long-term growth for the insurance brokerage firm.

Keywords: Machine Learning, Churn, Cross-selling, A/B testing

Sessão S2.5

Moderador: Rui Borges Lopes

Supply chains 2

Submissão #36

Modeling Sustainability and Uncertainty Awareness in Supply Chain Planning

Ana Amaro

Continuous challenges are being experienced worldwide and great emphasis is being placed on the fragility and vulnerability of organizations regarding the unpredictable conditions. Academics and practitioners defend the need for flexibility and adaptability to deal with complex changes and uncertainty. The environmental and social awareness are changing the concept of growth that guided companies for decades. Supply chain sustainability is being placed in the top priorities of companies' agenda. Besides, the international dimension of supply chains, SC, as well as the complex partnership networks and competitiveness, increase enterprises' exposure. Thus, the assurance of service levels to customers' results progressively more complex. Following these motivations, a novel MILP formulation was developed to help the decision-making process at the planning level. Relevant KPI were selected to measure SC planning performance and to obtain high information content. The goal of the proposal is to develop a framework to assist SC managers at planning decisions. A mathematical formulation is proposed and the model applicability is shown through the solution of an industrial example. New insights concerning SC planning performance and sustainability indicators were brought from the practical implementation. The impact of sustainable policies in the SC planning strategy is evaluated for different managing conditions.

Keywords: Supply Chain Planning, Sustainability, Uncertainty, KPI, Optimization.

Submissão #37

Improving freight quoting through business analytics: a case study of a logistics service provider

João N. C. Gonçalves, Miguel Correia, M. Sameiro Carvalho

In the transportation sector, the process of estimating the profit margins to be applied to customer freight quotation requests is a problem of particular interest, which impacts strongly on customer relationship management. In practice, this process is typically conducted based on the subjective business experience of transport managers, posing challenges and delays in decision-making that can damage the customer relationship. This article explores a multivariate predictive analytics approach to support the process of estimating profit margins applied to customers for road freight transportation requests. Our approach consists of developing statistical learning models that make it possible to generalize historical relationships between a set of independent variables related to quotation requests and the respective profit margin applied and accepted by customers. The proposed approach is tested on empirical data from a portuguese logistics service provider. The results show that the proposed models have a good generalization capacity when tested on independent data under a rolling window evaluation mechanism. We discuss the managerial implications of the proposed approach and how it can serve as a decision support tool for applying profit margins to future requests for road freight transport quotation.

Keywords: Business Analytics, Freight quoting, Logistics, Customer relationship management

Submissão #38

Extending inventory supply chain planning to a multi-warehouse and multi-period context: a mathematical programming approach focused on a continuous review policy

Joaquim Jorge Vicente, Teresa Cardoso-Grilo

Inventory management has been widely studied by several authors. Nevertheless, there is still a small number of studies exploring its application at the supply chain level, despite being widely recognized that the collaboration between partners in the supply chain is critical to achieve more efficient inventory management decisions. In fact, such a collaboration fosters the global optimization of supply chains. In this paper, the inventory supply chain planning problem is addressed through the use of the continuous review (r,Q) policy, aiming at optimizing inventories throughout a supply chain while defining the amount of products transported among facilities over time. A mixed integer linear programming (MILP) model is built for that purpose and a multi-periodic/multi-warehouse/multi-retailer supply chain is considered as reference. This model adds to existing supply chain inventory management literature by extending existing models to a multi-periodic and multi-warehouse supply chain. The model, hereafter called CRP2InvSC model, allows to determine inventory levels, order quantities Q and reorder points r for each time period and each facility on a supply chain. Products flows between supply chain entities is also modelled. A case study based on a distribution supply chain is used to illustrate the applicability of the proposed model.

Keywords: supply chain management, inventory planning, mixed integer linear programming, continuous review policy

Submissão #39

Sustainability and resilience in location-routing problems: A systematic review

Bruna Figueiredo, Rui Borges Lopes, Amaro de Sousa

Sustainability and resilience are two important trends in the supply chain field. In recent years, the incorporation of sustainability concerns into the modelling of different problems related to the supply chain has received increasing attention. Although not yet thoroughly explored, the design and operation of resilient supply chains have also been a major concern, making it increasingly addressed in the literature. In the design and operation of supply chains, key decisions concern the location of distribution centers and subsequent distribution to customers. This work presents a systematic review of location-routing problems (LRPs) which integrate the concepts of sustainability, resilience, or both. The broad definition of sustainability and the ambiguity of the concept of supply chain resilience mean that the strategies and metrics applied may differ between different works, according to the authors and their objectives. This presentation will analyze how these concerns are integrated into the modelling of LRPs. It will also discuss the main characteristics of the models presented and the solution methods employed. Finally, some research gaps and suggestions for future work will be put forward.

Keywords: location-routing problem, sustainability, resilience

Sessão S3.1

Moderadora: Carina Pimentel

OR in Urban Development

Submissão #40

Decisões Estratégicas: O Caminho para uma Frota Sustentável na STCP

João Cunha, João Magalhães, Fábio Oliveira, Inês Correia e Aldina Correia

No contexto das restrições orçamentais e das preocupações ambientais, os gestores de frotas enfrentam desafios significativos ao escolher os veículos adequados. Além das considerações financeiras, questões como a redução das emissões de CO₂ e a manutenção da capacidade de oferta tornam-se cruciais. Este estudo visou encontrar a melhor combinação de autocarros para a STCP, garantindo custos mínimos. Com a intenção de substituir 28 autocarros a combustão por modelos elétricos, foram analisados 10 tipos diferentes, e considerado o relatório de contas de 2023 e aos planos orçamentais para 2024. Especificações técnicas, autonomia, custos de aquisição e operacionais foram estudados, culminando na construção de um modelo de programação linear. A ferramenta Solver do Excel foi utilizada para avaliar diferentes cenários e determinar a quantidade ótima de cada tipo de autocarro a ser adquirida. Os resultados demonstraram uma redução significativa nos custos operacionais, refletindo o compromisso da STCP com a eficiência financeira e ambiental. Além disso, foram realizadas análises de sensibilidade e limites, proporcionando insights adicionais para a tomada de decisão. This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia through project UIDB/04728/2020.

Keywords: Gestão de frotas, minimização de custos, redução de CO₂, Sustentabilidade, programação linear, solver do Excel

Submissão #41

Spatial multi-criteria decision analysis for rehabilitation priority ranking: a collaborative application to heritage workforce housing sites

Ana Paula Falcão, Rita Machete, Marta Castilho Gomes, Alexandre Bacelar Gonçalves

This work presents a methodology to rank heritage sites regarding rehabilitation, considering both the characteristics of building sites and of the urban environment in the surrounding area. The objective is to aid the decision process of building rehabilitation by ranking the sites according to their potential for re-emergence in the affordable housing rental market. The developed methodology is based on a combination of multi-criteria decision analysis (MCDA) and spatial analysis of geographical data, in order to construct an index, the “rehabilitation potential”, which is understandable by rehabilitation technicians and land managers and is applicable to support a list of priorities of building rehabilitation interventions. The methodology was applied to a case study consisting of a set of 33 heritage sites of the workforce housing typology in Lisbon. These were built in the early industrial age in Portugal and are owned by the city municipality. The application of MCDA was a collaborative process that brought together the expertise of the academy and of the public administration. The results included a sensitivity analysis and gave form to a recommendation of five sites, selected from the total workforce housing set, to be rehabilitated in the near future.

Keywords: Geographical Information Systems, Heritage rehabilitation and management, Rehabilitation potential index, Spatial Multi-criteria Decision Analysis, Workforce housing

Submissão #42

Otimização de planeamento operacional de logística urbana, com combinação de fluxos de passageiros e de mercadorias

Bruno Machado, Carina Pimentel e Amaro Sousa

Esta investigação aborda um problema de planeamento operacional no âmbito da logística urbana, em que uma rede de transporte de passageiros em autocarro é integrada com o processo de transporte urbano de mercadorias, e com um serviço de entrega de última milha, para enviar mercadorias para os centros das cidades. O objetivo é reduzir o número de veículos comerciais movidos a combustíveis fósseis que circulam dentro dos limites da cidade, exclusivamente para transporte de mercadorias, contribuindo assim para reduzir os efeitos negativos das atividades de logística urbana, nomeadamente a poluição, o ruído e o congestionamento do tráfego. Propõe-se um modelo de programação linear inteira para apoiar o planeamento do processo de distribuição com o objetivo de minimizar o tempo de entrega do operador de última milha. Resultados considerando instâncias baseadas numa rede real de autocarros da cidade do Porto, Portugal, mostram a eficiência do modelo proposto.

Keywords: Logística Urbana Integrada, Planeamento Operacional, Modelação Matemática

Sessão S3.2

Moderadora: Tânia Ramos

Routing Problems 2

Submissão #43

A robust optimization approach for the vehicle routing problem with synchronization

Ricardo Soares, Sophie N. Parragh, Alexandra Marques, Pedro Amorim

This research addresses the Vehicle Routing Problem (VRP) with Synchronization, which aims to minimize overall routing costs while ensuring tasks across different routes are properly synchronized. While prior research has largely concentrated on the deterministic aspect of this issue, our paper introduces a robust optimization approach to handle uncertainties in vehicle travel times between clients for the VRP with Synchronization. We build upon existing methods to propose mathematical models for this problem, accompanied by a branch-and-cut algorithm designed to tackle more challenging scenarios. Additionally, computational experiments are conducted to explore and analyze the main performance indicators of these models and the effectiveness of the solution algorithm.

Keywords: routing, synchronization, robust optimization

Submissão #44

Comparing different algorithms to solve the Smart Waste Collection Problem

Manuel Lopes, Diana Jorge, Joana Santos, Tânia Ramos

Waste collection companies are gradually undergoing digital transformation by integrating volumetric sensors into their waste bins, which provide real-time data on fill levels, enabling these companies to enhance collection operations. Consequently, the challenge lies in effectively selecting which bins to visit each day and determining the optimal routing sequence – a problem that has been referred as the Smart Waste Collection Routing Problem in the literature. Different solution methods have been proposed to solve it ranging from heuristic and metaheuristic to optimal methods passing by approximate or quasi-optimal algorithms. With different assumptions and optimality goals, it is often difficult to compare different algorithms and test them in different scenarios. In this work, we build a simulator, based on real data, considering from 50 to 210 waste bins. With this simulator, different scenarios regarding waste bins' filling rates can be generated in order to run the different algorithms for several simulated months to have a statistically significant comparison. Three algorithms integrate this simulator for comparison purposes: a quasi-optimal algorithm based on submodular optimization, a hybrid metaheuristic based on Simulated Annealing and Neighbourhood Search, and a matheuristic that consists of a heuristic combined with an exact optimization algorithm. Comparing these algorithms is possible to provide further insights into their differences mainly in terms of the quality of service, collection efficiency, and computational time.

Keywords: Vehicle Routing Problem, Waste Management, Smart Waste Collection, Simulator

Submissão #45

Strategic Sensor Placement Problem in Waste Management

Joana Santos, Ana Barbosa-Póvoa, Daniele Vigo, Tânia Ramos

In waste management, an important challenge is monitoring container's filling levels for better routing planning. This work explores this challenge and aims to define the most strategic container's locations to install sensors, which will measure the amount of waste inside them. The impact on the collection operation of partial sensorization compared to no sensors or a fully sensorized network is studied. A two-phase methodology is proposed where the first phase is based on some containers presenting a regular/stable filling rate, requiring periodic collection (Regular containers), therefore it is not profitable equipping them with sensors, contrarily to the Non-regular containers. By creating clusters of Non-regular containers with similar filling rates, and by sensorizing only one container within each cluster, information regarding the others containers' behaviour is somehow known. In the second phase, a Vehicle Routing Problem with Profits is solved, designing routes based on sensors' information, which visit the Regular containers and select the Non-regular containers worth visiting. Applied to a real case study from a Portuguese company, ERSUC, this methodology yields significant profit improvement, zero overflows, and a 20%-40% reduction on the number of routes performed over 16 weeks, with either full or partial sensorization, compared to the current situation with no sensors.

Keywords: Sensors, Smart Waste Collection, Waste management, K-means, Vehicle Routing Problem with Profits, Partially sensorized network

Sessão S3.3

Moderador: Miguel Constantino

Urban Logistics

Submissão #46

Last-mile Delivery with Heterogeneous Crowdshipping and Service Levels

Tiago Monteiro, João Pedro Pedroso, Ana Viana

The growth of e-commerce intensifies competition among retailers as customers demand faster, more affordable, and more convenient delivery options. Innovative solutions such as crowdshipping have emerged. In crowdshipping, in addition to professionals, ordinary citizens (a.k.a. occasional couriers - OCs) participate in the delivery process (e.g., Amazon Flex and Roadie). The OCs can be classified into two classes depending on their commitment to the company: dedicated OCs and en-route OCs. Dedicated OCs register in a platform, provide a schedule with their availability, and can accept some suggested deliveries for a compensation. En-route OCs are in-store customers who make deliveries on their way home, with no or little detours, also for compensation. This work proposes a decision-support tool to help decision-makers study the trade-off between customer service levels and operational costs for different workforce compositions and compensation schemes. The tool analyses scenarios involving the retailer's fleet, occasional couriers, or a hybrid combination. As a collateral result, the traveled distance of different workforce compositions and compensation strategies is measured, offering insights into their environmental impact and empowering informed decision-making that balances economic, service, and sustainability goals.

Keywords: last-mile delivery, crowdshipping, heterogeneous occasional couriers, service level

Submissão #47

Applying machine learning for sequence prediction in last mile delivery

Farzam Salimi, António Galvão Ramos

As logistic and transportation continue to evolve, there is a need for new approaches to tackle the complexities involved in last mile delivery. This study aims to introduce a machine learning approach to understand the sequences of deliveries. To fulfill this goal, first, the delivery zones were divided into 49 districts and 3349 of its combinations based on available historical data of a delivery company in north of Portugal. It started by defining the whole service region as a district and partitioning it into more districts. After that, the transitional probabilities were used to find a primary sequence of districts. Ultimately, Various machine learning models such as Logistic Regression, Decision Tree, Random Forest, K-Nearest Neighbor, and Support Vector Machine applied to predict the first few zones of sequences. The comparative analysis reveals the strengths and limitations of each algorithm in handling sequence prediction tasks. There were differences in model performances, and Random Forest and SVM have shown higher accuracy (up to more 10%) than the other models while Random Forest runtime was lower than SVM. This research offers a foundation for sequence prediction in last mile delivery problem using RNN and LSTM which are more suited for sequence prediction tasks.

Acknowledgements: This work is financed by National Funds through the Portuguese funding agency, FCT (Fundação para a Ciência e a Tecnologia, I.P.) within the project TacitRouting reference 2022.08808.PTDC (<http://doi.org/10.54499/2022.08808.PTDC>).

Keywords: last mile delivery, machine learning, districting, sequence prediction, vehicle routing problem

Submissão #48

Sistema de Apoio à Decisão para produção de artigos de uniforme da Guarda Nacional Republicana

Eduardo Lérias, João Miranda, Paulo Ferreira

O processo de produção de artigos de uniforme da Guarda Nacional Republicana (GNR) é analisado sob a égide da Investigação Operacional para desenvolver um sistema de apoio à decisão que, através da programação linear, permite maximizar a rentabilidade total da produção e encontrar a combinação mais rentável para produzir diversos artigos de uniforme, tendo em conta a disponibilidade de recursos humanos e materiais. Através da aplicação prática da teoria da decisão e da teoria de sistemas, estuda-se uma função objetivo que, atenta a todos os requisitos, permite maximizar a rentabilidade e, ainda, são equacionados outros dois cenários hipotéticos em que o aumento de recursos humanos e materiais ao processo e a introdução de componentes pré-fabricadas no processo produtivo são possíveis alternativas, sendo esta última a que apresenta melhores resultados.

Keywords: GNR, uniformes, rentabilidade, programação linear, teoria da decisão, teoria de sistemas

Sessão S3.4

Moderadora: Cristina Lopes

OR Education Production Planning

Submissão #49

Teaching Operational Research using Games and Simulation: a case study

Cristina Lopes, Eliana Costa e Silva

The use of gamification in teaching is not a novelty. It has been recognized as an effective method for fostering academic and practical skills, while simultaneously enhancing student engagement and motivation. In this work, we report on the use of web-based apps in classroom for introducing concepts and methods of Operational Research (OR) to students of Logistics and Business. Specifically, the Burrito Optimization game, available by Gurobi, and the TSP DYI app, developed by William Cook of the University of Waterloo, are employed to introduce mathematical optimization. The Burrito Optimization game simulates the facility location problem, challenging students to strategically position food trucks to optimize costs and profits, thereby acquainting them with linear programming models. Similarly, the TSP DYI app gamifies the TSP, encouraging student participation and competition while acquainting them with heuristic algorithms and optimization techniques. Through student feedback analysis, this study explores the efficacy of these gamified approaches in enhancing student engagement with OR concepts and motivating further exploration of complex topics. These web-based apps serve as entry points for aspiring data scientists and problem solvers, teaching why optimization is valuable and important, why it is difficult and why solvers and other optimization algorithms are essential. Acknowledgement: This work has been supported by national funds through FCT - Fundação para a Ciência e Tecnologia, under the projects UIDB/05422/2020 and UIDB/04728/2020.

Keywords: Gamification, TSP, Facility Location Problem, Teaching

Submissão #50

From theory to practice: optimizing production with operational research in a learning factory

Ana Beatriz Rodrigues, Samuel Moniz, Cristovão Silva

This study explores the integration of learning factories in education, emphasizing the practical implementation of operational research for efficient production line management. Focused on optimizing the assembly of pneumatic cylinders, considering three product variants and specific constraints, this work aims to align models with industry demands, offering students a hands-on experience that bridges theory with practical application. Through the application of operational research, the methodology identifies essential constraints and objectives to optimize production capacity within the learning assembly line environment. An integral aspect of the research is the development of a graphical application, enabling dynamic visualization of the optimization planning problem and fostering a comprehensive understanding of the production process. Significantly contributing to the effective integration of learning factory environments, the study ensures students gain a realistic experience in running assembly lines with a solid comprehension of production management concepts. The practical implementation not only provides a tangible solution for production optimization but also demonstrates the viability and efficacy of the proposed approach. In short, this work aims to offer valuable insights to academics, industry professionals, and educators involved in the convergence of education and advanced production practices.

Keywords: Learning factory, Production line management, Optimization planning

Submissão #51**An Optimization Approach to the Tactical Production Planning in a Filling Company**

Catarina Pereira Soares Novais dos Santos

In today's competitive business environment, companies aim to improve product quality, reduce costs, and satisfy customers. Effective production planning is essential for achieving these goals and enhancing organizational performance. Through analytical methods, companies optimize their medium-term planning. This ensures efficient resource utilization from raw materials to final products, meeting delivery deadlines. Production planning requires decision-making at various levels, necessitating coordination and integration across functions. The study focuses on addressing production planning issues within a filling company. A medium-term optimization approach was developed to generate weekly plans over a 17-week horizon, utilizing a mixed-integer programming formulation and aiming to ensure efficient resource allocation. The model introduced a significant advancement by incorporating raw materials availability, addressing upstream planning by considering future arrivals and potential purchases of raw materials. Additionally, the methodology introduced the concept of safe quantity, which involves determining order quantities that can be safely anticipated based on historical customer reliability, allowing to improve production flexibility and increase the potential for order aggregation. The methodologies improved both factories, increasing total produced quantity. This led to a 3.4% and 10.1% decrease in unitary production cost for Factory 1 and 2, respectively. Additionally, the plans improved raw materials management, reducing average delay times.

Keywords: Filling Company, Tactical Production Planning, Optimization Model

Sessão S4.1

Moderadora: Maria Teresa Pereira

Industrial Applications

Submissão #52

Barreiras à implementação do Lean Six Sigma na indústria de processos químicos: uma abordagem combinada ISM-MICMAC

Caroline Tortorelli, Amílcar Arantes

Lean Six Sigma (LSS) é uma metodologia robusta de melhoria de processos que combina Lean e Six Sigma para atingir a excelência operacional. Este estudo tem como objetivo analisar as barreiras à implementação do LSS na indústria de processo química (IPQ) que permitam o desenvolvimento de medidas de mitigação práticas e eficazes. Este estudo utiliza pesquisa de métodos mistos. Uma lista de barreiras à implementação do LSS extraídas da literatura foi ordenada por especialistas da IPQ brasileira, e com conhecimentos em LSS, por intermédio do método de Delphi. De seguida, foi utilizada uma abordagem combinada de Modelagem Estrutural Interpretativa (ISM) e a análise Multiplicação de Referência Cruzada de Matriz de Impacto Aplicada a uma Classificação (MICMAC), apoiada por um grupo focal. Os resultados mostram a existência de seis barreiras principais à implementação do LSS na IPQ no Brasil, nomeadamente a falta de tempo para a sua implementação, de uma compreensão sistémica do LSS, de alinhamento estratégico entre o LSS e as estratégias corporativas, de comprometimento da administração de topo com a implementação do LSS, de formação em LSS, de comunicação e transparência na organização no que respeita às responsabilidades durante a implementação do LSS.

Keywords: Indústria Química, Indústria de processo, barreira, ISM, MICMAC, Delphi

Submissão #53

Eco-Efficient Sequencing of a Rotating Machine Operations in Safety Shoe Manufacturing: A Multi-Objective Heuristic Approach

Romão Santos, Catarina Marques, Miguel Sousa, Rui Rebelo, Jorge Pinho de Sousa

The footwear manufacturing industry brings together a set of unique features, such as, high seasonal demand, short product life cycles, and high product/volume mix, that together with technological advances, grows the complexity associated with the efficient management of production processes. This is particularly relevant in sophisticated injection molding machines, which imposes additional constraints on more traditional planning and scheduling tasks. Therefore optimizing operations in such machines requires innovative planning approaches able to accommodate both, process and technical, specifications. This study presents a novel methodology employing multi-objective heuristic optimization to efficiently sequence operations in a rotating injection machine. By considering dependencies like molds, color setups, and rotation times, the goal is to minimize late orders and energy consumption. The developed approach aims to generate optimized sequencing plans by balancing these objectives according to the decision-maker preferences. By adjusting the importance of each indicator, various scenarios will be explored, allowing managers to align plans with operational priorities. Each scenario provides detailed plans, including mold changes and order allocation for each lap of the machine. This research contributes for enhanced production efficiency and sustainability in a real-world case-study, by providing a decision-making tool for optimized sequencing plans tailored to specific needs and goals.

Keywords: Footwear industry, Eco-efficient production planning, Multi-objective optimization, Heuristics, Sustainability

Submissão #54

Sistema de Apoio à Decisão para produção de artigos de uniforme da Guarda Nacional Republicana

Eduardo Lérias, João Miranda, Paulo Ferreira

O processo de produção de artigos de uniforme da Guarda Nacional Republicana (GNR) é analisado sob a égide da Investigação Operacional para desenvolver um sistema de apoio à decisão que, através da programação linear, permite maximizar a rentabilidade total da produção e encontrar a combinação mais rentável para produzir diversos artigos de uniforme, tendo em conta a disponibilidade de recursos humanos e materiais. Através da aplicação prática da teoria da decisão e da teoria de sistemas, estuda-se uma função objetivo que, atenta a todos os requisitos, permite maximizar a rentabilidade e, ainda, são equacionados outros dois cenários hipotéticos em que o aumento de recursos humanos e materiais ao processo e a introdução de componentes pré-fabricadas no processo produtivo são possíveis alternativas, sendo esta última a que apresenta melhores resultados.

Keywords: GNR, uniformes, rentabilidade, programação linear, teoria da decisão, teoria de sistemas

Submissão #55

A mathematical model for optimization of the autoclave occupancy

M. Teresa Pereira, Marisa Oliveira, Inês Esteves, Fernanda A. Ferreira

This work presents an optimization model, and continuous improvement tools applied to the painting, autoclave equipment, of a company in the aeronautical sector, to increase the availability and efficiency of the equipment, reflected in an improvement of the Overall Equipment Effectiveness and simultaneously reduce energy costs. The greenhouse optimization model made it possible to achieve improvements, namely maximizing the occupation of the oven and, at the same time, efficiently distributing the parts across the trolleys and painting shelves. The mathematical model led to very positive results on the flow of the entire production plant, as it reduced delays that usually occurred in this process. A 92% reduction in time was achieved in the preparation/masking phase of the pieces and a 20% reduction in energy consumption per piece, which also translates into a 40% increase in greenhouse occupancy.

Keywords: OEE, Optimization model, Energy; Autoclave, Aerospace

Sessão S4.2

Moderadora: Maria João Alves

Multiobjective Optimization

Submissão #56

Project portfolio management bi-objective model considering the leaving problem

Jorge Noro, Luis Dias

This article is based on a recent new bi-objective optimization model for project portfolio management where projects selected to be implemented, and by whom, are set. The objective functions seek to maximize the economic gains of the project portfolio selected and to minimize the probability of agents leaving the organization. The skills development of the agents allocated to these projects are monitored, and the constraints consider the workload of the agents and the way the distribution of work affects their employment commitment, considering the dimensions of Absorption, Dedication and Strength of the UWES (Utrecht Work Engagement Scale). In this work new decision variables and new constraints related to the leaving problem are considered, for the probability of an agent to leave the organization. Experimental results are presented, for a scenario based on the experience of administration offices for the management of research and innovation projects at a higher education institution.

Keywords: Project, Portfolio, Multi-objective optimization, Staffing, Project allocation, Leaving problem, Work Engagement

Submissão #57

Modelos Multiobjetivo em Problemas de Setorização

Ana Maria Rodrigues, Cristina Lopes, Valeria Romanciuc, José Soeiro Ferreira, Elif Öztürk, Cristina Oliveira

Os problemas de setorização estão relacionados com a divisão geográfica em pequenas áreas, também designadas por setores, com o objetivo de simplificar um problema complexo partindo-o em problemas mais pequenos. Vários critérios podem ser considerados, sendo os mais comuns o equilíbrio e a compacidade. As aplicações são diversas, nomeadamente recolha de resíduos, distribuição logística, serviços de apoio domiciliário, definição de territórios de vendas ou zonas de policiamento. Este trabalho enquadra-se em problemas de localização de centros de distribuição (armazéns) e alocação das unidades básicas (clientes) a cada centro de distribuição. Foram usados modelos de programação inteira com métodos multiobjetivo, designadamente o método lexicográfico e o método da soma ponderada. Um conjunto de instâncias geradas aleatoriamente com dimensões de 43 a 250 unidades básicas e 10 centros de distribuição foi avaliado. Concluiu-se que, com o método lexicográfico se obteve melhores resultados nas instâncias de maior dimensão, produzindo setores mais equilibrados. O método da soma ponderada conseguiu melhores resultados nas instâncias mais pequenas, conduzindo a soluções com setores mais compactos.

Keywords: Setorização, problemas de localização, otimização multiobjetivo, programação inteira, método lexicográfico, método da soma ponderada

Submissão #58

Using Geometric Distance Functions to Assess Performance Evolution: A Statewise Look at the Pre-vaccination COVID-19 Reaction in the USA

Miguel Alves Pereira, Duarte Caldeira Dinis, Diogo Cunha Ferreira, José Rui Figueira, Rui Cunha Marques

Since the initial diagnosis of COVID-19 in the United States on January 20, 2020, the decentralised nature of the country's response to the pandemic led to the adoption of diverse strategies across its states, resulting in varying outcomes. In this study, we assess the temporal evolution of pre-vaccination pandemic response performance among different states in the USA from March 2020 to January 2021. Utilising the Hicks-Moorsteen index based on geometric distance functions, we overcome known limitations of other indices to provide a comprehensive evaluation. Composite indicators, derived using the 'Benefit-of-the-Doubt' approach, serve as the basis for index computation. Our findings reveal that eleven states consistently occupied the performance frontier, while five states never did during the selected time intervals. Despite an overall average decline in performance from March 2020 to January 2021, one state demonstrated the highest instances of performance growth, while seven states experienced the most instances of performance reduction. Notably, our analysis underscores that, despite variations in COVID-19 mitigation policies, the majority of best-performing states were early implementers of a state of emergency, non-essential business closures, and mandatory mask usage in public spaces. We discuss health and cohesion policy implications derived from patterns of performance change.

Keywords: Hicks-Moorsteen index, geometric distance functions, Benefit-of-the-Doubt, performance evolution, COVID-19

Submissão #59

O que são soluções pessimistas em problemas 'bilevel' multiobjetivo?

Maria João Alves, Carlos Henggeler Antunes

A otimização 'bilevel' trata problemas de decisão hierárquica em que dois decisores, o líder e o seguidor, controlam diferentes variáveis e têm as suas próprias funções objetivo sujeitas a restrições interdependentes. Trata-se de uma estrutura de programação matemática em que um problema de otimização de nível inferior está embutido num de nível superior. Quando há incerteza na reação do seguidor, porque o problema de nível inferior tem soluções ótimas alternativas ou múltiplas funções objetivo, o líder pode adotar uma perspetiva otimista ou pessimista. Enquanto que os conceitos de otimismo e pessimismo estão bem estabelecidos quando existe uma só função objetivo para o líder, o mesmo não acontece quando há múltiplas funções objetivo em ambos os níveis. A maior parte da literatura procura calcular a fronteira de Pareto otimista (soluções eficientes para o líder, considerando que as escolhas do seguidor são sempre as mais favoráveis para o líder). Contudo, esta abordagem pode não ser realista e a definição de fronteira de Pareto pessimista pode não ser consensual. Nesta comunicação é proposta uma definição de frente de Pareto pessimista para problemas de otimização 'bilevel' com múltiplas funções objetivo nos dois níveis, que é comparada com a otimista. Estes conceitos são ilustrados com exemplos, enfatizando as dificuldades associadas ao cálculo dessas soluções.

Keywords: Otimização bilevel, multiobjetivo, frentes de Pareto, otimismo, pessimismo

Sessão S4.3*Moderador: Filipe Alvelos***Forest Fire Management****Submissão #60****A robust approach for the prepositioning of resources for wildfire suppression**

Francisco Marques, Agostinho Agra, Helena Alvelos, Ana Raquel Xambre, Filipe Alvelos

We consider the problem of prepositioning a set of firefighting resources for wildfire suppression. As wildfires are highly affected by uncertainty we devise a two-stage model where the prepositioning of resources are first-stage decisions and the movement of these resources after the fire ignitions are known are the second-stage decisions. We use mixed integer programming and the minimum travel time principle to model the fire spread in the landscape and decisions related to the prepositioning and movements to attack positions of the resources. To model uncertainty we use robust optimization based on a discrete set of scenarios which represent ignition locations, wind speed and directions. As the size of the model grows considerably with the number of scenarios, a row-and-column decomposition algorithm is proposed. Computational experiments based on a actual landscape are reported showing the efficiency of the decomposition algorithm.

Keywords: Fire suppression, Robust optimization, Decomposition algorithm**Submissão #61****Encaminhamento de veículos para combate estendido a incêndios florestais**

Marco Marto; Filipe Alvelos

Neste trabalho é apresentado o problema de encaminhamento de veículos para combate estendido a incêndios florestais. O problema consiste em determinar a rota (i.e. a sequência de nodos) de cada um de um conjunto de veículos e os nodos em que ataca o incêndio. Propõe-se um modelo de programação inteira mista (mixed integer programming, MIP) que, além das rotas dos veículos, incorpora a propagação do incêndio, diferentes tipos de ataque e permite a utilização de diferentes funções objectivo (únicos ou hierárquicos, por exemplo, minimizar número de pontos sensíveis atingidos e minimizar a área queimada). Um aspecto fundamental do MIP é a modelação do tempo: na sua movimentação, os recursos têm de chegar a qualquer local antes do fogo; nos ataques indirectos, os recursos têm de terminar o ataque antes do fogo chegar; nos ataques directos, por exemplo, os recursos têm de iniciar o ataque num determinado intervalo temporal com início na chegada do fogo. Discute-se a dificuldade de resolução do problema e possíveis abordagens para a resolução de instâncias reais. Este trabalho foi financiado pela FCT - Fundação para a Ciência e Tecnologia no âmbito do projecto PCIF/GRF/0141/2019 "O3F - An Optimization Framework to Reduce Forest Fire".

Keywords: supressão de incêndios florestais, programação inteira mista, problemas de rotas

Submissão #62

Uma heurística baseada em MIP para ataque inicial a incêndios florestais

Filipe Alvelos, Marco Marto, André Mendes

Os incêndios florestais são um problema global que exige contributos de diferentes domínios para fazer face aos seus múltiplos e potencialmente graves impactos. Neste trabalho é formulado um modelo de programação inteira mista (mixed integer programming, MIP) para posicionar e encaminhar recursos de combate a incêndios (por exemplo, equipas terrestres e helicópteros) no ataque inicial. Este modelo integra variáveis relativas à propagação do incêndio (baseada no princípio de que o caminho que o fogo percorre entre dois pontos de uma paisagem é o mais rápido) e variáveis relativas à movimentação e posições de ataque dos recursos em redes específicas dos tipos de recursos (e.g. estradas para recursos terrestres). Dada a dificuldade de resolução do modelo exacto, é proposta uma heurística que alterna entre MIP (para posicionamento) e algoritmos de árvore do caminho mais curto (para encaminhamento). Apresentam-se experiências computacionais conduzidas com pyO3F (uma framework python que está a ser desenvolvida no âmbito do projeto “An optimization framework for reducing forest fire”) numa paisagem real em Portugal. Este trabalho foi financiado pela FCT - Fundação para a Ciência e Tecnologia no âmbito do projecto PCIF/GRF/0141/2019 “O3F - An Optimization Framework to Reduce Forest Fire”.

Keywords: Incêndios florestais, Optimização, Programação Inteira, Heurísticas

Submissão #63

Solving a sequencing firefighting resource problem with a genetic algorithm

Marina A. Matos, Rui Gonçalves, Ana Maria A. C. Rocha, Lino A. Costa, Filipe Alvelos

In recent years, the forest fires have been increasing and strategies need to be found to improve/help decision-making in firefighting. This study addresses the firefighting resource dispatch problem optimization, which involves knowing how many, which and when the firefighting resources should be assigned sequentially to extinguish several ignitions. The approach involves a lexicographic optimization, in which priorities are established in a specific order. The primary priority is to minimize the total burned area and the other priority is to minimize the total time it takes to extinguish all active ignitions. A genetic algorithm is used to test and validate this lexicographic optimization using some generated instances. This work has been supported by FCT - Fundação para a Ciência e Tecnologia within the project PCIF/GRF/0141/2019: "O3F - An Optimization Framework to Reduce Forest Fire".

Keywords: Dispatch Problem, Lexicographic Optimization, Genetic Algorithm

Sessão S4.4

Moderadora: Joana Dias

Healthcare

Submissão #64

Multi-objective optimization to inform hospital collaboration and elective surgical patient inter-hospital transfers

Mariana Oliveira, Daniel Santos, Ana Barbosa-Póvoa

A mismatch between demand for surgical procedures and the available capacity within hospitals is a prevalent issue in countries with national healthcare systems like Portugal. This disparity often results in prolonged waiting times for surgeries, which can significantly affect patients' health outcomes and treatment efficacy. In efforts to mitigate the challenges associated with delivering timely care, hospitals may opt to transfer patients to facilities with available resources, which can enhance operational efficiency and alleviate waiting lists and delays. Nevertheless, such transfers can impose burdens on both patients and operating room managers as well as increase overall system costs. This study proposes a multi-objective optimization model designed to support informed decision-making regarding hospital collaboration to reduce delays and waiting times, while also minimizing costs and travel distances. It evaluates the trade-offs between costs incurred by collaborating and non-collaborating hospitals, maximum travel distances, and waiting time targets before surgeries. Preliminary results suggest that, for certain surgical specialties in Portugal, inter-hospital patient transfers can effectively reduce waiting lists. By leveraging such models, hospitals can strategically engage in collaborative efforts to optimize resource allocation and decrease waiting times, thereby enhancing the overall quality of patient care.

Keywords: Health Services, Tactical decisions, Optimization

Submissão #65

Aligning actionable monitoring with health technology assessment in remote care management: combining business intelligence, multicriteria decision analysis and participatory approaches to build a multidimensional management dashboard

Rafael Miranda, Filipa Baptista, Isabel Albuquerque, Mónica Oliveira

Remote patient monitoring (RPM) holds promise for accessible and equitable care delivery, regardless of location. Successful RPM implementation and ongoing operation demand vigilant monitoring and evaluation for improvement opportunities and adjustments. Yet, there is still a need for enhanced value assessment methods and tools to inform adopters about RPM implementation value and address current challenges related to patient resistance, health professionals' scepticism, and expensive setup and maintenance. Within this context, our study proposes a novel framework integrating business intelligence, multicriteria decision analysis and participatory methods to build a multidimensional management dashboard (MMD) to aid decision-makers in continuously monitoring and evaluating RPM programs. Following a collaborative value modelling paradigm, this framework combines stakeholder engagement and decision-aiding methods and tools for (a) involving MMD end-users in selecting performance indicators aligned with RPM value, (b) building a flexible multicriteria value model for customised analysis and a classification model for identifying RPM areas requiring corrective actions, and (c) integrating indicators and model information into a user-friendly MMD, incorporating stakeholder preferences. The framework is now being applied to the collaborative development of an MMD for a heart failure RPM program in a Portuguese public health unit.

Keywords: Remote patient monitoring, Dashboard development, Health technology assessment, Collaborative modelling, Heart failure

Submissão #66

Designing a multi-level hierarchical network for the provision of hospital care: A Portuguese case study

Maria Lopes, Daniel Santos, Ana Barbosa-Póvoa

Ensuring the efficient provision of healthcare services while balancing costs and access is one of the most fundamental goals in NHS-based countries. Optimizing decisions related to the facilities' location, demand allocation and installed capacity are crucial to achieving this goal. In this study, we address the challenge of optimizing healthcare service provision within NHS-based systems by developing a bi-objective mixed-integer linear programming model accounting for the multi-hierarchical structure of the Portuguese hospital network. This model aims to minimize travel time for improved hospital accessibility and reduce operational and investment costs for increased efficiency. A demand forecast model is included in this approach, which combines demographic, geographical and administrative information to predict future healthcare demand. The model is applied to a case study in Portugal, and the results are compared with the existing network. The integration of the population forecast model into the optimization framework makes this approach particularly valuable for long-term healthcare system sustainability in response to demographic changes.

Keywords: Hospital Network Design, Location-Allocation Model, OR in Healthcare

Submissão #67

Otimização biológica no planeamento de tratamentos de radioterapia

Diana Aires, Brígida Ferreira, Humberto Rocha, Joana Dias

Cerca de 50% dos doentes com cancro são sujeitos a radioterapia. A otimização dos planos de tratamento de radioterapia pode ser melhorada através de modelos radiobiológicos, capitalizando a sua correlação direta entre a dose de radiação administrada e os resultados clínicos. No entanto, a sua implementação acrescenta complexidade ao processo de planeamento do tratamento, introduzindo funções objetivo não lineares e não convexas. Este estudo aborda a otimização do planeamento do tratamento em Radioterapia de Intensidade Modulada (IMRT), incorporando modelos radiobiológicos e recorrendo a simulated annealing. Para avaliar as vantagens do novo algoritmo de otimização proposto, foram selecionados quatro casos de tumores diferentes: cancro da mama, da cabeça e do pescoço, do pâncreas e da próstata. Os resultados demonstraram uma diminuição considerável da probabilidade de complicação dos tecidos normais e um aumento da dose global no volume alvo para todos os casos testados. Isto indica uma poupança significativa dos órgãos circundantes em risco, sendo que, simultaneamente, se verifica um aumento na dose média no volume alvo. Em conclusão, os modelos radiobiológicos emergem como ferramentas com o potencial de produzir resultados de tratamento interessantes. A integração de metaheurísticas revela-se uma boa opção permitindo tirar partido dos benefícios dos modelos radiobiológicos.

Keywords: simulated annealing, otimização em saúde, radioterapia

Sessão S4.5

*Moderador: José Fernando Oliveira***Maritime Logistics Transportation**

Submissão #68

The berth allocation problem under uncertainty: a distributionally robust optimization perspective

Filipe Rodrigues

Berth allocation problems are amongst the most important problems occurring in port terminals, and they are greatly affected by several unpredictable events. As a result, the study of these problems under uncertainty has been a target of more and more researchers. Following this research line, we consider the berth allocation problem under uncertain handling times. Robust optimization and stochastic programming are the most common approaches used to deal with uncertainty in BAPs. Here, we study the BAP under a distributionally robust optimization. We assume that each vessel has an associated deadline to finish its operations, but delays can occur. Therefore, we aim to minimize the worst-case of the expected sum of delays of vessels with respect to a set of possible probability distributions of the handling times. The solutions of the proposed model are obtained by an exact decomposition algorithm for which several improvements are discussed. An adaptation of the proposed algorithm for the case where the assumption of relatively complete recourse fails is also presented. Extensive computational tests are reported to evaluate the effectiveness of the proposed approach and to compare the solutions obtained with those resulting from the stochastic and robust approaches.

Keywords: Distributionally robust optimization, port terminals, uncertainty

Submissão #69

A Simulation Tool for Optimizing Port Operations

Catarina Coelho Carvalho, Romão Santos, Catarina M. Marques, Jorge Pinho de Sousa

Container terminals play a critical role in global logistics systems, as part of broader intermodal networks, by connecting maritime and land transport. The evolution of containerization and technological advances has significantly impacted maritime container terminals, requiring adaptations to handle a higher demand and increasing volumes. In this context, the primary challenge lies in improving productivity, reducing operational costs, and enhancing competitiveness, while coping with strong spatial and operational constraints. Moreover, managing complex logistics systems involves multiple entities and intertwined flows, requiring tools such as simulation to support strategic decision-making, enabling the analysis of multiple scenarios based on real-time data and forecasts. Therefore, this work presents a decision-support tool developed in the FlexSim software, to analyze different container terminal configurations, with a particular focus on automation and sustainability considerations. A discrete-event-simulation model was developed to study multiple scenarios impacting productivity, resource utilization, and waiting times. The proposed approach aims at facilitating the test and evaluation of management strategies for ports operations with preliminary results showing that the sizing of AGV fleets and their planning affect the total operating time, the energy consumed and the costs associated with charging AGVs.

Keywords: Port operations, Container terminals, Decision Support Systems, Simulation, Sustainability

Submissão #70

Optimizing multi-attribute pricing plans for different carsharing user profiles

Masoud Golalikhani, Beatriz Brito Oliveira, Maria Antónia Carravilla, José Fernando Oliveira

Carsharing operators (CSOs) typically develop various pricing plans based on different attributes, such as registration fees, travel distance, and travel time fees, as part of their strategic decisions. Each plan can have various rates across different periods and areas to increase vehicle utilization and adjust the interactions between demand and supply. Potential customers can choose a plan tailored to their travel needs to join carsharing systems. Hence, when developing plans, CSOs must analyze the customers' travel behaviors and spatial and temporal parameters that may affect the demand. However, in literature, there is a lack of realistic plans, and most works assumed only one plan with a single attribute (i.e., price per minute), which is equal for all users, ignoring the actual structure of complex plans and the heterogeneity of users. Thus, we formulate a mathematical model to design the optimal combination of multi-attribute plans with time- and location-dependent rates that maximize CSOs' profit. Computational results on trip datasets from Brooklyn, New York showed that the model can find the optimal or near-optimal solution for real-sized problems within a reasonable time limit. Moreover, we developed a relax-and-fix-based algorithm to efficiently produce high-quality results for large-scale instances within a shorter timeframe.

Keywords: Revenue management, Carsharing, Pricing plans, Fleet management

Submissão #71

Factors affecting transport mode choice and their implications for sustainable mobility: an empirical analysis of the Asprela University Campus

Sayeh Fooladi Mahani, Beatriz Brito Oliveira, Lia Patrício, Vera Miguéis, Maria Antónia Carravilla, José Fernando Oliveira

This study explores sustainable urban transportation at Porto's Asprela Campus. The area was chosen for its distinctive features: it is the location of three universities and a hospital, and a diverse mix of commuters including students, daily commuters, and occasional visitors. These unique characteristics provide a rich backdrop for exploring the preferences and perceptions associated with urban transportation. The study examines how individuals aged 18 years or older choose various modes of urban transportation, such as public transit, micro-mobility, ride-hailing, and car-sharing to commute to the area for various reasons, including work, study, hospital visits, and others. The survey developed consists of three parts: factors influencing transportation mode choices, specific modes used to reach the area, and socio-demographic information. The survey's innovation is combining two aspects: asking about factors influencing urban travel choices and delving into actual practices. This provides a comprehensive overview of urban transportation choices, bridging the gap between preferences and real-world actions. The study's findings can significantly help mobility companies and policymakers make informed decisions to improve multi-modal transportation and sustainable mobility. Also, identifies important factors in choosing urban transportation modes, which can contribute to developing enhanced demand models to support urban mobility design and strategic decisions.

Keywords: Transportation mode choices, Survey method, Sustainable urban transportation, Demand model

Sessão S5.1

Moderador: Agostinho Agra

Energy

Submissão #72

Otimização do desenho de parques eólicos com partilha de vala

Adelaide Cerveira, Amaro de Sousa, E.J. Solteiro Pires, José Baptista

A produção de energia está cada vez mais direcionada para as renováveis, onde a energia eólica se destaca. Num parque eólico onshore, a energia elétrica é recolhida numa subestação a partir das várias turbinas eólicas através de cabos elétricos colocados em valas no solo. Neste trabalho, aborda-se o problema de otimização do desenho de um parque eólico, conhecida a localização da subestação e das turbinas eólicas, considerando um determinado conjunto de cabos elétricos disponíveis. O objetivo é selecionar os cabos a utilizar e as ligações a efetuar, para interligar todos as turbinas à subestação, de modo a minimizar o custo do investimento inicial mais o custo das perdas de energia elétrica durante o tempo de vida do parque eólico. Assume-se que cada vala pode acomodar um conjunto limitado de cabos, o que torna este problema numa variante mais complexa dos problemas do desenho de parques eólicos abordados anteriormente. Este problema é mais adequado ao caso real e conduz a ganhos substanciais no custo total. O problema é definido como um modelo de Programação Linear Inteira, onde são incluídas desigualdades válidas. Os modelos são aplicados a vários parques eólicos até um máximo de 115 turbinas eólicas. AGRDECIMENTOS: Este trabalho é financiado por fundos nacionais através da FCT- Fundação para a Ciência e a Tecnologia, I.P., no âmbito do projeto LA/P/0063/2020. DOI 10.54499/LA/P/0063/2020 | <https://doi.org/10.54499/LA/P/0063/2020>

Keywords: Otimização, parque eólico, rede de distribuição

Submissão #73

Enhancing optimal design of hybrid renewable energy systems through Markovian availability approach

Luciana Yamada, Flávia Barbosa, Luís Guimarães

Achieving a complete energy transition by 2050 with a net-zero emissions economy requires prioritizing the decarbonization of energy systems, which means reducing the use of fossil fuels and increasing the adoption of renewable energy technologies. However, the variability in single-source renewable energy (RES) systems poses operational challenges due to fluctuating energy production. Addressing this variability involves enhancing reliability by integrating different energy profiles in hybrid renewable energy systems (HRES). Efficiently designing an HRES involves determining the optimal combination of renewable sources, their sizes, device types, and system locations. This study employs an optimization model, considering a Markovian availability approach, to define the optimal system sizing. The goal is to maximize an economic indicator by selecting the most suitable combination of RES and considering the system's availability. Decision variables include the number of energy source technologies and device types for installation. Cable capacity limitations within the existing park's infrastructure are also considered. This study explores the economic feasibility of transitioning a wind park into an HRES or enhancing the capacity of the current energy source and the impact of availability in sizing models.

Keywords: Hybrid renewable energy systems, Optimization, Availability, Markov Chain

Submissão #74**Optimizing wind farm cable routing under uncertainty**

Agostinho Agra, Adelaide Cerveira

Wind power is an important source of green energy. Here we consider the problem of designing the cable network that connects the wind turbines (WT) to the substation in wind farms. The aim is to minimize both the infrastructure cost and the cost of energy losses over the wind farm's lifetime, taking into account the uncertainty in the load factors at the WTs due to the uncertainty in the wind direction and speed. The load factors are assumed to be random variables whose realizations are described by a finite set of discrete scenarios, with an unknown probability distribution belonging to an ambiguity set. This set consists of all distributions within a predefined distance from a reference distribution. A two-stage mixed-integer model is proposed, where the choice of connections and the type of cable used are first-stage decisions, while the losses depend on the realized scenarios and the corresponding probabilities. A major advantage of this model approach is that by varying a single parameter value, which controls the size of the ambiguity set, one can obtain the stochastic programming solution and the worst-case (robust optimization) solution. Computational results are reported.

Keywords: Wind farm, cable routing, distributionally robust optimization

Sessão S5.2*Moderador: Jorge Orestes Cerdeira***Operação Ferroviária****Submissão #75****Suporte algorítmico para o planeamento da capacidade em operadores ferroviários**

Gonçalo P. Matos, Luís Albino, Ricardo L. Saldanha

Para ajustar o serviço a futuras necessidades de transporte e condições de funcionamento os operadores ferroviários tentam antecipar as necessidades de recursos, nomeadamente de material circulante e tripulantes. Essa antecipação é feita com grande antecedência por causa dos longos tempos de entrega de material circulante e de formação do pessoal. Normalmente a previsão das necessidades de recursos é feita com métodos simplistas e empíricos que dão origem a estimativas demasiado grosseiras só para um conjunto de casos muito limitado. Como forma de superar essas dificuldades desenvolveu-se um sistema de apoio à decisão altamente configurável que integra um modelo de previsão e uma "pipeline" de optimizadores que permite responder a perguntas como estas: tendo em conta a evolução das necessidades de transporte nos últimos anos, quantas unidades de material circulante e tripulantes vai ser necessário adquirir e recrutar para suprir as necessidades de transporte previstas para daqui a cinco anos? Qual a distribuição desses tripulantes pelas bases operacionais? Quantos tripulantes vai ser necessário recrutar para fazer face a uma alteração prevista no normativo laboral? Além de se dar uma perspetiva sobre os algoritmos usados e a forma como eles estão encadeados, apresentam-se também alguns resultados obtidos com casos de uso paradigmáticos.

Keywords: Planeamento da capacidade, Optimização, Operação ferroviária**Submissão #76****Optimização do planeamento de operações ferroviárias em redes locais**

Sara Cruz, Carlos Iglésias, Ricardo L. Saldanha

Por forma a garantir uma utilização eficiente e eficaz dos seus recursos os operadores ferroviários planeiam ao detalhe todas as operações necessárias à realização do serviço de transporte que pretendem fornecer. Uma parte importante dessas operações são as que se realizam nas redes locais das estações, por exemplo: embarque e desembarque de passageiros em plataformas, estacionamento de veículos, bem como os movimentos que um veículo tem de fazer para se deslocar entre os vários pontos da rede local desde a sua chegada vindo de outra estação até à sua partida para outra estação. O planeamento destas operações está sujeito a múltiplas restrições, como por exemplo restrições que estabelecem tempos mínimos para o embarque, desembarque e inversão de marcha, restrições relacionadas com a ordem de entrada e saída dos veículos nos parques bem como com as normas de segurança da circulação na rede local. Propomos uma meta-heurística de recozimento simulado para planear de forma eficaz e eficiente as operações ferroviárias em redes locais que assumimos repetirem-se com uma periodicidade semanal. Como forma de demonstrar a sua aplicação prática apresentamos resultados computacionais em cenários de transporte de passageiros com diferentes objetivos de otimização, bem como uma análise comparativa dos mesmos.

Keywords: Planeamento, Operações ferroviárias, Redes Locais

Submissão #77**Minimizing costs in signal provision by communication antennas along a railway line**

Adérito Araújo, J. Orestes Cerdeira, Nuno Lopes, Ana Moura

We address a wireless network design problem on a railway line. Given a finite set of locations along a railway line and different types of communication antennas that can be installed at each of these locations, which locations and which type of antenna should be selected to ensure a certain level of signal coverage along the railway line while minimizing construction costs? We formulate the problem as 0/1 linear optimization model, and report computational experiments using real and simulated data. The computational tests showed that the model can be used to solve moderately large instances, which we believe to be the expected sizes of the largest instances that arise in real problems.

Keywords: Wireless network design, Base station deployment, Railway communications, Optimization, Integer linear programming

Sessão S5.3

Moderadora: Elsa Silva

Cutting and packing problems

Submissão #78

Improving the efficiency of Logic-Based Benders Decomposition for large-scale optimization

Paulo Jorge Nascimento, Cristóvão Silva, Carlos Henggeler Antunes, Samuel Moniz

Large-scale optimization, particularly in NP-hard problems, is known to be very challenging. For these problems, (meta-)heuristics are frequently used to obtain a near-optimal solution in an affordable computation time. However, when an optimal solution is required, decomposition methods can be the only practical alternative. Logic-based Benders decomposition (LBB) is a generalization of the Benders decomposition that allows sub-problems to be any optimization or constraint satisfaction problem, making it applicable in a large range of hard optimization problems. The efficiency of an LBB is largely dependent on how it is built. This work aims to explore how the efficiency of LBB can be further improved in a problem of nesting and scheduling in Additive Manufacturing, and how that can be replicated in other problems. Several techniques were explored to further increase the efficiency of the models used for the master and the sub-problems. Additionally, as the sub-problems are used to generate cuts on the master problem, obtaining maximum information from the sub-problems is crucial for strengthened cuts. Lastly, when the master problem has symmetrical optimal solutions, leading it to solutions that align with the ones obtained by the sub-problems is critical. Results demonstrate that by carefully designing an LBB, the computational performance can differ in the orders of magnitude.

Keywords: Large-scale optimization, Logic-based Benders decomposition, Computational Performance, Nesting, Scheduling

Submissão #79

Online three-dimensional packing problems with static stability constraint

Sara Ali, António Galvão Ramos, José Fernando Oliveira

Static stability is a significant packing requirement since an unstable loading can result in potential damage to items, containers, and operators during the loading/unloading operations. Nevertheless, this important requirement has often been oversimplified in the context of online three-dimensional packing problems. In online scenarios, items arrive one by one and require immediate and safe packing decisions without prior information on unpacked items, while rearranging packed items is not allowed. To provide valuable insights into selecting an appropriate static stability strategy in online scenarios, we developed several heuristics under four stability constraints, i.e., full-base, partial-base, full-polygon-base, and new partial-polygon-base support. Evaluating the impact of constraints on the efficiency of heuristics across different sizes of real datasets showed that heuristics with polygon-base stabilities have superior performance against the others regarding the number of used bins. However, assessing the quality of the constraints in providing a stable packing layout using the 'static mechanical equilibrium' approach as a benchmark showed that although under polygon-base constraints, more than 87% of items are stables, this amount is lower than other constraints. It indicates that in selecting a stability strategy, there is a trade-off between increasing items' stability and decreasing the number of used bins.

Keywords: Online 3D packing problems, Packing heuristics, Static stability constraints

Submissão #80

OnLine Irregular 3D Packing with Stability constraints

Pedro Rocha, António Ramos, Elsa Silva

In this work the Irregular 3D Packing problem is tackled for a variant where the items are received in real-time, also known as an "on-line" configuration. The task of packing irregularly shaped three-dimensional (3D) items in real-time presents formidable challenges, particularly when the items arrive sequentially without prior knowledge of their specific shapes. This factor increases the complexity of achieving efficient use of the volume and maintaining stable configurations during assembly and transportation of pallets containing irregular items. Addressing static stability requires careful accommodation of the balance and weight distribution of the irregular items during the packing process, also made more challenging due to the requirement that their placement must be done in their order (sequence) of arrival. The proposed approach continuously evaluates the stability of the configuration as more items are added adjusting their placement to prevent collapses or instability within the container. Additional problems also arise after completing the item packing, since the full container requires handling in order to be expedited for transportation, which is subject to dynamic stability constraints, where horizontal movement and vertical impacts add additional stress to the container and its items changing the force distribution and their support capability, leading to potential collapses, and causing deformation (or catastrophic) of the items if support thresholds are exceeded. The problem and the identified challenges are tackled using a placement heuristic that selects and validates possible placement positions (addressing static stability), which is then reinforced by a physics based simulation environment to validate other aspects of structural integrity (deformation and compressibility) and acceleration limits for transportation (addressing dynamic stability). This process is also monitored in parallel using a Machine Learning algorithm that learns to suggest potential placement positions that fulfill the required criteria without the downsides of the extensive computational cost incurred by the use of irregular shapes and the physics based simulation environment. These innovations ensure that the approach is effective in real-time scenarios, providing stable configurations for irregular items even when dealing with the inherent uncertainties of unknown item characteristics. The algorithm's adaptability and effectiveness position it as a promising solution for industries requiring on-the-fly packing of irregularly shaped items. Acknowledgments: This work is co-financed by Component 5 - Capitalization and Business Innovation, integrated in the Resilience Dimension of the Recovery and Resilience Plan within the scope of the Recovery and Resilience Mechanism (MRR) of the European Union (EU), framed in the Next Generation EU, for the period 2021–2026, within project Produtech R3, with reference 60.

Keywords: Online Irregular Packing, Static and Dynamic Stability, Physics Based Simulation, Machine Learning

Sessão S5.4

*Moderadora: Maria Cândida Mourão***Routing Problems 3**

Submissão #81

Integrating harvesting decisions with road planning and timber transportation

Marta Mesquita, Miguel Constantino, Susete Marques, José G. Borges

The primary challenges in forest management planning involve spatio-temporal decisions, particularly in harvest scheduling where stands are chosen for harvesting within specific time periods. This process must align with the design of a forest road network, facilitating machinery access to stands and timber transportation to sawmills. To address this problem, we propose a MILP model integrating harvest scheduling, road planning, and timber routing, aiming to maximize income calculated as the difference between the revenue of selling the harvested timber against the associated extraction, road building/maintenance, and transportation costs. However, this problem incorporates a NP-hard fixed charge network flow, making it challenging to solve real-life instances as their size and complexity increase. We developed a solution approach that iterates between solving an integrated problem considering a restricted road network and addressing a subproblem on road planning and timber routing across the full road network. In each iteration the subproblem solution provides information on how to improve the restricted forest road network. We apply this methodology to a real-life case study of a smallholding forest landscape in Portugal, demonstrating its practical applicability.

Keywords: Harvesting scheduling, forest road design, road building/maintenance, timber routing

Submissão #82

A metaheuristic for the family capacitated vehicle routing problem

Raquel Bernardino, Ana Pias

The family capacitated vehicle routing problem (F-CVRP) is an NP-hard problem that generalizes both the FTSP and the capacitated vehicle routing problem. The F-CVRP has practical applications in warehouse management in warehouses with scattered storage. We propose an iterated local search (ILS) algorithm comprising a local search phase and a perturbation phase. The local search procedure contains neighborhoods defined by moves inside each route, between routes, and between visited and non-visited nodes. Regarding the perturbation phase, it uses dynamic metrics to ensure the diversification of the search of the solution space. The computational experiment shows that the ILS algorithm can obtain solutions of better quality than the upper bound provided by the exact methods at the end of the time limit more efficiently.

Keywords: Family traveling salesman problem, iterated local search algorithm, dynamic metrics

Submissão #83

A multi-trip vehicle routing with release dates and interrelated periods – an automotive industry application

Leonor Santiago Pinto, Raquel Bernardino, João Janela, Carlos Martins, Maria Cândida Mourão, Filipe Rodrigues

This presentation introduces the multi-trip vehicle routing with release dates and interrelated periods (MTVRP-RDIP), motivated by a car components distribution to repair centers (warehouses) application. The routes start at different departure periods and have various durations. Thus, two routes starting at different periods may be active simultaneously, leading to interrelated periods. Moreover, a route may only start at a departure period if a vehicle is available, and the availability of a vehicle depends on the existing ones and on the active routes at that time period. The clients are classified according to their importance and represent warehouses that require car components, thus leading to the consideration of release dates. Delays in satisfying client orders result in penalty costs that must be minimized. The objective to minimize also includes routing costs and vehicle utilization costs. Mixed integer linear formulations and a matheuristic based on a rolling-horizon process are presented. Computational experience with 150 generated instances shows that the formulation provides solutions for the smaller ones, and the matheuristic obtains solutions in a reasonable time for the larger ones. Funding This work was partially supported by the Projects CEMAPRE/REM - UIDB /05069/2020 and CMAFcIO - UIDB/04561/2020, financed by FCT/MCTES through national funds.

Keywords: Multi-trip vehicle routing problem, Release dates, Interrelated periods, Matheuristic, Automotive industry application

EstudIO

A Storytelling Dashboard for Multicriteria Decision Making

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Problem description

Whether as individuals or organizations, we are all faced with making decisions, ranging from the simplest to the most complex. These decisions often involve considering various alternatives and evaluating different criteria. In the business world, this process can have far-reaching implications, affecting everything from operational efficiency to strategic direction. In this context, multi-criteria decision-making (MCDM) techniques such as Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ELECTRE and PROMETHEU methods have emerged as valuable tools (1). These techniques allow decisionmakers (DMs) to systematically evaluate multiple alternatives against a set of criteria, thereby facilitating more informed and rational decision-making. However, these techniques can be complex for decision-makers unfamiliar with their complexities (2). While the models provide a quantitative basis for decision-making, understanding the rationale behind a specific choice can be challenging for those tasked with leading to a lack of trust in the process (3). To address this problem, we have developed a dashboard that integrates data visualizations throughout the decision-making process. This approach enables decisionmakers of varying levels of expertise to effectively interpret the results, thereby enhancing their understanding in the decision-making process.

Problem relevance

The challenges associated with MCDM techniques are not merely academic as they have realworld implications where the ability to make informed decisions is more important than ever. Decisions based on MCDM techniques can significantly impact an organization's strategic direction, operational efficiency, and overall success. However, if DMs do not understand the process, they may be reluctant to use these techniques, or they may use them incorrectly. Several software tools exist to implement multicriteria decision analysis, while technically powerful, do not fulfill the purpose of this project, which is to visually deconstruct a multicriteria technique, functioning as a storytelling. Storytelling, in this context, refers to the ability to present the decision-making process in a narrative form that is easy to understand and follow. It involves breaking down complex processes into simpler parts and presenting them in a logical manner. This can help decision-makers understand the process better, see how different factors influence the decision, and appreciate the logic behind the final decision. Therefore, there is a pressing need for tools that can simplify the implementation of MCDM techniques and enhance the decision-maker's understanding in the results.

Methodology

Our methodology proposes a two-step approach, focusing on understanding the details of various multicriteria techniques and developing an effective visualization strategy. In the first step, we experimented with several multi-criteria techniques in a linear fashion. This allowed us to understand their workings, advantages, and disadvantages in a hands-on manner. By manipulating these techniques directly, we were able to gain a clear understanding of their potential for visual deconstruction. This hands-on experimentation was crucial in helping us understand how these techniques could be simplified and visually represented. In the second step, we focused on the visualization aspect. We started by clearly defining the type of problem we were facing and how we could tackle it. We then identified the tasks that

we wanted the user to be able to perform. This user-centric approach ensures that our dashboard would be tailored to the needs of the decision-makers, enhancing its usability and effectiveness. Once we had a clear understanding of the user tasks, we turned to the literature in the field of visualization analysis and design to guide our choice of visualizations. We carefully selected the visualizations to implement for each task, ensuring that our choices were well-justified and based on structured evaluation procedures (4).

Results

The validation of our dashboard is an ongoing process, and a crucial part of this validation will take place at the upcoming conference. We plan to conduct live testing of the dashboard during the conference, with volunteers participating in the process. This hands-on testing will provide valuable insights into the dashboard's efficiency and effectiveness. The volunteers, who will be decision-makers from various fields, will use the dashboard to implement MCDM techniques and interpret the results. Their feedback will be instrumental in understanding whether the dashboard is meeting its intended purpose of simplifying the implementation of MCDM techniques and enhancing the decision-maker's understanding and trust in the results. This live testing will also provide an opportunity to identify any potential areas of improvement. We believe that this iterative process of testing, feedback, and refinement is key to ensuring that our dashboard remains user-friendly, scientifically sound, and effective in facilitating informed decision-making. In conclusion, while we have made significant progress in developing this dashboard, we recognize that its validation is an ongoing process. We look forward to the upcoming conference as an opportunity to test our dashboard in a real-world setting and continue to refine it based on user feedback. We believe that this work represents a significant advancement in the field of decision-making, and we are excited about its potential to make MCDM techniques more accessible and trustworthy.

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Programação de máquinas paralelas dedicadas com setups dependentes da sequência de famílias e recursos adicionais

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Descrição do problema

Este trabalho centra-se num problema de máquinas paralelas em que um conjunto de tarefas deve ser processado. Como a alocação das tarefas às máquinas é conhecida previamente, resulta num problema de máquinas paralelas dedicadas. Os tempos de *setup* são dependentes da sequência de famílias e são necessários recursos adicionais de processamento e *setup*. Assim sendo, a situação estudada define-se como um problema de programação de máquinas paralelas dedicadas com *setups* dependentes da sequência de famílias e recursos adicionais (PMSR).

O sequenciamento das tarefas em cada máquina é limitado pela quantidade de recursos existentes, sendo a principal distinção desta realidade relativamente aos problemas clássicos de escalonamento. A resolução do problema envolve dois níveis de decisão: sequenciação e tempo. Cada máquina possui uma configuração inicial que é influenciada pelo número de operadores disponíveis para o turno. O estudo surge da necessidade do departamento de produção de uma empresa que fabrica peças de plástico por injeção para a indústria automóvel com um tempo máximo de resposta de 48 horas.

Cada tarefa pertence a uma família, tem um molde associado e é processada numa única máquina sem interrupção. As peças que partilhem o mesmo molde são uma família e um *setup* dependente da sequência deve ser efetuado entre tarefas de famílias diferentes. Diariamente é necessário proceder à ordenação dos moldes para a produção em cada máquina. Os operadores são necessários para processar as tarefas e as equipas de *setup* realizam as trocas de molde. O número de *setups* simultâneos é limitado pela disponibilidade de pontes rolantes. Os operadores e as equipas de *setup* são recursos renováveis e dinâmicos. O número de operadores para cada turno é conhecido antecipadamente e o sistema deve fornecer soluções de sequenciamento no início de cada turno. O objetivo do departamento é responder à procura diária de peças, respeitando as restrições de capacidade, elegibilidade da máquina e as disponibilidades de operadores e de equipas de *setup*. Para refletir as condições reais do problema, foi proposta uma nova função objetivo que consiste na minimização da soma dos *makespan* de todas as máquinas. Esta função objetivo conduz a soluções compactas que além de minimizar o tempo de conclusão de cada máquina, permite a minimização dos tempos ociosos e do número de *setups*.

Relevância do problema

O escalonamento da produção é crucial para garantir o nível de serviço neste mercado exigente. Como tal, estabeleceu-se como meta o desenvolvimento de um sistema de apoio à decisão para o problema da empresa. O sistema de apoio à decisão proposto pretende minimizar as ineficiências existentes ao nível do chão de fábrica, possibilitando a investigação do impacto desta solução no desempenho global das empresas. Assim sendo, a resolução do problema estudado pode conferir uma vantagem competitiva para a empresa.

Em termos técnicos, este estudo apresenta algumas contribuições relativamente ao trabalho que serviu de base para esta dissertação. De facto, adaptaram-se dois modelos matemáticos gerais ao problema específico de máquinas paralelas dedicadas. Tendo em conta que os sistemas de produção são contínuos, introduziu-se uma configuração inicial das máquinas. Foi proposta uma nova função objetivo que pretende a minimização da soma dos *makespan* de todas as máquinas. Os modelos matemáticos de referência foram generalizados para serem capazes de resolver problemas com *setups* dependentes da sequência de famílias. Além disso, o estudo fornece informações valiosas sobre a eficácia de diferentes estratégias para a resolução de problemas PMSR em contextos reais.

Face ao exposto, é possível concluir que foi desenvolvida uma estrutura de dados composta por parâmetros e variáveis que retratam na plenitude o problema real da empresa.

Metodologia

Para resolver este problema foram adaptados dois modelos matemáticos. Um modelo segue a abordagem *strip-packing* e o outro é indexado ao tempo. Os testes computacionais mostraram que o modelo *strip-packing* tem um desempenho superior comparativamente ao modelo indexado ao tempo. Após esta conclusão, o estudo prosseguiu apenas no modelo *strip-packing*. Como este modelo matemático só se mostrou capaz de resolver instâncias com até 8 máquinas e 24 tarefas (pequena e média dimensões), foi desenvolvida uma heurística matemática. Uma das estratégias utilizadas na heurística matemática foi o mecanismo de *warm-start* em que se desenvolveu uma metaheurística TS para gerar soluções iniciais válidas e que funcionam como *upper bound*. Para reduzir o espaço de soluções inferiormente, desenvolveu-se uma heurística construtiva (SCTUR) que gera soluções que funcionam como *lower bound*.

Com base na realidade da empresa, foram criados cinco conjuntos de problemas com dimensões diferentes. Para cada um dos conjuntos foram geradas aleatoriamente 10 instâncias com tempos de processamento, tempos de *setup* e famílias por máquina gerados a partir de distribuições uniformes de $U(20,240)$, $U(30,50)$, e $U(1,3)$, respetivamente. O número de operadores para suportar o processamento das tarefas nas máquinas foi gerado segundo a distribuição uniforme de $U(1,4)$. Cada *setup* necessita de uma equipa de *setup* e a alocação das tarefas às máquinas também foi um processo aleatório.

Resultados

Os resultados computacionais destacam a eficácia da heurística SCTUR como *lower bound*, produzindo soluções bastante mais próximas da ótima, comparativamente aos valores da relaxação linear, com desvios médios de 3,61% e 5,09% para instâncias pequenas e médias, respetivamente. A metaheurística TS obteve soluções ótimas em 80% e 50% das instâncias pequenas e médias, respetivamente. Nas instâncias grandes (16 máquinas e 40 tarefas), o *gap* médio para a solução da heurística SCTUR (*lower bound*) foi de 8,88%. Além disso, o TS apresentou resposta computacional razoável nos problemas com até 32 máquinas e 100 tarefas. As diferentes abordagens da heurística matemática apresentaram resultados promissores na resolução deste problema, destacando-se a estratégia que combina o TS e a heurística SCTUR. Esta estratégia alcançou um ganho de 79,61% comparativamente ao desempenho do modelo matemático, obtendo um *gap* médio de 4,24% para as instâncias grandes. Face ao exposto, concluiu-se que as estratégias da heurística matemática têm impacto nas instâncias de maiores dimensões, onde o modelo matemático apresenta dificuldades.

A Numerical Approach for the Aircraft Deconfliction Problem with Speed Regulation

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Problem description

In the field of air traffic management, ensuring a safe distance between flying aircraft while optimizing specific objectives is a critical challenge known as the Aircraft Deconfliction Problem (ADP). Traditionally, human Air Traffic Controllers (ATC) handle this task by adjusting aircraft altitudes, trajectories, directions, or speeds to resolve potential conflicts in restricted airspace. However, there is a growing interest in introducing automation to aircraft deconfliction. One intriguing approach is the concept of *subliminal speed control* (1) which consists in subtly adjusting an aircraft's speed in the case of collision risk. It is proved that this approach permits to effectively reduce the number of conflicts in the airspace before direct control.

Problem relevance

Aircraft, as aerial transportation, has become the most popular and effective mean to reallocate people, goods and raw materials. Being the fastest and safest mode of global transportation, it has become a primary choice for travel, including domestic trips within a country. With the current high number of flights per day, which is expected to double in the next two decades, it is essential to address conflicts between aircraft in shared airspace. These conflicts may occur when aircrafts come too close along their planned trajectories, violating safety margins. Ensuring air traffic safety requires effective prevention and resolution of such conflicts. However, the technology for conflict detection and resolution has not kept pace with aircraft advancements and the increasing volume of flights. Manual procedures by ATC, including trajectory observation and pilot instructions, still prevail. Controllers and pilots face substantial workloads, particularly in congested areas, leading to delays or unwanted routes. To address these issues, there is a growing need for automated air traffic control systems with effective computational support to assist human operators.

Methodology

We study one possible model of the ADP problem via subliminal speed regulation approach. This model has the form of a Semi-Infinite Programming (SIP) problem which can be solved numerically using existing SIP solvers or applying the known discretization approach combined with Nonlinear Programming (NLP) solvers. We rigorously tested various SIP and NLP solvers on an available database of ADP problems in two and three-dimensional spaces and concluded that these solvers do not permit the solution of the SIP model in a short time, thus making it impossible to apply the subliminal speed regulation approach without resorting to some approximate methods or heuristics, which naturally reduces the accuracy of the solution. After, we studied the mathematical properties of the model and proved that it can be reduced to an equivalent NLP problem with only three quadratic constraints. Although this NLP problem is not convex, numerical experiments have shown that it can be effectively solved in a very short time. In what follows, we formulate the SIP and NLP models for the ADP problem, justify their equivalence, and briefly discuss the numerical results.

SIP Model

Consider the following SIP model of the 3-dimensional ADP problem (2):

$$\begin{aligned} \min \quad & \sum_{i \in A} (q_i - 1)^2, \\ \text{s. t.} \quad & \sum_{k=1}^3 [(x_{ik}^0 - x_{jk}^0) + t(q_i v_i u_{ik} - q_j v_j u_{jk})]^2 \geq d^2 \quad \forall t \in [0, T], q_i^{\min} \leq q_i \leq q_i^{\max}, \forall i < j \in A. \end{aligned}$$

Here $A = \{1, \dots, n\}$ is the set of aircraft flying in a shared airspace, $[0, T]$ is the time horizon measured in hours, d is the safe distance between aircrafts, measured in Nautical Miles, x_{ik}^0 and u_{ik} are the k -th components of the initial position and the direction of aircraft i , respectively; v_i is the initially planned speed of aircraft i . The variables, $q_i, i \in A$, are the ratios of modification of the initially planned speeds of the aircrafts, and $[q_i^{\min}, q_i^{\max}]$ represent the feasible range of these ratios. If $q_i = 1$, we say that the speed of the aircraft i is unchanged, if $q_i \geq 1$, then the speed is increased and if $q_i \leq 1$, then the speed is decreased. Notice that the SIP model contains uncountably many constraints quantified over a continuous time symbol $t \in [0, T]$. These constraints ensure the aircraft's separation requiring that the squared Euclidean distance between each pair of aircraft (i, j) to be greater than or equal to d^2 at each instant.

Equivalent NLP reformulation of the SIP problem

Let us rewrite the constraints' function of the SIP problem in the form

$$\bullet \quad f(t) := \sum_{k=1}^3 [(x_{ik}^0 - x_{jk}^0)^2] - d^2 + \sum_{k=1}^3 t [(q_i v_i u_{ik})(x_{ik}^0 - x_{jk}^0) - (q_j v_j u_{jk})(x_{ik}^0 - x_{jk}^0)] + \sum_{k=1}^3 t^2 (q_i v_i u_{ik} - q_j v_j u_{jk})^2 \geq 0.$$

Denote: $c := \sum_{k=1}^3 [(x_{ik}^0 - x_{jk}^0)^2] - d^2$, $b := \sum_{k=1}^3 (q_i v_i u_{ik})(x_{ik}^0 - x_{jk}^0) - (q_j v_j u_{jk})(x_{ik}^0 - x_{jk}^0)$, and

$a := \sum_{k=1}^3 (q_i v_i u_{ik} - q_j v_j u_{jk})^2$. Then, evidently, $f(t) = at^2 - 2bt + c$.

Consider the following conditions:

Condition A: For all $t \in [0, T]$ it holds: $f(t) \geq 0$.

Condition B: The following inequalities hold true: $f(0) = c \geq 0$, $f(T) = aT^2 - 2bT + c \geq 0$, $\sqrt{f(0)f(T)} \geq bT - c$.

The following proposition can be proved.

Proposition. *Conditions A and B are equivalent.*

Based on the theoretical result formulated in the Proposition, we obtain the following equivalent NLP formulation of the SIP problem:

$$\bullet \quad \min \sum_{i \in A} (q_i - 1)^2, \text{ s. t. } f(0) \geq 0, f(T) \geq 0, \sqrt{f(0)f(T)} \geq bT - c.$$

Results

The project includes two stages of numerical experiments with the database from the *github* repository supported by University of Toulouse (3): one series of experiments solved the SIP model and the second, the equivalent NLP reformulation. On the first stage, the SIP model instances were solved using the function package *scipy.optimize* of Python and the *optimization toolbox* of Matlab. The numerical experiments produced different but comparable results: both solvers used the procedures based on discretization and were either unable to find a solution, or the time for a solution was unacceptably long. We also compared the results with other authors (4) who used different approaches to the same problem, and conclude that none of the results obtained are completely satisfactory. On the second stage of the numerical experiments, the NLP formulation was tested by all available NLP procedures implemented on the Matlab and Python softwares. The best results in terms of the objective function were obtained using the Matlab *optimization toolbox*, while the best compilation time was shown on the test in Python. These results permit us to conclude that the proposed approach based on the equivalent NLP reformulation has clear advantages in terms of numerical solution of the problem, and the accuracy of the SIP model does not suffer when it is applied.

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Sistema de Apoio à Decisão para aquisição de ração para os cães da Guarda Nacional Republicana

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Descrição do problema

A contratação pública é um processo burocrático, que envolve um conjunto de procedimentos, regulados pelo Código dos Contratos Públicos, para a aquisição de bens e serviços necessários ao desempenho de funções do Estado. A Guarda Nacional Republicana (GNR) como Força de Segurança, enquadra-se neste regime, porque pertence à administração direta do Estado. Para garantir a alimentação dos cães adultos que estão ao serviço operacional, nas várias valências, o Comando da GNR de Portalegre tem à disposição três tipos de ração seca, uma à base de carne de frango (ração 1), outra de carne de borrego (ração 2) e outra à base de salmão (ração 3). As missões atribuídas à especialidade cinotécnica da GNR exigem um treino diário com exercício muito intenso, que carece de um regime alimentar rigoroso. A referência para a quantidade de ração a administrar aos cães é o equivalente a 2-3% do seu volume corporal. Considerando que as rações têm diferentes composições nutricionais, o problema consiste em determinar a combinação e a quantidade ótima de cada tipo de ração a fornecer aos cães, para satisfazer as respetivas necessidades nutricionais diárias e minimizar o custo total da alimentação.

Tabela 1 — Características nutricionais das rações

Nutrientes	Ração 1 (g/kg)	Ração 2 (g/kg)	Ração 3 (g/kg)	Refeição (g/dia)
Hidratos de Carbono	300	250	100	80
Proteínas	250	150	300	80
Gorduras	250	300	400	40
Vitaminas/Minerais	20	30	20	6
Custo (€/kg)	4,50	4,00	3,00	

Fonte: Elaboração Própria

Relevância do problema

A programação linear assume especial relevância na gestão eficiente e eficaz dos recursos públicos e, neste estudo em particular, constitui um valioso contributo para o processo de tomada de decisão, relativamente ao tipo de ração e respetiva quantidade a adquirir e à definição da combinação ótima. A adoção deste modelo matemático, numa ótica de eficiência, garante uma alimentação mais adequada e saudável aos cães, através de uma distribuição eficiente das rações e sem desperdícios. Por outro lado, tem ainda um impacto significativo ao nível das decisões organizacionais e estratégicas, no âmbito do planeamento e conceção dos procedimentos públicos para aquisição de ração para os canídeos da GNR.

Metodologia

Este trabalho tem como objetivo minimizar o custo da alimentação diária dos cães, usando a programação linear. Na prossecução de tal desiderato, começámos por efetuar uma análise exploratória dos dados disponíveis sobre a composição nutricional e do preço de cada uma das rações, apresentadas pelas empresas que reúnem as condições de integrar o lote de fornecedores de bens ao Estado. Numa segunda fase, traçámos quatro cenários onde se equacionaram eventuais roturas de “stock” ou oscilações de preços e formulámos uma função objetivo, com as respetivas restrições nutricionais dos cães, em cada cenário. No primeiro cenário é analisado o problema, tendo em conta a disponibilidade dos três tipos de ração, com os preços de tabela, que atualmente estão em vigor no mercado. O segundo cenário antecipa a rotura de “stock” da ração 1, considerada a mais completa do ponto de vista nutricional para os cães adultos e com

maior procura no mercado. O terceiro cenário equaciona uma redução de 25% do preço da ração 2, por ser aquela que tem menos procura no mercado. Por último, o quarto cenário prevê uma eventual rotura de “stock” da ração 3.

Para efetuar a análise de sensibilidade do problema e identificar as combinações ótimas de diferentes tipos de ração, dos quatro cenários, recorreremos ao programa LINDO v6.1. No final, construímos uma matriz de análise e apoio à decisão com a informação obtida.

Resultados

A matriz de análise e apoio à decisão, identifica, por cenário, o preço que cada ração pode variar, sem alterar os valores ótimos da função objetivo, a quantidade de ração a administrar por animal e a quantidade exata de sacos, de cada tipo de ração, para efeitos de elaboração do caderno de encargos do concurso público. Este instrumento funciona como um “tableau” de referência e permite-nos, em cada cenário e com rigor científico, selecionar a ração mais eficiente. Orienta os tratadores dos cães a administrar uma alimentação adequada, sem desperdícios e garante toda a informação necessária para o decisor desencadear o processo de contratação pública e definir os critérios de adjudicação de acordo com os princípios gerais da contratação pública. Com as devidas adaptações ao nível das restrições nutricionais, este instrumento pode ser aplicado no processo de aquisição de ração para os cachorros em crescimento e para as fêmeas durante o período em que estão a procriar. Este estudo permitiu concluir que compensa adquirir a ração mais cara porque, sendo mais completa, carece de menos quantidade para garantir a nutrição diária dos cães adultos. A utilização deste instrumento de apoio, no processo de aquisição de ração para os 300 canídeos da GNR, permite uma redução de consumo de ração superior a 10.000 Kg e uma poupança anual superior a 30.000 €. Assim, o alargamento da aplicação deste estudo ao processo de aquisição de ração para os cavalos e a outros processos de aquisição de bens e serviços, teria um impacto significativo, ao nível da gestão do orçamento da GNR, garantindo os princípios da concorrência, transparência e eficácia dos procedimentos de contratação pública.

Tabela 2 — Matriz de Análise e Apoio à Decisão

	RAÇÃO 1	RAÇÃO 2	RAÇÃO 3	REFEIÇÃO
CENÁRIO 1 Estabilidade Preços	2,50 € – 5,21 € Quantidade 246 g Proporção (4/5)	< 3,35 €/kg	1,50 € – 5,50 € Quantidade 62 g Proporção (1/5)	1,29 € 308 g
CENÁRIO 2 Rotura “stock” X1	Ø	1,50 € – 7,50 € Quantidade 267 g Proporção (2/3)	1,60 € – 8,00 € Quantidade 133 g Proporção (1/3)	1,47 € 400 g
CENÁRIO 3 Promoção X2 (-25%)	< 4,12 €/kg	1,50 € – 3,35 € Quantidade 267 g Proporção (2/3)	1,20 € – 4,29 € Quantidade 133 g Proporção (1/3)	1,20 € 400 g
CENÁRIO 4 Rotura “stock” X3	0 € – 6,67 € Quantidade 320 g	< 2,70 €/kg	Ø	1,44 € 320 g

Fonte: Elaboração Própria

Reserve Crew Scheduling in Passenger Rail Transport

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Problem description

This work focuses on determining an algorithm for scheduling reserve crew duties in a way that facilitates the process of handling disruption scenarios. Reserve crew members are workers who don't have any specific job previously defined. They only know that they have to sign in and sign out at a specific location and time. They have to be prepared to cover work that became unassigned due to disruptions during the day. The main objective of this thesis is to create an algorithm that has duty schedules as input and returns reserve crew schedules. Figure 1 shows three duty schedules each one characterized by the following sequence of operations to be performed by a crew member: sign in at a specific time in the operational base or simply base (Ddr or Ah), sequence of travelling operations (green lines) and sign out at a specific time in the base. Figure 2 shows three reserve crew schedules each one characterized by two operations separated by idle time: sign in at a specific time in the base (Ddr or Ah) and sign out at a specific time in the base.



Figure 1. Duties schedules from two bases (input)

Figure 2. Reserve crew schedules for two bases (output)

For testing purposes, this work uses a dataset with 719 duties distributed by 28 operational bases from a specific weekday.

Problem relevance

In most cases, the only way to avoid train trips from being cancelled, as a consequence of managing disruptions, is by having reserve resources that help solve problems on the ground. This increases the problem's complexity but maintains the railway punctuality and reduces potential negative impacts on passenger's lives. Reserve crew members help reduce the number of cancelled trips and extra hours made by employees. It is difficult to identify where and when a reserve crew member will be needed, which is why determining the right amount of reserve crew members at the right time and base station is a challenge. This work uses metaheuristics, combinatorial optimisation and simulation to solve the problem presented.

Methodology

To solve the reserve crew scheduling problem, an algorithm is schemed in Figure 3. Firstly, it starts by importing the input data, namely, duties information, and parameters. The reserve crew schedules are generated based on duties workload because it is an approximation of reserve crew demand. The duties workload represents the number of workers that work at that time and that have a duty that starts and ends in the same base of the workload. Each base has a duty workload and is divided hourly.

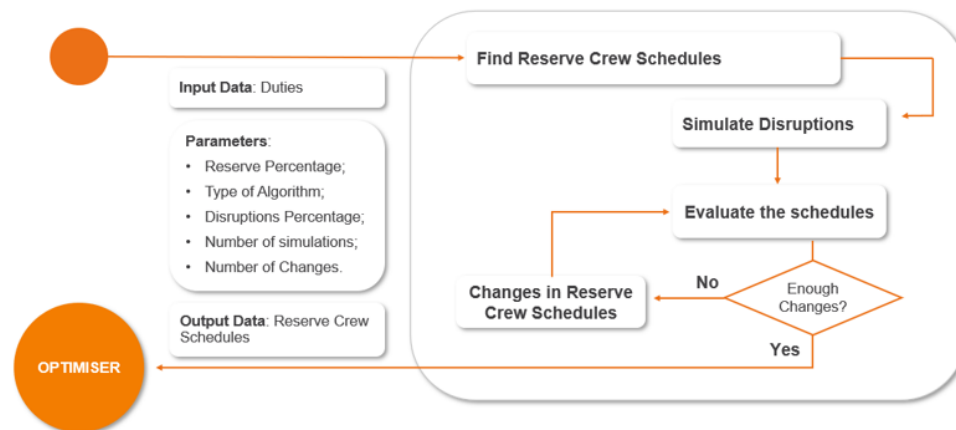


Figure 3. Scheme of reserve crew scheduling algorithm

After importing the input data, it starts by calculating the number of reserve crew members, as the result of multiplying the given reserve percentage by the number of duties from that base. After that, a schedule is computed for each reserve crew member with one of the following methods: the peak approach and the window approach.

The peak approach will start by finding the hour with the highest workload and will define it as a working hour of the duty. After that, it will compare the workload of the previous and next hours and select the hour with the highest load as a working hour. This procedure will continue until the schedule is complete, which means 8 hours of work.

The window approach calculates the sum of workload for every set of 8 hours that is a possible schedule and selects the one that has a higher sum. Then, it assigns these 8 hours as working hours, finishing the first reserve crew schedule.

After each schedule is computed the duties workload must be updated, to set the new reserve crew demand. As the workload is updated, the next schedules computed will likely be different from the previous ones.

Once a set of reserve crew schedules is computed, it has to be evaluated. The evaluation is made by subjecting the schedules to several disruption scenarios randomly generated with simulation. The only disruption considered is crew absenteeism, the most current one. The number of absent workers per base is given by a Poisson distribution that takes as a parameter the percentage of the number of working shifts at that base that day. It uses a uniform distribution to assign the duties that are going to be considered absent employees, each individual has an independent probability of being absent. The evaluation phase compares the workload of duties that became absent with the workload of reserve crew schedules, at each base, to obtain scores. When more duties become absent than reserve crew members are available, it assumes that railway trips were cancelled.

The goal of the changes procedure is to improve the evaluation score. It represents a second review of the schedules made before but, this time, including the assessment made with the simulated disruptions. The number of changes the procedure will make in the reserve crew schedules is a parameter, this procedure ends when that number of changes is reached. For each change, the procedure starts by selecting the hours and bases with the highest number of insufficient reserve crew members and unused reserve crew members. Secondly, a reserve crew member that is working in the hour and base with the highest number of unused reserve crew members is selected to have its schedule changed. The schedule and the base are changed to the one with the highest number of insufficient reserve crew members. The rescheduling process is made with the peak approach but this time with the insufficient reserve crew workload.

The final evaluation is made in the SISCOG optimiser. A powerful tool that uses a considerable amount of computation time where a disruption scenario must be selected to test the set of reserve crew schedules made in the algorithm.

From data to action: transforming warehouse operations with simulation

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Problem description

Our case study analyzes the operations in a warehouse that receives, tests, and packages graphics boards to customers. The whole process begins with the supplier sending three different graphic boards corresponding to each supplier: A, B, and C. The boards arrive in bulk containers (with 60 boards of a specific type), which are then redirected to an unpackaged goods storage. After that, the bulk containers are separated from their contents, and the boards are tested and packaged with the proper Nvidia box to then return to the same bulk containers. At the end of these processes, bulk containers are stored in packaged goods storage. To complete the orders, workers proceed to retrieve each order (an order only contains one type of board) using a pick and pack process, which then are shipped to the respective customer.

Problem relevance

Our main objectives for this simulation study are: i) to determine the optimal stock management parameters based on the reordering point reordering quantity strategy; ii) to define the number of workers needed to carry out pick and packing operations; and iii) to improve the overall warehouse operations strategy, thus reducing warehouse costs and maximizing warehouse service level.

The application of simulation modeling to complex problems leads to various solutions that potentially can reduce costs and increase the overall efficiency of the systems. In our case, simulation is a powerful tool to run experiments targeting cost reduction, evaluate the lot size, understand the dynamics of buffer behavior, reduce supplier delivery delays, or even change inventory management policies and strategies.

Methodology

Our approach to solving the problem began with a conceptual modeling of the whole system to better understand the logistics processes of the warehouse. In this regard, the logical method of reproducing the system and thus optimizing it is to use simulation to find and solve the main bottlenecks. Through the development of a warehouse flow diagram, we have the possibility of transposing all processes and constraints into a simulation model, while considering key performance indicators.

Before the development of the simulation model, it was necessary to perform preliminary data analyzes and to conceive initial ideas about the inefficiency of the system. With Python, we were able to fit real data with statistical distributions, such as board quantity per customer order, interarrival and pick and pack times. After collecting data and developing the simulation model, we carry out verification and validation phases. Using theoretical values such as lead time in the pick and pack section, conceptual representation, visual animation, graphics analysis, and statistical results, it was possible to ensure proper validation of the simulation model.

Results

Results show that logistic delays are the main factors that influence low service levels and global warehouse costs. Additionally, having a 100% service level, it is clear that inventory costs increased significantly.

With a structured scenario analysis, we achieved a total warehouse cost of \$2.7 million in one year of simulation and a service level of 99 percent.

Reducing the lot size from 60 to 24 in theory not only reduces the percentage of time that the test machine is starved, but also reduces the blockage time. Simulation results show that it is possible to reduce the total warehouse costs by \$130K per year (less 4.8% compared to the company's actual setting) and keep 99% of the service level. In addition, one of the system bottlenecks is the buffer between the test and packaging machines, which only allows five boards simultaneously and thus does not meet the model's performance requirements. So the appropriate solution is to increase the buffer's occupancy to 30 boards (value achieved after careful evaluation of buffer occupancy for a one-year assessment). This improvement reduced annual warehouse costs by \$150K (less 5.6% compared to the current system) and maintained a service level of 99%.

However, the improvement that yields the greatest potential to reduce annual costs is to standardize the lead time of the suppliers, which means that instead of having a different distribution of delivery time for each supplier, we could reach an agreement that only one distribution of delivery time will be followed for all three suppliers. This, and the change in the product flow strategy to one-piece flow, could have a major impact on total warehouse costs of around \$1 million per year, which is almost 40% lower than the actual system and still maintaining a service level of 99%. The proposed strategy basically consists of, instead of having one line for all three types of board, we consider specific product lines, which allowed to remove the intermediate packaged goods storage. As a result, reducing the delivery time of suppliers is the most effective strategy for reducing global costs, but it is also the most difficult strategy to achieve it, as it leads to changes in contractual agreements with suppliers.

This project was carried out in the Operations Simulation course, 2023-2024 edition of the Master's in Industrial and Engineering Management of the University of Coimbra. The case study was provided by SIMIO.

Otimização de um problema integrado de balanceamento de postos e afetação de recursos: Um caso de estudo

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Descrição do problema

Este trabalho apresenta um caso de estudo de uma empresa do ramo automóvel, onde foi desenvolvido um estudo de balanceamento de postos de trabalho e afetação dos colaboradores a esses mesmos postos num processo de inspeção. Este estudo decorreu da necessidade de se alterar o Takt-Time de 33 minutos para 38,5 minutos devido a um decréscimo nas vendas e a um período de turbulência na chegada de material para produção. Dado o contexto em que operava a empresa, o objetivo seria reduzir o número de pessoas, diminuindo o número de postos na linha de inspeção. Para além do desenvolvimento do balanceamento dos postos, foi também estudada a melhor afetação dos colaboradores aos mesmos, de modo a perceber qual seria o melhor esquema de atribuição tendo em conta a aptidão de cada trabalhador e a alteração realizada no balanceamento das tarefas nos postos.

Relevância do problema

Para além de uma boa capacidade produtiva e qualidade dos seus produtos, as empresas precisam cada vez mais de melhorar ativa e continuamente os seus processos tornando-os cada vez mais eficazes e eficientes. Assim, eliminar desperdícios é fulcral para a garantia da eficiência dos processos. Um dos desafios atuais das organizações é fazer uma boa gestão do processo produtivo e da capacidade do mesmo, incutindo em todos os envolvidos a importância de o melhorar. Otimizar o balanceamento das atividades realizadas nos postos de trabalho contribui decisivamente para a gestão dos processos, impulsionando a redução de desperdícios e o dimensionamento da capacidade produtiva, contribuindo para um melhor aproveitamento dos recursos disponíveis, potenciando assim a produtividade (1). No entanto, o conceito de produtividade é uma medida também relacionada com o fator humano e precisa, por isso, de ser considerada como tal (2). Desta forma, para além do balanceamento das atividades realizadas nos postos de trabalho, é também importante considerar o fator humano e, nesse sentido, a sua afetação a essas atividades.

Através do presente trabalho, foi possível não só obter soluções para os problemas de balanceamento e afetação, mas permitir que os colaboradores da empresa pudessem executar tarefas para as quais estariam mais aptos, quer a nível de know-how, quer a nível físico. Para isso, foi desenvolvida uma abordagem que integra os dois problemas estudados de balanceamento de linhas e de afetação de tarefas.

Metodologia

Para o desenvolvimento da abordagem referida, recorreu-se a abordagens exatas, mais concretamente a modelos de programação linear inteira (PLI). Estes modelos foram implementados em OPL e testados com as instâncias reais, através de dados fornecidos pela empresa, no contexto do processo em estudo.

Numa primeira fase, foram desenvolvidos e testados dois modelos de programação linear inteira para a resolução do problema de balanceamento de linhas, baseados no modelo apresentado por Simaria, 2001(3), e no modelo de Bowman modificado por White, 1961 (4). Um dos modelos, Modelo A, tem como único objetivo a minimização do número de postos de trabalho. Posteriormente foi implementado um outro modelo, Modelo B, bi-objetivo, pretendendo-se minimizar o número de postos e maximizar as eficiências dos mesmos. Após a implementação e teste dos modelos para o processo em estudo, escolheu-se a melhor solução, tendo passado a linha de seis para cinco postos de trabalho.

Como a linha era inicialmente composta por seis colaboradores distribuídos pelos seis postos de trabalho, e um colaborador adicional em processo de formação, foi também necessário definir um novo esquema de afetação dos colaboradores aos novos postos. Deste modo, numa segunda fase, foram desenvolvidos dois modelos de PLI para resolução do problema de afetação dos recursos humanos, que potenciasses a produtividade relacionada com as diferentes *skills* dos colaboradores. Ambos os modelos, Modelo C e Modelo D, foram baseados no modelo apresentado por Bouajaja Dridi, 2017(5), e, para ambos, o objetivo foi maximizar o benefício da afetação dos colaboradores, sendo o balanceamento das tarefas um dado previamente conhecido e consistindo na solução de balanceamento obtida na primeira fase. Os modelos foram implementados segundo duas abordagens, uma em que os modelos são chamados a resolver os problemas individualmente, e uma outra em que os modelos são implementados em conjunto e de uma forma sequencial.

Para o caso em estudo, havia à disposição sete colaboradores para serem alocados aos cinco postos de trabalho. No entanto, se apenas estivessem disponíveis cinco colaboradores e se algum dos colaboradores apresentasse restrições quanto à possibilidade de realizar determinadas tarefas, a afetação dos recursos aos postos seria interdependente do balanceamento dos postos. Desta forma, numa terceira fase, foi desenvolvido um novo modelo de PLI, Modelo E, que resulta da integração do problema de balanceamento de postos com o problema de afetação de recursos humanos aos mesmos, problema ao qual se atribuiu a designação de PIBLAR.

Resultados

O estudo da otimização da linha de inspeção englobou o desenvolvimento de um total de cinco modelos de otimização: dois destinados ao problema de balanceamento das tarefas, dois orientados para o problema de afetação de recursos e um englobando a integração destes dois problemas. Estes modelos foram implementados em OPL, recorrendo ao CPLEX- IBM ILOG Optimization Studio, num computador com processador de 1.50 GHz.

Relativamente aos resultados obtidos para o balanceamento, considerou-se para a escolha da melhor solução, o maior valor da eficiência média e, simultaneamente, o maior número de postos de trabalho cuja eficiência é superior a 95,9%. Para estes critérios, concluiu-se que, como esperado, o Modelo B devolve melhores resultados, já que considera a eficiência dos postos. Já para os resultados obtidos para a afetação de recursos, concluiu-se que, dependendo do objetivo principal, a escolha pode recair sobre o Modelo D ou Modelo C, caso seja mais favorável maximizar o desempenho posto a posto, ou obter melhores resultados ao nível do desempenho global, respetivamente. Relativamente ao PIBLAR, concluiu-se que a abordagem de integração dos problemas, traduzida pela implementação do Modelo E pode ser mais benéfica em relação à implementação dos modelos de balanceamento e afetação de forma independente, em casos em que o balanceamento e a afetação sejam interdependentes. Esta situação ocorre, por exemplo, quando o número de colaboradores é igual ao número de postos de trabalho, e se pretende, não só potenciar a afetação dos recursos aos postos de trabalho, mas também, em simultâneo, melhorar a eficiência dos postos de trabalho, estando o balanceamento dos postos dependente das capacidades e das limitações dos colaboradores disponíveis. Deste modo, conseguir-se-á obter uma solução que adequa o balanceamento dos postos de trabalho aos diferentes colaboradores disponíveis tendo em conta as suas capacidades e limitações.

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Implementação de um algoritmo de análise multicritério numa empresa do ramo automóvel

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Descrição do problema

O trabalho que aqui se apresenta enquadra-se na definição e implementação de um plano de melhoria da Qualidade de uma empresa do setor automóvel, inserido no tópico de “redefinição de regras e standards”.

Face à necessidade de alocar novos colaboradores a determinado posto de trabalho, recorreu-se a um concurso interno para selecionar os colaboradores mais aptos para desempenhar novas funções na linha de inspeção final de veículos.

Numa situação inicial, constatou-se que a tomada de decisão relativamente à escolha de trabalhadores internos para um posto produtivo se baseava no conhecimento pessoal que as chefias possuíam desses mesmos colaboradores.

Com o objetivo de melhorar este processo de escolha, surgiu a necessidade de estabelecer critérios que permitissem selecionar os melhores candidatos. Através de várias sessões de brainstorming, juntamente com chefias diretas de produção e do responsável pela garantia da qualidade, foram estabelecidos os seguintes parâmetros a avaliar: (i) tempo de trabalho na empresa; (ii) período de trabalho em funções semelhantes; (iii) resultados dos últimos testes realizados; (iv) *multiskill* desenvolvida; (v) capacidade de comunicação e (vi) motivação.

Relevância do problema

Face a um desenvolvimento tecnológico acentuado nas últimas décadas, as empresas procuram cada vez mais obter vantagens competitivas, e pretendem, neste contexto, obter respostas rápidas e eficazes a problemas que surgem no seu quotidiano. Como tal, a indústria automóvel caracteriza-se por investir em processos otimizados e tecnologias mais rentáveis que permitam uma maximização do lucro a longo prazo.

Extrapolando para qualquer tipo de indústria, no seguimento do desenvolvimento empresarial, é necessário garantir o alinhamento e coerência das ações tomadas com os objetivos organizacionais. Com esse intuito, o processo cognitivo de seleção entre uma ou várias opções, por parte de um gestor, adquire cada vez mais uma importância fulcral.

Neste sentido, considera-se que uma forma objetiva de apoiar a tomada de decisão passa pela aplicação de algoritmos de análise multicritério onde são escolhidas determinadas opções em detrimento de outras, com fundamentação racional.

Por consequência, a existência de concursos internos promovidos por parte das empresas representa um método de seleção cada vez mais frequente, uma vez que significa a criação de valor para a própria empresa, investindo no desenvolvimento e formação das pessoas.

Metodologia

De forma a atingir o objetivo de selecionar os melhores candidatos tendo em conta os critérios previamente definidos, decidiu-se aplicar um algoritmo de análise multicritério, nomeadamente o algoritmo TOPSIS.

Esta escolha deve-se ao facto de o algoritmo apresentar um índice de performance para cada candidato, ter em conta a proximidade à solução ideal e a distância à pior solução, ser um modelo racional que não obriga à utilização da mesma escala de valores para os diferentes critérios, e as etapas do algoritmo não dependerem do número de candidatos/critérios (1)(2). Não obstante, a complexidade computacional não originou tempos de execução do algoritmo que pusessem em causa o prazo para a tomada da decisão.

Os principais ganhos inerentes à aplicação do algoritmo TOPSIS passaram por obter o melhor candidato possível, tendo em conta os critérios previamente seleccionados, assim como desenvolver uma ferramenta capaz de replicar a utilização deste algoritmo em diferentes tipos de problemas.

Resultados

A aplicação deste método refletiu-se num programa desenvolvido em Microsoft Excel, utilizando um vasto conjunto de macros resultantes da programação em VBA, onde foram implementadas as etapas necessárias para elaborar o algoritmo.

Como tal, o utilizador deste programa apenas tem de seleccionar o número de candidatos e critérios a avaliar, preencher o peso de cada critério assim como a preferência relativamente a cada um deles (maximizar ou minimizar). Após este preenchimento, o utilizador escolhe a opção de “Calcular” e automaticamente é gerado um índice de performance para cada candidato, sendo sinalizados a uma cor diferente aqueles que apresentam os três melhores. Na figura 1 está representado um exemplo de uma utilização do programa (com valores meramente ilustrativos).

Candidatos	Critérios	Matriz de seleção de candidatos segundo algoritmo TOPSIS							CALCULAR	APAGAR VALORES	
6	7			Critério 1	Critério 2	Critério 3	Critério 4	Critério 5	Critério 6	Critério 7	
				x1	x2	x3	x4	x5	x6	x7	
				0,1	0,3	0,2	0,1	0,1	0,1	0,1	
			Pesos	Max	Max	Max	Max	Max	Max	Min	
	Rank	Performance	Preferência								
	2	0,572483398	Candidato 1	a	1	4	7	7	8	6	9
	4	0,320329841	Candidato 2	b	0	5	8	8	8	5	8
	3	0,399558668	Candidato 3	c	0	4	8	8	8	8	4
	1	0,689594081	Candidato 4	d	1	5	7	7	8	4	5

Figura 1: Exemplo de utilização do programa desenvolvido

O desenvolvimento deste programa dotou a empresa de uma ferramenta que se revelou versátil e que acabou por ser útil, não só relativamente ao objetivo inicial de seleção de colaboradores, mas também para outros fins, tendo mesmo sido utilizada para um outro projeto de seleção de fornecedores. É de realçar que o nível de sucesso da aplicação deste método depende sempre do facto de os critérios seleccionados por parte da empresa serem os mais relevantes para a decisão em questão.

Futuramente, com o desenvolvimento de KPI que permitam avaliar a qualidade das decisões, poderá aferir-se o impacto, a longo prazo, deste tipo de algoritmo numa organização.

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Operational Research Models for Kitting Systems in the Warehouse of the Future

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Problem description

The automotive sector faces increasing challenges and opportunities in the current industrial landscape, where mass customization and the integration of advanced technologies stand out as fundamental drivers. This industry plays a crucial role in the economic growth of the European Union (EU) and given the high investment capacity and innovation capacity of other regions and significantly lower labor costs, it is essential for the third largest transformative industry in Portugal to develop projects and initiatives that accelerate innovation and technological progress in the sector.

Problem relevance

Although the automotive industry is one of the most advanced in the field of robotics, with a strong tradition in production automation, picking and kitting processes are still predominantly carried out by operators, which has three considerable consequences: higher margins of error, resulting in constraints on production lines; lack of information to understand and remedy the failure, decreasing the operational efficiency; increased risk of injury to the operators involved in this operation and dependence on the variability associated with the human labor. The limited automation of picking and kitting processes is mainly due to (i) the complexity underlying a broad and diverse range of possible combinations of components/parts due to the increasing trend of mass customization in automotive production, (ii) the high diversity of parts/components (and their suppliers) in each industrial unit, and (iii) the complexity and variability of the characteristics of the parts to be handled and included in the kits, due to their geometric shapes and physical-mechanical characteristics.

Within this context, robotic systems applied to the kitting process emerge as a crucial research area and it becomes critical to conduct an efficient process mapping study of the operations capable of automation, as well as to define new strategic approaches or technological solutions that can streamline the most complex processes and thus provide significant gains in terms of productivity and competitiveness on the factory floor, freeing up operators for more demanding and higher value-added tasks.

Methodology

The foundation of this work lies in a thorough understanding of the conditions that determine the success of hybrid kitting systems. It proposes innovative hybrid strategies that effectively overcome these challenges, identifying essential research questions associated with automated and collaborative kitting operations design. The methodology to address this relevant issue resorts on quantitative modeling of the operations inherent in the kitting process through Mixed-Integer Programming (MIP) models (1).

The layouts of Asynchronous and Sequential Hybrid Kitting Systems are presented and analyzed in detail, exploring the developed MIP models aiming for optimized component allocation to minimize the total cycle time of the process. The application of these models is validated with accurate data from an automotive manufacturer located in Portugal, providing an in-depth assessment of the impact of various critical parameters, such as the batch size, the total number of SKUs, and parameters related to the different bins and components present in the warehouse. It also considered parameters related to robotic kitting, collaborative kitting, and parameters related to the tigger train.

The models incorporate the pick-to-light system to support human operators in the component picking process, enhancing human picking efficiency and taking into account the inherent processes in this system, but also the inclusion of the time required to send kits to the Border of Line (BoL) ensuring that the entire kitting process is comprehensively captured, from assembly to delivery of kits.

Results

Results highlight the effect of batch size, with a tendency for a 10% increase in total cycle time for each unit increase in batch size for larger batch sizes; regarding the impact of errors in the picking process, it showed that a higher value leads to an increased allocation of components to the collaborative area, resulting in longer cycles. The results related to the simultaneous picking parameter showed that having a higher number of components picked simultaneously by operators significantly reduces cycle times. Additionally, the impact of the number of Autonomous Mobile Robots (AMRs) and operators in the kitting areas was examined, revealing that allocating an additional operator provides more competitive advantages in total cycle time than adding another AMR.

For a detailed analysis of each system, various scenarios of component allocation between kitting areas are explored, elucidating that optimal component allocations (obtained from the models) result in shorter cycle times, with a slight advantage for the Sequential system. Finally, the relationship between the energy consumption of Automated Guided Vehicles (AGVs) and kitting operations in a fully automated area is investigated, presenting opportunities to minimize this consumption through an Integer Programming model.

The contributions of this project empower industry decision-makers to choose kitting systems aligned with their objectives, whether emphasizing kit preparation quality through the implementation of the Asynchronous Hybrid Kitting System or considering a faster assembly line-like approach for kit preparation through the proposed Sequential Hybrid Kitting System. The developed models introduced several innovations, advancing upon existing literature, in studying the impact of the AMRs and Human operators allocated to the kitting area; in introducing a new approach to modeling the distances traveled by pickers along the storage racks, offering a more accurate representation of the real-world operational dynamics; in considering evacuation time for empty bins, the AGV travel time and the gripper changing time for both the AMR and the manipulator.

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Sustainability of cutting and packing problems: beyond waste minimization

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Problem description

Cutting and Packing (CP) problems are challenging combinatorial optimization problems that have many relevant industrial applications and arise whenever a raw material must be cut into smaller parts while minimizing waste, or products must be packed, minimizing the empty space.

Two-dimensional rectangular guillotine Single Large Object Placement Problems (SLOPP) are problems of output value maximization type. They consider a single large object of length L and width W , which is not sufficient to accommodate all the small items. Each item has fixed minimum and maximum quantity requirements and is associated with a value v that may or may not correspond to its physical area. Thus, the goal is to select a subset of the small items with a maximum total value to be packed into the large object.

The challenge is to develop a mixed-integer linear programming (MILP) model for the two-dimensional (2D) rectangular CP problem, based on the Floating-Cuts model (1), integrating waste minimization and pattern complexity minimization under a multi-objective optimization framework. The goal is to deepen the study of the relevance of explicitly addressing the impact of the geometric complexity of cutting patterns on raw material consumption.

Problem relevance

The significance of addressing CP problems extends beyond mere waste reduction. Despite the prevalent inclination in various industries towards simplistic approaches for material cutting, the cutting patterns' complexity still needs to be explored within the existing literature to be applied in practice. Therefore, this new way of looking at these problems may trigger even better approaches, with the consequent economic and environmental benefits.

Methodology

Our study evaluated the complexity of cutting patterns based on the mathematical model implemented by the Floating-Cuts model for the general rectangular cutting problem (1). We assessed the complexity by adding specific constraints and adequately modifying the objective function of the general model. Through the development of various instances, we examined final cutting patterns by introducing different complexity indicators into the objective function and its related constraints. We used the GUROBI solver with Python as the programming language to obtain solutions. Below, we present the decision variable, objective function, and problem constraint related to controlling complexity associated with the "number of different item types in a pattern" in equations 1-3.

Decision Variable

$$\begin{aligned} \Delta_i &= 1, \text{ if item type } i \text{ is cut from the cutting pattern} \\ \Delta_i &= 0, \text{ otherwise; } i = 1, \dots, n. \end{aligned} \tag{1}$$

Objective Function

$$\text{Maximize } (1 - \text{weight}) \cdot \sum_{i=1}^n \sum_{j=1}^m v_i \cdot (s_{ij} + t_{ij}) - \text{weight} \cdot L \cdot W \cdot \sum_{i=1}^n \Delta_i \tag{2}$$

Constraint

$$\Delta_i \geq \delta_{ij}, \forall i = 1, \dots, n; \forall j = 0, \dots, m. \tag{3}$$

Where L and W are respectively the length and the width of the large object; m the number of sub-rectangles j that can be cut from the large object through vertical or horizontal guillotine cuts; n the number of different item types i ; v_i is the value of item type i ; s_{ij} and t_{ij} are respectively the number of items of type i placed side by side (horizontally) and on top of each other (vertically) in the cutting pattern; δ_{ij} is a binary decision variable which is equal to one if an item of type i is assigned sub-rectangle j and zero otherwise.

The binary decision variable (1) represents whether item type i is cut or not from the cutting pattern. The objective function (2) balances maximizing the values of items assigned to the rectangular plate with controlling the complexity associated with the "number of different item types in a pattern," where this balance is achieved by applying a weight factor. And the constraint (3) ensures that if an item type i is cut from the cutting pattern, then this item is also assigned a sub-rectangle.

Results

We performed several computational experiments to evaluate the performance of the model in terms of waste minimization and cutting pattern complexity. We can see in Figure 1 that by increasing the weight of complexity in the objective function, the number of different types of objects placed on the cutting pattern is reduced, but the packing density is lowered. Therefore, by changing the weights in the objective function, it is possible to achieve a trade-off between economic and environmental efficiency. The example shown has a large object with $W = L = 100$ cm and $n = 25$.

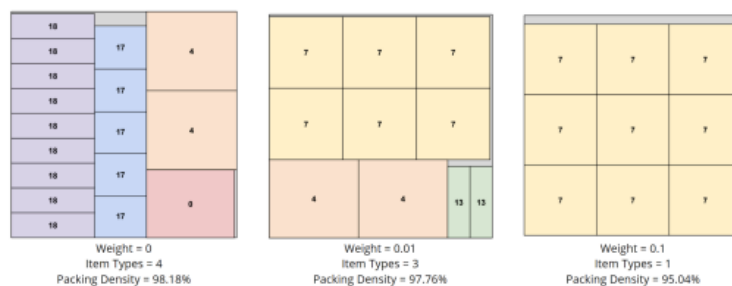


Figure 1 – Optimal cutting patterns obtained for different weights applied to the objective function.

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