5th CONFERENCE ON

SUSTAINABLE SUPPLY CHAINS

Graz

July 3-5, 2025

BOOK OF ABSTRACTS

UNIVERSITY OF GRAZ

CONFERENCE PROGRAM

	Friday, 04.07.2025	
	Room A	*Room B*
Session 1	***Food Supply Chains***	***Game Theory for Circular Supply Chains and Sustainability***
	Aquaponics-Based Sustainable Food Production Network – Stefan Killian	Who Leads the Way? Buyer vs. Supplier Initiatives in Supply Chain Carbon Footprint Reduction - Elif Kuscu
	Optimizing Agri-Food Supply Chains: A literature review of future research perspectives - Sonia Alikhah	Incentivizing Supplier Repair Efforts for Circular Supply Chains - Wenjie Tu
	Optimizing local food supply chain operations: Insights from theory and practice - Christian Fikar	A Game-Theoretical Approach to Design Contracts for OEMs to Incen,vize End-of-Life Service Provider Partnerships in A Circular Economy - Meihui Jiang
Session 2	***Interdisciplinary approaches towards Sustainability and Circular Supply Chains***	***Sustainability in transportation networks***
	Decision-Making in Circular Supply Chains for Returned Used Products: A Synergy of RL and DES - Elmar Steiner	Expediting in a supply chain with Markov-modulated transport delays - Hannah Yee
	Enhancing Supply Chain Sustainability and Transparency through Spatial Knowledge Graphs - Leonie Engemann	Battery Replenishment and Repositioning Problem in Electric Barge Networks - Rob Zuidwijk
	Make-to-Order Production with Sustainable Content under the Flexibility of a Mass-Balance-Approach - Felix Papier	Optimizing raw material sourcing in electric vehicle battery supply chains under social sustainability considerations - Lea Franze

	Saturday, 05.07.2025	
	Room A	*Room B*
Session 3	***Designing sustainable supply chains***	***Tackling the multi-criteria of Sustainability***
	Design matters: Consumer preferences for the design of a subsidy scheme for the use of repair services - Iris Etzinger	How to measure the efficiency and sustainability of symbiotic supply chains? - Vânia Filipa Barbosa Veloso
	Designing Cost-Efficient and Resilient Hydrogen Supply Chain Networks for Aviation: A Multi-Period Optimization Approach - Akin Ögrük	Addressing Multiple Dimensions of Sustainability and Uncertainty in the Design of Novel Biochar Supply Chains for Electric Steelmaking - Damiana Chinese
	Sustainable Mining Supply Chain Optimization - Linda Javiera Canales Bustos	Environmental and operational optimization of Central Sterile Supply Departments in Danish and German hospitals - Lukas Meßmann
	Competition for used apparel acquisition between charities and for-profit organizations - Sabrina Rosa Rinder	Fit-for-purpose water reuse in water stressed supply chains: A case study on the textile and apparel industry - Bruna Mota
Session 4	***Boundaries for Sustainability***	***Sustainability in Vehicle Routing***
	Fairness, Wages, and Data Quality in the Human AI Supply Chain - Charles Corbett	Reducing Emissions: The Energy Saving Potential of Weight Consideration in Vehicle Routing Problems - Soo Youn Kwon
	Conditions for sustainable platinum mining: Insights from artisanal and small-scale mining in Colombia -Juan Sebastián Lara-Rodriguez	A fast approximate scenario addition method and its application to the two-stage robust green location routing problem - Johannes Kager
	Creating Impact: A Cross-Functional Perspective on Sustainability Management - *Tobias Breitenbach*	Towards diesel-free logistics: economic and environmental fleet mix optimisation for refrigerated vehicles - Andrea Tuni

SESSION: FOOD SUPPLY CHAINS

Title: Aquaponics-Based Sustainable Food Production Network

Presenter: Stefan Killian

Co-Authors: Thomas Felberbauer, Pamela C. Nolz, Jamilya Nurgazina

Resilient, efficient, and sustainable food production systems are the vital structures of modern economy and society. Due to climate change and global population growth, innovative, efficient, and sustainable food production systems are urgently needed. Decentralized vertical farming can enable resource use efficiency and productivity of food production systems in controlled environments. Such systems include alternative food production approaches – aquaponics systems – which are circular, soil-less, and water-grown vertical systems designed to produce fish, plants, and vegetables in a controlled environment.

We investigate an aquaponic production network in Austria with a simulation model considering different aspects such as energy efficiency, resource usage, profitability, and cascadic factors, e.g., waste minimization. To enable product provenance and food supply chain transparency, a distributed ledger- and Internet of Things-based digital framework is developed that enables efficient information exchange and evidence on food quality and sustainability to end consumers and other stakeholders in the supply chain.

We will compare different scenarios of the production network with varying scales in Austria and globally and present computational results and managerial insights. This work is supported by the EDEN project No.897774 funded by the Austrian Research Promotion Agency (BMK).

Keywords: aquaponics; circular economy; sustainable food supply chain

---

Title: Optimizing Agri-Food Supply Chains: A Literature Review of Future Research Perspectives

Presenter: Sonia Alikhah

Co-Authors: Mehdi Sharifyazdi, Andreas Rudi, Frank Schultmann, Vahid Nokhbeh

Agri-Food Supply Chains (AFSCs) face critical challenges impacting global food security and environmental sustainability. With 30% of food wasted annually, contributing 8-10% of global greenhouse gas emissions, optimizing AFSCs is crucial. These supply chains must address issues like product perishability, demand uncertainties, climate variability, and complex logistics. Despite numerous optimization approaches, many models fail to adequately address the complex interdependencies between supply chain stages. Limitations include focusing on isolated stages and limited integration of critical decision variables. This research reviews recent advancements in Operations Research (OR) applications to AFSCs, emphasizing integrated planning models to enhance food security, sustainability, and efficiency. With global food

demand projected to rise by 35-56% by 2050, this work is essential for addressing challenges posed by population growth and environmental uncertainties. Key findings reveal emerging trends in AFSCs, including multi-objective optimization balancing economic, environmental, and social factors, and increased use of stochastic optimization to manage uncertainty. Future research should focus on developing stochastic and machine-learning mathematical frameworks to improve efficiency and models integrating different planning horizons and supply chain stages. This study synthesizes research, identifies trends, and creates a roadmap for optimizing and implementing these models in the real world, emphasizing OR as a driver of efficiency, resilience, and sustainability in global food systems.

Keywords: Sustainable Supply Chain, Food, Operation Research, Agri-Food Supply Chains

---

Title: Optimizing Local Food Supply Chain Operations: Insights from Theory and Practice

Presenter: Christian Fikar

Co-Authors: Christine Mendoza Pardo, Suad Saliju

Since the last Conference on Sustainable Supply Chains, we have worked with two rural regions in Bavaria, Germany, which are aiming to improve their logistics operations to increase the share of regional food in the hospitality sector and communal catering. This talk provides insights from both theory and practice on common challenges faced within such initiatives, particularly focusing on inefficiencies resulting from a lack of digitalization and inefficient logistics solutions. Within the project, a model-driven decision support system combining agent-based simulation with metaheuristic vehicle routing procedures was developed and planning tools were provided to the project partners to run real-world trials. A particular focus was set on evaluating the initiatives' desires to build a local food hub to improve the consolidation of shipments. Results show that rather than building new hubs, local food initiatives should focus on utilizing existing resources more efficiently by strengthening both horizontal and vertical cooperation within short food supply chains. Furthermore, introducing digital logistics platforms can help to lower organizational hurdles and improve operations.

Keywords: Short Food Supply Chains; Food Logistics; B2B; Simulation Optimization

SESSION: INTERDISCIPLINARY APPROACHES TOWARDS SUSTAINABILITY AND CIRCULAR SUPPLY CHAINS

Title: The shift to a circular economy necessitates circular supply chains to reprocess used products efficiently

Author: Elmar Steiner

The shift to a circular economy necessitates circular supply chains to reprocess used products efficiently, with strategies like repair, spare parts scavenging, refurbishment, and recycling forming crucial components of closed-loop systems. The intricacy of these processes is compounded by uncertainties in returned goods' quantity, quality, and timing, alongside interdependencies among reprocessing options. Traditional optimization approaches struggle with the complexity of disposition-inventory decisions in reverse supply chains. This study introduces a novel data-driven model utilizing reinforcement learning (RL) to enhance decision-making for reprocessing used products, with a focus on short-term operational decisions. We design a stylized model representing a complex decision-making environment and propose an innovative approach to integrate discrete event simulation (DES) and RL. Simple submodels derived from this complex model are implemented using DES and evaluated within the RL-DES environment, allowing stepwise assessment. Findings indicate that the chosen modular RL-DES approach aligns well technically, enabling rapid adaptation of the optimized simulation model. Results are comparable to a naive grid-search method, with less than a 3% profit gap and a runtime increase of less than double for the more complex submodel. This study addresses challenges such as limited real-world data availability, the need for a versatile approach, and scalability for real-world applications by introducing a modeling approach integrating DES and RL, generating artificial simulation data to overcome data scarcity. Additionally, viability and scalability are demonstrated using simple submodels. While promising, the study emphasizes the importance of careful parameterization even in simple models.

Title: Enhancing Supply Chain Sustainability and Transparency through Spatial

Knowledge Graphs

Presenter: Leonie Engemann

The complex global supply chains are increasingly facing challenges from geopolitical instability, protectionism, climate change, and evolving regulatory requirements such as the German Supply Chain Due Diligence Act (LkSG) and the European Corporate Sustainability Due Diligence Directive (CSDDD). This study introduces Spatial Knowledge Graphs (SKGs) as a novel approach to tackle these challenges by integrating supply chain, environmental, and risk data for improved analysis and visualization in order to facilitate informed decision-making.

The study is based on a case study of a large German backpack manufacturer. The company's supply chain data is linked to environmental and geopolitical risk indicators to enable a detailed analysis of critical supply chain dynamics. Entities such as factories, materials and

suppliers are modelled in a graph-based structure that captures their relationships across multiple supply chain levels. This structured approach enables a comprehensive analysis of dependencies, vulnerabilities and risks within the supply network. Key methods of analysis include centrality and cluster metrics, which enable the identification of critical nodes and clusters, and dynamic risk monitoring to assess the impact of external disruptions, such as extreme weather events, on the resilience of the supply chain. By integrating data on environmental and social aspects, the framework further supports the tracking of compliance with international sustainability regulations.

Results highlight the ability of SKGs to improve transparency and traceability while supporting agile risk management strategies. Visualizations and analytics reveal critical nodes and material dependencies across all supply chain stages, thereby offering the basis for analysing the state of resilience and to derive a risk mitigation strategies. Combined with regional data on the environmental and social performance, these insights empower companies to adapt their sourcing strategies and enhance supply chain sustainability.

By providing a holistic view of supply chain dynamics and fostering proactive risk mitigation, this work demonstrates the transformative potential of Spatial Knowledge Graphs in building resilient and sustainable supply chains, equipping companies with tools to navigate increasingly uncertain global markets.

Title: Make-to-Order Production with Sustainable Content under the Flexibility of a Mass-Balance-Approach

Presenter: Felix Papier

Co-Authors: Mohsen ElHafsi, Jim Shi

Producers increasingly have to guarantee a minimum share of sustainable content (SC) in the products they sell, for example, recycled or bio-sourced. The procurement of sustainable material is often subject to higher uncertainty compared to sourcing virgin material. For example, for post-consumer recycled plastics (PCR), the producer has to buy recycled plastics from many, typically small recyclers, whose output volume and pricing are often volatile. Furthermore, the production processes of material producers are intertwined, and sustainable content is mixed with non-sustainable content during production. Therefore, producers typically use the mass-balance approach (MBA), which leaves freedom to the producer to allocate (virtually) the SC to end products, under the condition that the total allocated SC amount in the end products does not exceed the total SC amount sourced. This feature renders the dynamics of the MBA different from traditional inventory management. For example, the manufacturer can 'anticipate' the use of SC content within the same time period, under the condition to have the required quantity sourced at the end of the period.

In this paper, we analyze how a producer can use the MBA to better serve clients with a product that has a minimum SC. We are interested in the interplay between the flexibility the MBA provides and the difficulty to source SC from a volatile supply market. We show that the optimal policy exhibits a double-threshold structure, and that managers can leverage the MBA to lower their inventory and to mitigate the adverse effects of supply market volatility.

SESSION: DESIGNING SUSTAINABLE SUPPLY CHAINS

Title: Sustainable Mining Supply Chain Optimization

Presenter: Linda Canales-Bustos

Co-Authors: Ana Barbosa Póvoa

The mining industry plays a pivotal role in the global energy transition, which is essential for achieving net-zero carbon emissions. As the backbone of renewable energy technologies, mining supplies critical minerals indispensable for clean technology production. Consequently, the demand for these minerals is projected to increase substantially. However, driving the energy transition presents significant challenges for this industry, including high energy consumption, reliance on fossil fuels, substantial technological investments, supply chain complexity, and environmental and social impacts. This research aims to address these challenges by optimizing the mining supply chain to enhance efficiency and sustainability amid increasing mineral demand. By integrating clean technologies, the study seeks to reduce carbon emissions and improve energy efficiency. Given the high capital investments required, long-term planning for the mining supply chain is proposed to ensure economic viability and sustainability, considering the industry's economic, social, and environmental impacts. An optimization model for long-term mining supply chain planning, encompassing multiple echelons, periods, and products, is presented. A case study of the Chilean mining industry is conducted, providing an analysis of the energy transition challenges faced by this sector. By offering a decision support tool for mining sector decision-makers, this work aims to help transform the mining industry towards sustainability and facilitate the global energy transition.

Keywords: Sustainable supply chain, Optimization model, Energy transition, Mining industry, Decarbonization.

Title: Designing Cost-Efficient and Resilient Hydrogen Supply Chain Networks for Aviation: A Multi-Period Optimization Approach

Presenter: Akin Ögrük

Co-Authors: Christian Thies

Hydrogen-based propulsion concepts for aircraft are seen as a promising solution toward the decarbonization of aviation. As the development of corresponding aircraft models progresses, critical questions surrounding the green hydrogen supply network have emerged. This study tackles the hydrogen supply chain network (HSCN) design problem for the aviation sector through a multi-period mixed-integer programming (MIP) model. The objective is to minimize the total cost of the hydrogen supply network by balancing strategic decisions (e.g., supplier locations, capacities, and transportation infrastructure) and operational decisions (e.g., hydrogen flows and storage quantities) across multiple periods. The model incorporates spatial and temporal variations in hydrogen supply and demand, accounts for techno-economic characteristics of storage, liquefaction, and transportation (e.g., economies of scale), and addresses

specific characteristics for hydrogen handling (e.g., losses). The application is demonstrated using German airports, evaluating both local production and economically viable hydrogen import options, while factoring in the projected European Hydrogen Backbone pipeline and underground storage infrastructure. These considerations allow the model to reflect realistic constraints, opportunities, and costs associated with the hydrogen supply chain, making the results more applicable to real-world scenarios. Optimal network designs and results are presented and analyzed for various hydrogen supply and demand scenarios. Additionally, the outcomes of the multi-period model are briefly compared to those of an earlier single-period approach. The findings provide valuable insights into the cost-efficient and resilient design of HSCN, addressing the evolving needs of the aviation sector through dynamic, multi-period modeling.

Keywords: Supply Chain Network Design · MIP · Sustainable Aviation · Hydrogen

---

Title: Strategic Decision-Making for SSbD Products: A Two-Stage Stochastic Optimization Model

Presenter: Yael Perlman

Co-Authors: Sara Westreich

The Green Deal aims to drive a transition towards safer and more sustainable chemicals, materials, and products while fostering technological progress and ensuring health and environmental protection. To support this vision, the Chemicals Strategy for Sustainability and the Zero Pollution Action Plan emphasize the need for a paradigm shift towards prevention-based risk governance through the adoption of safe-and-sustainable-by-design (SSbD) principles. The SSbD approach proactively integrates five key dimensions—health, environment, social impact, economic viability, and functionality—into the early design stages of new chemicals, materials, and products.

In this paper, we analyze the optimal decision-making strategies of manufacturers producing SSbD-approved products, which are differentiated based on an SSbD index. We formulate this decision-making process as a two-stage stochastic programming problem: In the first stage, the manufacturer determines its resource allocation and production capacity to maximize expected profit under demand uncertainty. In the second stage, after uncertainty is resolved, the manufacturer optimizes production and pricing decisions while remaining constrained by prior investment choices.

Keywords: Sustainability, Safety, Design; Optimization; Newsboy

---

Title: Design matters: Consumer preferences for the design of a repair subsidy

Presenter: Iris Etzinger

Co-Authors: Marc Reimann

Repair plays a crucial role in the circular economy, offering a sustainable alternative to fast consumption-disposal cycles. Despite its environmental and economic benefits, the use of repair services is declining. A key barrier is the (perceived) high cost compared to buying new products. Several European countries have introduced financial incentives to address this, with schemes differing in aspects such as cost coverage, application process, and funding source. Research suggests that consumer preferences vary across segments, but little is known about which design features resonate most. This study investigates 1) what the most preferred design of a subsidy scheme looks like and 2) how different consumer segments shape these preferences.

Using adaptive-choice-based conjoint analysis and a post-task questionnaire, we surveyed a representative sample of Austrian citizens. Participants evaluated hypothetical financial incentive schemes differing in aspects like funding level, application process, payment modality and participating repair shops. Preliminary findings show that funding height is by far the most important attribute, while the choice of participating repair shops is least relevant. Familiarity with existing schemes increases preference for similar designs, indicating a framing effect. Socio-demographic differences are evident: higher-educated respondents prefer fixed budgets, while lower-educated favour unlimited ones. Highincome participants strongly reject carbon tax funding; lower-income groups prefer higher subsidy levels, especially full cost coverage. Insights into design preferences can guide policy decisions in the context of the new Right-to-Repair legislation, making subsidies more effective and helping to mainstream repair in society.

Keywords: Repair, financial incentives, design, conjoint, consumer segments

---

Title: Competition for Acquisition Between Non-Profit and For-Profit Organizations in the Resale Used Apparel Market

Presenter: Sabrina Rosa Rinder

Co-Authors: Marc Reimann, Gilvan C. Souza, Guido Voigt

There is increased competition for the acquisition of used apparel from consumers as more for-profit organizations (FPOs) are entering a market that has been dominated by charities. Our research focuses on the competition between charities and FPOs. Specifically, we study how consumers' used apparel return decisions are impacted by (1) the organizations' social orientation, (2) the financial reward level, and (3) the convenience level.

We conduct incentivized discrete-choice experiments in a laboratory. Participants bring one piece of used apparel that they no longer need to the lab, and then decide whether to give their used apparel to a charity, to an FPO, to the residual waste, or to take it back home. The alternatives differ in terms of financial rewards, information about the organizations' social activities, and convenience. Using a multinomial logit model, we find that financial rewards

significantly impact consumers' return decision for both FPOs and charities. Further, charities can significantly influence consumers' return behavior in their favor by increasing convenience levels. This is not true for FPOs, which have to combine convenience with the provision of information on their social activities to significantly impact consumers' return behavior. Consumers with a higher moral identity are not likely to return used apparel to either a charity or a FPO unless the residual value of their used apparel is high enough.

SESSION: BOUNDARIES FOR SUSTAINABILITY

Title: Fairness, Wages, and Data Quality in the Human AI Supply Chain

Presenter: Charles J. Corbett

Co-Authors: Martin Gonzalez Cabello, Auyon Siddiq

Digital supply chains, including those that support artificial intelligence (AI), share notable similarities with physical supply chains – including multiple levels of outsourcing, reliance on low-wage labor, and limited transparency – raising ethical concerns about upstream labor conditions. Through a survey of workers on a major digital labor ("crowdwork") platform, this presentation will address some of the factors that shape workers' perceptions of fair treatment and examines how platform design can influence worker welfare. Drawing from physical supply chains, it provides guidance for managers on how to promote responsible labor practices in digital supply chains. The presentation will also describe some results from an analytical model linking data quality to wages offered, suggesting that some of the effects of increasing wages are not immediately intuitive.

Keywords: crowdwork, data quality, fairness, welfare, supply chain

---

Title: Conditions for Sustainable Platinum Mining: Insights from Artisanal and Small-Scale Mining in Colombia

Presenter: Juan Sebastián Lara-Rodríguez

Co-Authors: Morgane M.C. Fritz

This article examines the necessary conditions for sustainable artisanal and small-scale Platinum mining (ASPM) in Colombia as a critical raw material (CRM). Hypothesising the environmental, social, economic, and institutional dimensions based upon the Sustainable Development Goals (SDGs) frame, we employ generalized and ordinary least squares to analyze variables within each dimension that impact ASPM. Through legal instruments, we gathered comprehensive data from mining authorities regarding extraction, formalization, and miner registration across 1,122 municipalities throughout the 2010s. Our findings reveal multifaceted associations across dimensions: in the environment, whilst illegal gold mining shows a positive causal effect on ASPM, coca cultivation displays varying impacts. In the social dimension, higher multidimensional poverty has a significant positive effect on platinum extraction, while violence exhibits a negative causal bond. In the economic dimension, both infrastructure improvements and rural technological progress have significant negative effects on ASPM activity. In the institutional pillar, higher corruption levels show a positive causal link with extraction, whilst armed illegal groups display divergent effects - FARC-EP rebels relate negatively to production, while paramilitary presence connects positively. These findings underscore that sustainable ASPM requires coordinated interventions: strengthening environmental enforcement, addressing poverty whilst improving security, developing infrastructure and rural technification for formalization, and implementing anticorruption measures alongside

peacebuilding efforts. This case could enhance both local development and global CRMs supply diversification originating from artisanal and small-scale mining (ASM).

Keywords: Critical raw materials; Sustainable development goals; Artisanal and small-scale mining; Platinum

---

Title: Creating Impact: A Cross-Functional Perspective on Sustainability Management

Authors: Moritz Fleischmann, Philip Joos, Benjamin Maury, Elfriede Penz, Tobias Breitenbach

External and internal stakeholders are increasingly holding companies accountable for the impact of their business activities on both stakeholders and society at large. Most prominently, they demand that business practices be sustainable. To transition towards sustainability, companies are using a variety of levers in multiple business functions, including finance, accounting, marketing, and operations. Similarly, scholars in these fields are investigating approaches to sustainability. However, this research largely takes a siloed, monodisciplinary perspective, even though the measures available in different functional areas are clearly and strongly interconnected. Many scholars have pointed out this deficit and have called for more interdisciplinary research on sustainability.

With this paper, we intend to respond to this call and contribute to developing more holistic approaches to sustainability management. Specifically, the paper aims to provide an overview of relevant interdependencies among sustainability levers in major functional areas. We start by reviewing the individual areas' sustainability approaches and summarizing their corresponding key levers for managing sustainability. We then systematically investigate the connections between these levers, deriving causal chains that link decisions over multiple steps to sustainability impact. This provides insights into interdependencies that current research largely treats as black boxes. We then synthesize our findings in a framework that maps available levers and their interconnections. This framework is intended to serve as a basis for aligning decisions across a firm's functional areas, thereby allowing appropriate trade-offs and, eventually, maximizing sustainability impact.

SESSION: GAME THEORY FOR CIRCULAR SUPPLY CHAINS AND SUSTAINABILITY

Title: Who Leads the Way? Buyer vs. Supplier Initiatives in Supply Chain Carbon Footprint Reduction

Presenter: Elif Kuşcu

Co-Authors: Özgen Karaer, Tarkan Tan

Reducing supply chain emissions has become critical for firms facing growing regulatory and consumer pressures, particularly as downstream partners exhaust internal opportunities for emission reduction. Supply chain collaboration is essential to address the substantial improvement potential where resources and responsibilities are unevenly distributed.

We analyze two supply chain collaboration models—Buyer-Led and Supplier-Led—using game-theoretic modeling within a setting where the buyer (he) bears a carbon price and the supplier (she) controls most of the product's carbon footprint. The supplier, as the producer, invests in reducing the product carbon footprint, while the buyer, as the downstream partner, may incentivize the supplier. In the buyer-led collaboration, the buyer offers a wholesale price premium rate contingent on carbon footprint improvement, and the supplier decides her emission reduction efforts accordingly. In the supplier-led collaboration, the supplier proposes an investment cost split and, in turn, commits to a carbon footprint improvement level determined by the buyer.

Our analysis reveals that the supplier-led collaboration consistently reduces emissions and enhances both environmental and financial performance in markets with accessible and affordable technologies. However, the buyer-led collaboration proves critical in markets with limited technology access. Our findings offer actionable insights for managers to optimize collaboration strategies based on market conditions.

Keywords: supply chain collaboration; scope 3 emissions; supplier development; carbon regulations; game theory

---

Title: Incentivizing Supplier Repair Efforts for Circular Supply Chains

Presenter: Wenjie Tu

Co-Authors: Tarkan Tan, Nail Tahirov, Gizem Mullaoglu

Motivated by a collaboration with a leading firm in the semiconductor industry, this study examines the reverse supply chain for high-value optical components. The buyer, responsible for assembling and maintaining modular machines sold under service contracts, faces high spare parts turnover due to responsive maintenance obligations that require immediate on-site replacement of faulty modules. This practice leads to the accumulation of reusable, high-value failed components at off-site repair facilities. Due to limited in-house repair capabilities,

the buyer seeks to engage suppliers to repair these components, offering the potential to enhance circularity and cost efficiency by increasing the reuse of components for maintenance services. However, suppliers often prioritize producing and selling new components over repairs, creating misaligned incentives. This study explores the contract design to align supplier incentives with the buyer's reuse rate target, aiming to reduce maintenance costs and improve sustainability through repair and reuse. We model this interaction as a Stackelberg game, where the buyer compensates the supplier for repairs based on a pre-defined incentive structure, and the supplier adjusts repair proportions in response. We analyze various incentive structures to enhance supply chain performance, finding that well-structured incentives can achieve both cost-efficiency and sustainability goals.

Keywords: supply chain contracting, circular economy, game theory, sustainability.

Title: A Game-Theoretical Approach to Design Contracts for OEMs to Incentivize End-of-Life Service Provider Partnerships in A Circular Economy

Presenter: Meihui Jiang

Co-Authors: Rob Zuidwijk, Stef Lemmens, Morteza Pourakbar

The shift from product-selling towards Product-as-a-Service (PaaS) enables Original Equipment Manufacturers (OEMs) to retain product ownership, facilitating sustainable practices such as repair, refurbishment, and remanufacturing through product-return systems, achieving Circular Economy (CE) by improving reusing. With the increasing reliance on outsourced End-of-Life Service Providers (EoLSPs) for crucial operations, such as repair and refurbishment, the success of these systems depends heavily on the strategic design of contracts between OEMs and EoLSPs. These contracts influence the balance of control, autonomy, and motivation, ultimately determining the effectiveness of product-return systems. However, limited research has explored how to structure contracts to incentivize EoLSPs in this Circular Business Model (CBM) to achieve high service quality, operational efficiency, and sustainability goals.

This study employs a game-theoretical approach to analyze the interaction between OEMs and EoLSPs. Using empirical evidence from Dutch OEMs and EoLSPs, we developed a game-theoretical model to explore incentive mechanisms and control systems. We investigated optimal contract designs incorporating performance-based incentives, penalties, and revenue-sharing structures. The proposed model identifies strategies for optimizing mutual benefits, high-quality service delivery, operational alignment, and environmental sustainability.

This research provides actionable insights for practitioners to design contracts in product-return systems that strengthen OEM-EoLSP partnerships, advancing CBMs and achieving shared sustainability goals. The study also incorporates insights from empirical cases, highlighting real-world practices and gaps in current contractual arrangements. Additionally, it offers specific guidance for the electronics industry, where effective product recovery and lifecycle extension are critical to addressing E-waste and resource scarcity problems.

Keywords: Contract Design, Game Theory, Circular Economy, Circular Business Models, Product-Return

---

SESSION: SUSTAINABILITY IN TRANSPORTATION NETWORKS

Title: Expediting in a Supply Chain with Markov-Modulated Transport Delays

Presenter: Hannah Yee

Co-Authors: Heletjé van Staden, Robert Boute

Shifting from road transport to sustainable transport modes is an effective approach for decarbonizing freight transport. However, these modes are slower, depart according to a service schedule, and are prone to delays. Consequently, sustainable modes are less responsive to urgent transport needs, which hinders their usage in supply chain operations.

To address this, we investigate an expediting strategy in a supply chain that combines a sustainable transport mode with road transport for inventory replenishment. All replenishment orders initially depart using the sustainable transport mode. Shipments on the sustainable mode experience delays, where the probability of facing a delay is governed by a Markov process. An expediting terminal mid-route allows for selected units to be expedited using road transport. While road transport may be more expensive, it is also faster and less likely to face long delays. As such, expediting complements the lower speed and delays on the sustainable transport mode, increasing the responsiveness to urgent inventory needs.

The problem is formulated as a periodic review inventory model with the objective of minimizing cost. We propose a heuristic state-dependent base stock policy to determine the ordering and expediting decisions, using updated information about delays and inventory. Our results show that expediting reduces inventory costs, enabling a cost-effective usage of sustainable transport modes. We also find that a larger modal shift is achieved when using road transport only after the expediting terminal, instead of using it from the origin as in conventional dual transport mode solutions.

Keywords: Sustainable freight transport, dual transport mode, transport delays, inventory, expediting

---

Title: Battery Replenishment and Repositioning Problem in Electric Barge Networks

Presenter: Rob Zuidwijk

Co-Authors: Lavanya Meherishi, Pieter L. van den Berg

Electric barge propulsion in Europe has gained traction as a promising solution for reducing carbon emissions in inland waterway transport, with innovations such as swappable batteries taking center stage. This research addresses the battery replenishment and repositioning problem (BRRP) within a barge service network, focusing on the application of swappable battery containers in inland barge systems. To address range concerns, electric barges equipped with swappable battery technology can carry multiple battery containers in designated onboard docking stations, using only one battery at a time for power. This capability

introduces unique challenges relating to the various battery replenishment actions barges can undertake. Additionally, barges can transport extra battery containers as cargo to meet the replenishment needs of other barges in the network. Thus, the BRRP tackles the dual challenge of using battery containers as portable energy sources for barge propulsion and repositioning them to fulfill the energy requirements across the barge network. The study further explores the role of external modes, such as trucks, in the process of battery repositioning. We model the problem as an Integer Linear Program, with the overall solution strategy divided into two phases. From our numerical experiments, a strong interdependence between barge energy mobility and the design of repositioning services emerges. A key finding of this research is the trade-off between investing in additional batteries and repositioning them across the network. Ultimately, a combined approach using both trucks and barges for repositioning proves to be effective.

Keywords: Multimodal Freight Transport, Electric Barges, Battery Repositioning

---

Title: Optimizing Raw Material Sourcing in Electric Vehicle Battery Supply Chains Under Social Sustainability Considerations

Presenter: Lea Franze

Co-Authors: Karsten Kieckhäfer, Bruna Mota, Ana Barbosa-Póvoa

Driven by due diligence requirements, social sustainability has been receiving more attention in electric vehicle battery supply chains. Critical raw materials like cobalt and lithium, essential for battery production, carry significant social risks. Automotive companies address this by seeking sustainable supply sources, investing in mining projects, recycling batteries to recover raw materials, or engaging in supplier development. However, socially sustainable raw material sourcing is rarely studied in existing supply chain planning literature and often approached simplistically. To address this gap, we develop a novel approach for optimizing raw material sourcing and apply it to the supply chain of lithium-ion batteries for electric vehicles. Combining social life cycle assessment, activity analysis, and multi-objective optimization, our model determines optimal raw material sourcing strategies from multiple sites with varying costs and social risks for multiple periods, and evaluates where to implement supplier development measures to improve social risks. Three sourcing strategies are considered: long-term supply contracts, investments in mining projects, and investments in recycling plants. The net present value of these decisions is maximized in the economic objective function, while social risks (e.g., risk of child labor) are either limited by constraints or used as a second objective function. In a numerical experiment, we analyze how different objective functions impact sourcing strategies and the implementation of supplier development measures. We answer questions like: When is it economically beneficial to source from suppliers with high social risks and when to implement supplier development measures? When are investments in recycling plants economically and socially beneficial?

Keywords: Raw material sourcing, Multi-Objective Optimization, Social sustainability, Supplier development, Supplier selection

SESSION: TACKLING THE MULTI-CRITERIA NATURE OF SUSTAINABILITY

Title: How to Measure the Efficiency and Sustainability of Symbiotic Supply Chains?

Presenter: Vânia Veloso

Co-Authors: Ana Carvalho, Ana Barbosa-Póvoa

Industrial Symbiosis (IS) has been studied extensively, yet gaps remain in aligning its objectives with supply chain management (SCM) practices and measuring symbiotic relationships effectively. Prior research highlights the need for comprehensive indicators for sustainable industrial symbiosis networks (ISNs). Aviso et al. (2022) emphasize the importance of developing better indicators for sustainable ISNs, while Turken & Geda (2020) identify gaps in existing eco-industrial park measures related to urban waste, social welfare, and resource use reduction. Addressing these gaps is essential to ensure that IS initiatives contribute meaningfully to sustainable and efficient supply chain operations.

This study aims to develop a framework for assessing symbiotic supply chains (SymSCs) by identifying key IS objectives in SCM, such as resource efficiency, waste reduction, and collaboration. The framework will translate these objectives into key performance indicators (KPIs) that comprehensively measure SymSC sustainability and efficiency. The methodology involves qualitative data analysis using both deductive and inductive approaches to identify relevant KPIs, a Web-Delphi process with iterative surveys to reach consensus on SymSC objectives and KPIs, and focus groups engaging Delphi participants to validate findings and ensure industry alignment. Stakeholder insights, including those from academics, industry professionals, and policymakers, will be gathered via the Web-Delphi process and focus group meetings, ensuring diverse perspectives are incorporated into the framework.

The expected outcome is a validated performance assessment framework for SymSCs, outlining essential KPIs for sustainability and efficiency, grounded in academic literature and real-world case studies, and refined through stakeholder engagement.

Keywords: Industrial Symbiosis, Symbiotic Supply Chains, Performance Assessment, Sustainability Metric, Supply Chain Efficiency

---

Title: Addressing Multiple Dimensions of Sustainability and Uncertainty in the Design of Novel Biochar Supply Chains for Electric Steelmaking

Presenter: Nicola D'Andrea

Co-Authors: Damiana Chinese

The modern world relies on steel for infrastructure development, but its production is carbon intensive and accounts for 7–9% of global greenhouse gas emissions. The possibility of decarbonizing the steelmaking process by replacing fossil carbon with biocarbon from waste

biomass has been the subject of many studies. In particular, the techno-economic feasibility of replacing coal with biochar has been confirmed for scrap-based electric steelmaking, which is considered the lowest carbon emission technology route for steel production. However, supply chain risks and a lack of knowledge of procurement markets are recognized as major barriers to the integration of novel fuels into electric steelmaking. Appropriate supply chain design is a key step in overcoming these barriers. It involves quantitative modeling of alternative processing plant configurations, capacities, and efficiencies to determine the extent to which they affect the variety, cost, and availability of biomass feedstocks that can be used and consequently supply chain risks. Sustainable biochar supply chain design also requires the selection and proper assessment of environmental impact indicators, as the actual decarbonization benefits of biofuels are highly dependent on the location, time, and mode of harvesting and transport. This research contributes to the development of this topic by providing a systematic discussion of the relevant economic and environmental performance indicators relevant to the problem, by proposing a tailored hybrid approach based on CRITIC-TOPSIS MCDM methods and Monte Carlo simulation to evaluate and weigh such indicators, and by applying this approach to an actual European electric steelmaking case study.

Title: Environmental and Operational Optimization of Central Sterile Supply Departments in Danish and German Hospitals

Presenter: Lukas Messmann

Co-Authors: Robin Schlembach, Sebastian Schiffels, Axel Tuma, Jens O. Brunner

Central Sterile Supply Departments (CSSDs) play a critical role in the operation and for the overall environmental footprint of hospitals. Operationally, the batching of jobs and their scheduling and allocation to washer-disinfectors and sterilizers is a complex decision-making problem, with CSSDs being potential bottlenecks in surgery scheduling. Environmentally, CSSDs enable the reusing of surgical and other sterile equipment and thus help to reduce the environmental impacts of production and waste treatment associated with alternative disposable solutions. However, CSSDs themselves consume substantial amounts of electric and thermal energy, chemical cleaning agents, water, and disposable equipment. Critically, operational and various environmental objectives can be strongly conflicting. In this work, we develop a multi-objective two-stage batch-scheduling flexible flow shop optimization model of a CSSD, which is parameterized with German and Danish Life Cycle Assessment-based environmental data. The results underline the conflict between environmental objectives and especially the Total Completion Time. Compared with a real-world-oriented heuristic, a Pareto-optimal compromise solution could lower environmental impacts by more than 10%, the Total Completion Time by 5%, and the Makespan by about 1%. Furthermore, we explore the resulting environmental impacts for various scenarios, including differences in the impacts of a CSSD in Germany and Denmark and different steam generation alternatives. This study thus simultaneously provides insights into the optimization potential of CSSDs and contributes to the operational efficiency and sustainable transformation of hospitals.

Keywords: central sterile supply department; LCA; batch scheduling; multi-criteria optimization; sustainable healthcare

---

Title: Fit-for-Purpose Water Reuse in Water Stressed Supply Chains: A Case Study on the Textile and Apparel Industry

Presenter: Bruna Mota

Co-Authors: Eduarda David

Global water scarcity and pollution are intensifying due to rapid industrial growth, with the textile and apparel industry as a major contributor. Rising global demand, particularly in Asia, has shifted production to low-cost, water-stressed regions, exacerbating freshwater depletion. Fit-for-purpose industrial wastewater reuse offers a promising solution for sustainable water management in supply chains.

This study presents a multi-objective linear programming model for sustainable supply chain design, integrating wastewater reuse, inter-tier water exchanges, and regional water stress. Using a case study from the textile industry, the model supports strategic and tactical decisions, including supplier location, technology selection, water exchanges, and product flows.

The model considers four objectives: maximizing Net Present Value, minimizing freshwater consumption, reducing environmental impact measured through Life Cycle Assessment, and mitigating water impact by considering local water stress. A lexicographic multi-objective optimization is applied using the ε-constraint method.

Results suggest that relocating production to less water-stressed regions, combined with fit-for-purpose water reuse treatment technologies can decrease water impact by 84%, though at the cost of a 43% increase in overall environmental impacts. These findings highlight trade-offs in sustainable supply chain decisions and the role of wastewater reuse in reducing freshwater dependence.

Keywords: Sustainable Supply Chain Management; Multi-objective optimization; Industrial wastewater reuse

---

SESSION: SUSTAINABILITY IN VEHICLE ROUTING

Title: Reducing Emissions: The Energy Saving Potential of Weight Consideration in Vehicle Routing Problems

Presenter: Soo Youn Kwon

Co-Authors: Alexander Hübner

Heavy-duty vehicles (HDVs) are a significant source of greenhouse gas (GHG) emissions, accounting for approximately 6% of the European Union's total GHG. This paper seeks the potential to reduce GHG emissions from HDVs by optimizing routes for energy efficiency rather than distance minimization. An energy-minimization model is developed to consider factors such as payload and vehicle curb weight, both of which are critical considerations. In total, 1,680 instances were tested. This study challenges the commonly held assumption that minimizing distance results in energy efficiency. Our study results showed that incorporating energy in the objective function substantially decreases the energy needed compared to a pure distance minimization. The solutions frequently diverge from the distance minimization solutions. The energy minimization achieves energy savings of up to 11% with increased distance of up to 9%. Two of the factors that tend to affect the solution deviation the most are the GVWR and the vehicle capacity-to-curb-weight ratio.

Title: A Fast Approximate Scenario Addition Method and Its Application to the Two-Stage Robust Green Location Routing Problem

Presenter: Johannes Kager

Co-Authors: Marc Goerigk, Dorothee Henke, Fabian Schäfer, Clemens Thielen

In the location routing problem (LRP), the goal is to determine the location and size of facilities (warehouses), assign customers (stores) to opened warehouses, and plan delivery routes for vehicles while considering capacity constraints for both the facilities and the vehicles. The green variant extends this by incorporating greenhouse gas emissions into the objective alongside costs. We further assume the customer demands to be uncertain and to be given by a finite set of scenarios and model the problem in a two-stage robust optimization framework. In the resulting robust green LRP, strategic facility location decisions are made in the first stage, while operational assignment and routing decisions follow in the second stage once a demand scenario from the given uncertainty set has been realized.

This talk presents a new scenario addition method for two-stage robust mixed-integer programs with finite uncertainty sets and its application to the robust green LRP. Our method enhances existing approaches by leveraging dual bounds, imposing adaptive time limits, and incorporating gap propagation to allow for approximative solutions. Our results show that the proposed method significantly outperforms existing approaches, solving larger and more complex instances of the robust green LRP within practical time limits.

Title: Towards Diesel-Free Logistics: Economic and Environmental Fleet Mix Optimization for Refrigerated Vehicles

Presenter: Andrea Tuni

Co-Authors: Agustin Vergniaud, Silvia Poropat

EU companies are urged to reduce their logistics emissions to respond to upcoming environmental regulations. Updating the fleet mix can lower the environmental impact of road logistics, which remains key to ensure continuity in first- and last-mile transportation. The fleet mix decision needs to consider also the sustainability performance of refrigerators for temperature-controlled vehicles, which are extensively employed in food logistics.

This work thus aims to identify the optimal fleet mix of refrigerated vehicles for a supermarket chain, by minimizing operational costs and CO2e emissions, concurrently addressing economic and environmental objectives. A mixed-integer programming multi-objective model was developed and solved using the ε-constraint method. Five power generation systems for trucks and four refrigerator options were considered, while accounting for technical constraints of trucks-refrigerators combinations across three scenarios. The results identify the Pareto front of non-dominated solutions, highlighting an unbalanced trade-off between costs and CO2 emissions and demonstrating that alternative cost-efficient and environmentally-friendly solutions are available. 67.3% of the solutions on the Pareto front do not select LNG trucks and diesel refrigerators, obtaining a fossil fuel-free fleet. Refrigerator systems account for less than 20% of total emissions and their impact is more relevant in economically-oriented solutions.

This work contributes to the sustainable logistics literature by exploring the sustainable fleet mix optimization problem for refrigerated fleets, considering costs and CO2 emissions of both vehicle power generation systems and refrigerator operations. The work can guide practitioners to transition towards sustainable refrigerated fleets for road transportation, supporting the transition towards a low-carbon transport sector.

Keywords: fleet mix optimization, sustainable logistics, refrigerated vehicles, food supply chain

---