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Centre for Transportation and Logistics

INDIAN INSTITUTE of MANAGEMENT AHMEDABAD

ANNUAL REPORT 2023-24

Centre for Transportation and Logistics
INDIAN INSTITUTE of MANAGEMENT AHMEDABAD
विद्याविनियोगाद्विकास:

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Message from Co-Chairs

Dr. Debjit Roy
Ph.D. and MS (University of Wisconsin-Madison)
Intralogistics; Road and Oceanic Freight Transport
debjit@iima.ac.in | +91-79 7152 4823

Dr. Sandip Chakrabarti
Ph.D. (University of Southern California)
Sustainable transportation; Urban Transport Policy
sandipc@iima.ac.in | +91-79 7152 4949

The Indian Institute of Management Ahmedabad has a distinguished history of pioneering developments in research, practical application, and academics within the fields of logistics and transportation. CTL faculty members engage in robust research focusing on various aspects of logistics, supply chain and transportation sector. This includes exploring topics such as facility location, routing, warehousing, intralogistics, agri-logistics, public transportation planning, sustainable mobility, and policy caveats. The Centre aims to foster close connections with industry and government, tackling imperative challenges in policy and practice pertinent to the sector. CTL is actively immersed in addressing contemporary issues, such as developing streamlined strategies for Electric Vehicle (EV) operations and charging stations, utilizing big data to enhance mobility and safety, data analytics and productivity enhancement in supply chains, automation in warehousing, advances in maritime logistics & informatics, digitization in transportation, through its research and other initiatives.

The Centre hosted a one-day workshop on the emerging domain of 'Electric Vehicles and Smart Mobility', in 2023. The workshop included keynote talks, panel discussions, and research talks on multiple facets of smart and sustainable mobility by a panel of distinguished guests from industry, academia, and government. The workshop registered a significant turnout, with participation from both academicians and industry practitioners. Additionally, the Centre organized various research seminars, webinars and panel discussions throughout the past year, spearheaded by esteemed academicians and industry practitioners from around the globe. These distinguished guests delivered enriching talks on cutting-edge research, imperative scenarios, and innovative practices emerging in the ever-evolving realm of transportation & logistics. Throughout the year, CTL faculty members have made notable contributions in diverse transportation and logistics areas, including peer-reviewed research publications, white papers, thought leadership articles, research and consulting projects, and so on. Furthermore, our faculty's engagement in research and consulting projects has not only expanded our understanding of key limitations and possibilities in transportation and logistics but has also fostered valuable collaborations with industry stakeholders.

The Centre aims to advance in high-quality research while also supporting student-led projects and research initiatives pertinent to the transportation, logistics, and allied sectors. Through its various industry collaborations, projects, events, and other research outputs, the Centre remains steadfast in its purpose of identifying areas for improvement and refining strategies within the expansive field of transportation and logistics.

Centre Vision and Research Themes

Vision

To facilitate cutting-edge research in transportation, logistics and allied areas, and thereby contribute to scholarship, practice, and policymaking in India and abroad.

Centre Overview

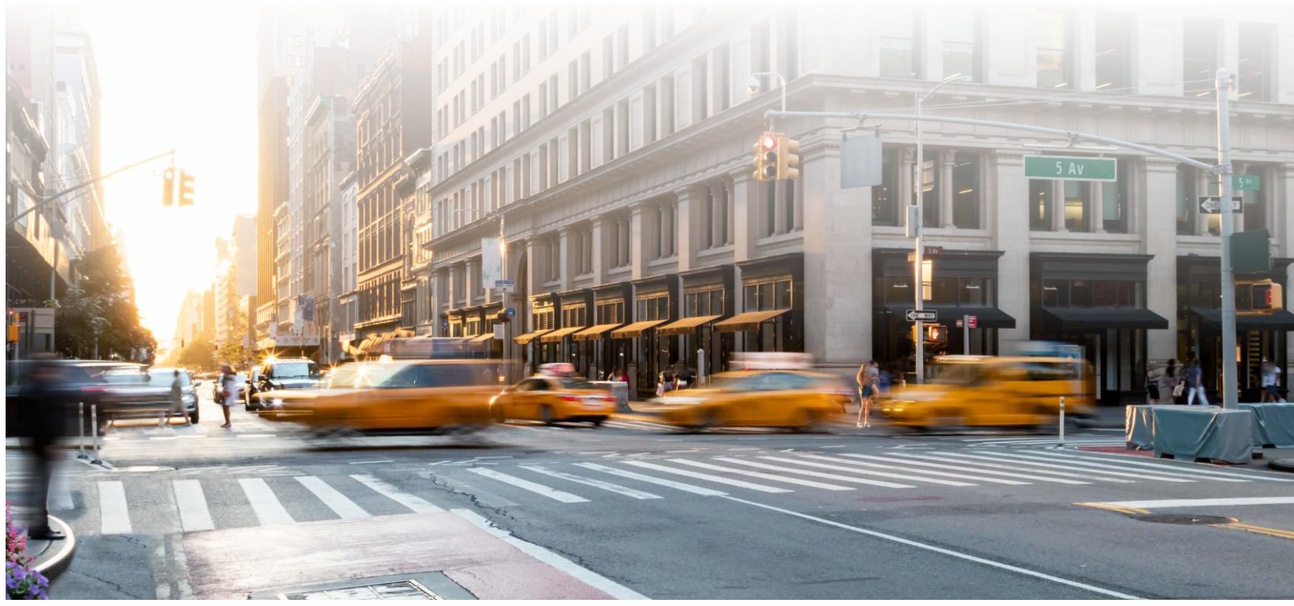
The IIMA Centre for Transportation and Logistics (CTL) will address critical passenger and freight transportation, and logistics challenges in India through an integrated, multidisciplinary program of research, post-graduate and executive education, technology transfer, and policy advice for enhancing the mobility of people and goods. CTL's objective is to contribute to improving the efficiency of multi-modal transportation systems and supply chain logistics, thereby promoting economic growth and fostering sustainable development.

Research Themes

The following strategic themes will constitute priority research areas for CTL. The themes have been identified based on current trends in research, innovations in practice, and policy priorities in India and across the world. Priority themes will be reviewed and updated periodically as the transportation and logistics industry/environment evolves.

Passenger Transportation and Sustainable Urban Mobility

Freight Transportation and Logistics



Passenger Transportation and Sustainable Urban Mobility

• Leveraging technology for improving urban and regional mobility

This theme focuses on examining emerging technologies such as intelligent route guidance systems, dynamic road pricing, smart parking, integrated transit fare systems, app-based shared transportation services, high-speed rail, etc., and their potential for improving passenger mobility and accessibility within and between cities. The impact of connected and autonomous vehicles in increasing safety and capacity utilization, enhancing system reliability, influencing travel behavior, and altering location choices of households and firms will be analyzed. Innovative ways of collecting and applying big data in transportation for evidence-based planning and improved real-time operations of multi-modal systems will be explored. The role of government and public policy for better leveraging technology will be considered.

• Reducing environmental impacts and enhancing resilience of transportation systems

This theme focuses on exploring ways to reduce environmental impacts of transportation while meeting or improving mobility. Research areas include: a) Ways to reduce carbon footprint of transport infrastructure (e.g., roads, airports, ports, public transit systems, etc.) construction, maintenance, and operation; b) New fuel and vehicle technologies across modes, including plug-in hybrids and battery electric vehicles, that significantly reduce lifecycle emissions, and c) Government actions, including pricing policies as well as mandates or restrictions, to promote supply and demand of low-carbon transportation systems. Research analyzing and suggesting improvements to the multi- modal transportation system's preparedness for short-notice (e.g., earthquake, terrorist attack, etc.) or planned (e.g., cyclone, virus outbreak, etc.) evacuation or system management at various geographic scales, and research exploring ways to develop systems that are resilient (with respect to damages and disruptions) to both short-notice events and long-term climatic changes will be covered under this theme.

• Promoting sustainable and safe urban transportation

This theme focuses on research involving strategies to promote shared (e.g., public transit, car- and ride-sharing arrangements, etc.), non-motorized/active (i.e., walking and bicycling), and low-carbon (e.g., electric vehicles) transportation in India's megacities and high-growth regions. Strategies can range from private sector initiatives/innovations in the provision and management of sustainable transportation modes and systems, to government policies (i.e., land use planning, supply-side investments, and demand management initiatives) to influence activity-travel decisions. Methods can span across disciplines, from travel behavior analysis using revealed preference or stated-choice surveys, to experimental approaches of evaluating the impacts of specific interventions. Issues of equitable access to jobs and other urban amenities, particularly for the transportation disadvantaged, will be addressed. Research exploring ways to make urban travel safer will also be covered under this theme. This theme is aligned with global initiatives including India's policy priority of promoting sustainable urban development, and the creation of healthy and liveable cities.

Freight Transportation and Logistics

• Optimizing logistics networks

This theme covers research for identifying optimal locations of facilities within a network and allocating customer orders to each location, which is an important decision area for all retailers including e-commerce players. For last mile delivery, optimal vehicle routing and minimizing customer misses is key to business profitability. Also, during disruptions, the optimal order fulfilment policies such as the choice of the warehouse location for fulfilling a customer order with due date constraints is critical. With recent growth in electric vehicles, designing and optimizing charging networks for transportation is another potential research area. Other areas of optimization include identifying optimal transportation mode, route, and time choice. The methods used in optimizing networks include integer programs, queuing theory, game theory and simulation.

• Managing terminal and warehouse operations

Managing the performance of logistics facilities such as warehouses or container terminals is critical for achieving high customer service levels. Many facilities are robotized today, and we expect more warehouses to be robotized in the future. Likewise, container terminals are undergoing automation. Performance analysis of such facilities using analytical and simulation models is a key step in the design conceptualization process. While traditional optimization and simulation methods are used to analyze decision problems in container terminals such as quay crane assignment problem, berth allocation problem, yard crane assignment problem, analytical models are also useful for long-term technology investment decisions in the terminals. Also, applications of IoT in intra-logistics will be investigated. Related research will be covered under this theme.

• Sustainable urban freight and last-mile connectivity

This theme will cover research aimed at improving the efficiency and reducing the negative environmental impacts of freight activity within cities. Strategies involving technological (e.g., low-carbon or non-motorised vehicles), land use (e.g., urban consolidation centres), analytics (e.g., optimized routing), and policy (e.g., taxes or restrictions) interventions will be evaluated. Research under this theme is significant given changes in consumer demand and preferences, and concurrent innovations in logistics and supply-chains.

• Improving eco-efficiency and safety of goods transportation

In India, commercial vehicles are a dominant source of CO_2 emissions. Old vehicles not only add to the emissions but also cause driver attrition. While the government is implementing the vehicle scrappage policies to eliminate polluting vehicles (over 15 years old) from the road, the implications of the scrappage policies on the vehicle demand estimation, overall CO_2 emissions, and driver productivity and safety is still unknown. This center would research policies to improve driver safety and retention. A project that attempts to link driving behavior with fuel efficiency and road safety has already been initiated.

CTL Faculty Members

The core research areas of the CTL faculty members :

Dr. Debjit Roy

Logistics and service systems including container terminals, automated warehouses, vehicle rental, trucking, dine-in restaurants | Stochastic processes | Queuing theory Optimization | Simulation | Empirical

Dr. Sandip Chakrabarti

Transport policy analysis | Transportation demand analysis and modeling
Land use-transportation interactions | Travel behavior/choice analysis
Public transit planning and policy | Active travel | Parking
Multi-modal system performance measurement and monitoring
Impact analysis of new transportation investments
Applications of big data in transportation

Dr. Prashant Das

Commercial real estate (Private Equity, REIT, CMBS, Sustainability, Hotels)
Sentiments | Valuation | Real estate in India

Dr. Amit Garg

Blockchain based peer-to-peer energy sharing and trading platform
Water-energy-agriculture-climate change nexus
Green infrastructure, energy policy and energy modeling | Green corporates
Green products and services | Adaptation policy for climate change impacts
Uncertainty assessment and risk management for corporates due to climate change
Carbon finance | Climate change mitigation policy | Solar agriculture pumps
Development, energy and climate change | Emission inventory assessment
Demand side management | New and renewable energy technology policy

Dr. Diptesh Ghosh

Metaheuristics | Evolutionary algorithms | Layout problems

Dr. Sachin Jayaswal

Facility location | Large-scale optimization | Stochastic optimization
Operations - marketing interface: pricing, lead time and capacity decisions
Product differentiation/price discrimination | Supply chain management.
Facility Location Problems with Stochastic Demand and Congestion
Network Design/Flow | Large Scale Optimization (Decomposition Techniques)
Stochastic Optimization | Game Theoretic Models in Operations/Marketing
Operations-Marketing Interface: Pricing, Leadtime, Capacity Decisions

Dr. Sunil Maheshwari

Turnaround management | HRM in healthcare management | Leadership

Dr. Sundaravalli Narayanaswami

Transport and operation (particularly railway and urban transport) education
Pricing and revenue management | Contingency and emergency management
Automation of operation and knowledge

Dr. Sriram Sankaranarayanan

Game theory | Optimization problem | Climate change | Energy market policies

Dr. Chetan Soman

Food supply chains | Advanced planning & scheduling in process industries
Application of simulation for decision making

Dr. Anish Sugathan

Governance | Environmental policy | Energy policy | Strategy
Sustainable development

Dr. Rama Mohana R Turaga

Public policy analysis and management | Environmental economics and policy
Corporate sustainability and corporate social responsibility
Pro-environmental behavior

Dr. Poornima Varma

International trade | Trade and agriculture | Issues of food security and food safety
Sustainable agricultural practices | Food security issues | Agricultural supply response
SPS and TBT in international trade | Price formation in agricultural markets
Agrarian transformation in India | Intra industry trade | Public distribution system
Pricing to market behavior of Indian exporters
Adoption of sustainable agricultural practices | Agricultural exports and food security
Crop diversification and agricultural growth | WTO related issues, trade and environment

Dr. Prahalad Venkateshan

Vehicle Routing | Facility Location | Network Design | Mathematical Programming

Dr. Sanjay Verma

E-governance | Knowledge management | Measurement of business performance
Use of Information Technology in Government | Strategies for improving Rail-Port Interface
Knowledge Management in Indian Organizations
Preemptive Resource Constrained Project Scheduling Problems
Multiple resource constrained project scheduling problems

Dr. Maya Ganesh

Public sector operations | Sustainable operations | Welfare benefit programs
Impact of information, technology and digitization on supply chains
Agricultural and food supply chains

Research Seminars & Webinars

The Centre organized nine research seminars & webinars across the year on various thematic areas

Topic	Speaker	Date
Putting Supply Chain Resilience Theory into Practice	**Dr. Arnd Huchzermeier** Chair of Production Management WHU – Otto Beisheim School of Management	July 5, 2023
A Data-driven Approach to Improve Artisans' Productivity in Distributed Supply Chain	**Dr. Somya Singhvi** Assistant Professor Data Sciences and Operations Department USC Marshall School of Business	July 7, 2023
Electric Vehicle Fleet and Charging Infrastructure Planning	**Dr. Francisco Castro** Assistant Professor Decisions, Operations and Technology Management UCLA Anderson School of Management	July 21, 2023
Design of Contingent Free Shipping Policy: The Role of Return Environment	**Dr. Ashish Kabra** Assistant Professor University of Maryland - Robert H. Smith School of Business	July 24, 2023
Managing Product- reusability under Supply Disruptions	**Dr. Prashant Chintapalli** Assistant Professor Management Science Ivey Business School at Western University	August 7, 2023
Logistics Transformation with Humans and Intelligence	**Dr. Jayashankar Swaminathan** GlaxoSmithKline Distinguished Professor Operations UNC Kenan-Flagler Business School The University of North Carolina - Chapel Hill	August 18, 2023
Bollywood Beats Boredom: Addressing Drivers' Limited Attention with Movie-Themed Alerts	**Dr. Anuj Kumar** Walter J. Matherly Professor Warrington College of Business University of Florida	November 20, 2023
MEL: Pioneering new avenues in Maritime Economics & Logistics research	**Dr. Hercules Haralambides** Professor of Maritime Economics and Logistics (MEL)	January 11, 2024
Maritime Informatics for a High-Performing and Sustainable Transportation and Logistics Industry	**Dr. Mikael Lind** Professor of Maritime Informatics, Chalmers University and Research Institutes of Sweden (RISE)	March 11, 2024

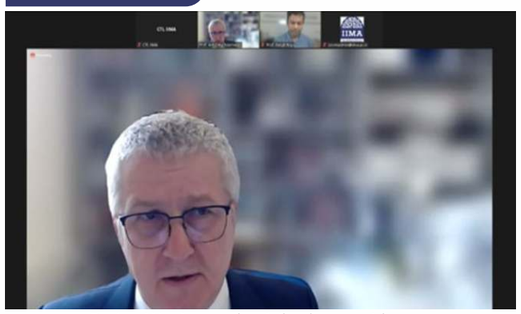
1. Putting Supply Chain Resilience Theory into Practice

'**Putting Supply Chain Resilience Theory into Practice**', a Research Webinar by **Dr. Arnd Huchzermeier**, Chair of Production Management, WHU – Otto Beisheim School of Management, was held on July 5, 2023.

Research Theme: Freight transportation and logistics
No. of attendees: 74
Moderated by: Dr. Debjit Roy

Dr. Arnd Huchzermeier holds a Ph.D. degree from the Wharton School, U.S., and a Dual MSc degree from the Karlsruhe Institute of Technology, Germany. He taught, among others, at Kobe University in Japan, the University of Chicago and the Wharton School in the U.S., and WHU's Otto Beisheim School of Management located in Vallendar, Germany. He has published, among others, in Management Science, Manufacturing & Service Operations Management, Marketing Science, Operations Research, Production and Operations Management as well as California Management Review and Harvard Business Review. In addition, he is co-author of ten management books on management quality for industrial excellence, the variable takt principle, supply chain finance, and blockchain technology. His research interests focus, among others, on the Operations Management-Marketing Interface and Global Supply Risk Management. Presently, he acts as Department Editor for the managerial journal Management & Business Review and as Senior Editor of two areas for the academic journal Production and Operations Management. His research was awarded with international prizes, such as the INFORMS Franz Edelman Award, the EURO Management Science Strategic Innovation Prize and the Marketing Science Practice Prize. For years, he has been actively involved in academic initiatives by retailer-manufacturer associations at the national and international level. Presently, he teaches primarily e-commerce operations management and analytics courses to graduate and executive students.

Talk Summary



Dr. Arnd Huchzermeier delivering a webinar on 'Putting Supply Chain Resilience Theory into Practice'

The talk focused on supply chain resilience in the midst of an increasingly disruptive global business environment. Prof. Huchzermeier discussed the multi-faceted nature of supply chain resilience which displays resistance-related to recovery-related characteristics. Four key enablers of supply chain resilience were identified, namely, end-to-end visibility, end-to-end control, continuous IT infrastructure and organizational readiness. Challenges in the implementation of supply chain resilience theories remain even though a wide body of literature on theories to overcome supply chain disruption exists. His research focused on identifying gaps between theoretical strategies and on-ground implementation through interviews with top supply chain managers from leading companies. The interviews helped identify the six most significant challenges like supply chain financing, accentuated efficiency and resilience trade-offs, fragmentation of decision-making, factor market limitations or heterogeneity of supply chains. The research revealed a one-size-fits approach for managing supply chain resilience across companies is undesirable. The study found intra-company supply chain process and inter-company supply chain integration as two major factors influencing any company's resilience strategy. Some recommendations by Prof. Huchzermeier to overcome the above-discussed challenges include building strong relationships with suppliers and contract manufacturers, adopting a hierarchical supply chain approach, establishing an independent supply chain risk management function, investing in strong relationships and using disruptions as a catalyst to bring required changes in the organization.

To Watch

Visit:
https://youtu.be/lck9TWtreyA

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2. A Data-driven Approach to Improve Artisans' Productivity in Distributed Supply Chain

'**A Data-driven Approach to Improve Artisans' Productivity in Distributed Supply Chain**', a Research Seminar by **Dr. Somya Singhvi**, Assistant Professor, Data Sciences and Operations, USC Marshall School of Business, was held on July 7, 2023.

Research Theme: Freight transportation and logistics
No. of attendees: 61
Moderated by: Dr. Maya Ganesh

Dr. Somya Singhvi is an assistant professor of Data Sciences and Operations at University of Southern California's Marshall School of Business. Somya received his Ph.D. in Operations Research from MIT, focusing on improving the design of digital agri-platforms and markets. Somya's research is driven by a desire to create social impact using a combination of field-based and data-driven research methods. He is particularly interested in developing actionable insights for supply chains and digital platforms in resource-constrained settings. His research has spanned a range of application areas, including agricultural, artisanal and healthcare supply chains, as well as ed-tech and charity donation platforms. Somya has received a number of recognitions for his work, including the George B. Dantzig Dissertation Award, MSOM Responsible Research Award, Public Sector Operations Best Paper Award, Doing Good With Good OR Award.

Talk Summary

Dr. Somya Singhvi delivering a seminar on 'A Data-driven Approach to Improve Artisans' Productivity in Distributed Supply Chain'

Artisanal businesses are the second largest provider of employment to rural communities, especially women. In India alone, almost 200mn people are directly employed in artisanal works. The global market is estimated to be $984bn. The fragmented nature of artisanal supply chains, labor intensive nature of the activity and stringent quality measures makes it challenging to improve artisan productivity despite high poverty levels and low productivity among artisanal communities. The study presents empirical evidence about the impact of supervisory visit on improving artisans' productivity for an Indian handmade rug manufacturing unit. Interactions with weavers, branch managers and quality supervisors revealed that supervisor visits are critical in the overall supply chain. The results show a 3-14% decrease in the weaving time of weavers upon a one-day reduction in the gap between two supervisory visits. This could boost weaver's monthly incomes by 15-17%. The observations showed the impact of visits on artisanal productivity to be heterogeneous across different levels of complexities involved in rug weaving. Further, the authors proposed a novel predict-then-optimize framework for routing and optimizing supervisor visits in the supply chain using the Optimizing Super Visit Problem (OSVP). The research has applications in improving workers' productivity for resource-constrained distributed supply chains where workers are located at different locations.

Dr. Somya Singhvi with Prof. Debjit Roy & Prof. Maya Ganesh alongside the on-campus attendees

To Watch

Visit:
https://youtu.be/irck0HxPOKA

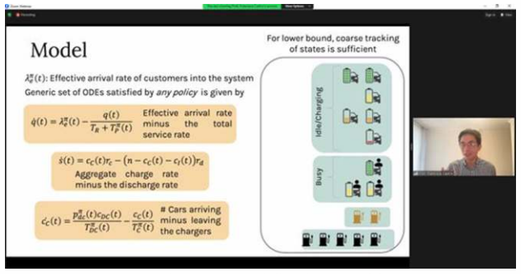
3. Electric Vehicle Fleet and Charging Infrastructure Planning

'**Electric Vehicle Fleet and Charging Infrastructure Planning**', a Research Webinar by **Dr. Francisco Castro**, Assistant Professor, Decisions, Operations and Technology Management, UCLA Anderson School of Management, was held on July 21, 2023.

Research Theme: Passenger transportation and sustainable urban mobility
No. of attendees: 97
Moderated by: Dr. Debjit Roy

Dr. Francisco Castro has been a faculty member at the UCLA Anderson School of Management since 2020, specializing in the operations and design of markets, particularly focusing on their spatial and incentive aspects. Previously, he served as a postdoctoral research scientist at Uber. Castro's research revolves around market design, developing models that capture essential market dynamics and utilizing rigorous theory to enhance understanding and explore new applications. His work offers practical guidelines for approaching matching, pricing, and capacity planning in digital marketplaces such as ride-hailing platforms. Castro holds a Ph.D. in Decision, Risk, and Operations from Columbia University Graduate School of Business, an M.S. in Mathematical Engineering from the University of Chile, and a B.S. in Engineering Sciences from the same institution.

Talk Summary



Dr. Francisco Castro delivering a webinar on 'Electric Vehicle Fleet and Charging Infrastructure Planning'

Technological advancements, government incentives and change in consumer behavior has led to an increase in EV adoption. This poses the problem of determining the minimum number of vehicles and chargers for a given service level along with a matching and charging policy that maximizes the service level for a system operator. The talk focused on finding an optimal electric vehicle (EV) fleet and charging infrastructure capacity planning problem in a spatial setting. The study provides a sharp characterization of the fleet size and the charging infrastructure requirements as the demand grows. The model assumed EVs and charging points distributed in a bounded region where customers arrive at rate λ and leave if they are not immediately matched. While a system in which charging times are negligible needs extra Θ(λ^(2/3)) vehicles on top of the nominal capacity, it shows that an EV system has a fundamentally different scaling. Due to charging times, the nominal capacity of the system is increased, but this extra capacity allows for an optimal EV dispatching policy to result in a fleet requirement of only Θ(λ) for ν ∈ (1/2, 2/3], depending on the number of charging stations and the size of the EV battery packs. The research proposes the Power-of-d dispatching policy, which achieves this performance by selecting the d closest vehicles to a trip request and choosing the one with the highest battery level. The study shows the use of partially charged EVs reduces fleet size requirement and power of d vehicles dispatch policy optimizes the tradeoff between SoC and pickup times. It provides valuable guidelines for determining the optimal fleet and charging infrastructure capacity for an EV-based on-demand transportation system.

To Watch

Visit:
https://youtu.be/N4MtXTVnIo0

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4. Design of Contingent Free Shipping Policy: The Role of Return Environment

'**Design of Contingent Free Shipping Policy: The Role of Return Environment**', a Research Seminar by **Dr. Ashish Kabra**, Assistant Professor, University of Maryland - Robert H. Smith School of Business, was held on July 24, 2023

Research Theme: Freight transportation and logistics
No. of attendees: 51
Moderated by: Dr. Debjit Roy

Dr. Ashish Kabra is an Assistant Professor at the Robert H. Smith School of Business at the University of Maryland. He conducts empirical and theoretical research using causal inference, structural estimation, game theory, and optimization methods. His research focuses on studying the interplay between platform operations, consumer behavior, and sustainability in the domains such as e-commerce, online B2B platforms, retail stores, and urban transportation. His research work has been published in top journals and has won several prestigious best paper awards. His teaching has been recognized with the prestigious Allen J. Krowe teaching award at the Smith School. Prior to joining Maryland, he completed his graduate studies in Operations Management at INSEAD, France, and undergraduate studies in Computer Science at BITS-Pilani, India.

Talk Summary

Dr. Ashish Kabra delivering a seminar on 'Design of Contingent Free Shipping Policy: The Role of Return Environment'

Return rates for online purchases (~15-40%) are almost double or triple compared to offline purchases (~5-15%). Shipping and return costs make up around 10% of the total cost for e-commerce retailers. The talk focused on designing an optimal Contingent Free Shipping (CFS) policy for e-commerce retailers based on their return policies. A CFS policy involves a retailer charging a certain shipping fee if the order value is below a certain threshold, which is free otherwise. In a CFS scenario, a customer may choose to pay a shipping fee in case of below-threshold purchases, pad up purchases to match or exceed the threshold level or abandon the purchase. While padding helps in economising the logistics cost for retailers, it also opens up the possibility of consumers indulging in bubble purchases (fake purchases) leading to enhanced return processing costs. The research studied the impact of return policies and hassle costs in the selection of CFS terms. The study was done in collaboration with a prominent e-commerce retailer in India which experimented with different CFS thresholds over a period of time. The study found that customers paid 15.7% to 23.0% of below-threshold demand out of which 9% to 18.5% are bubble purchases in case of a lenient return process. However, in case of a stringent return process, almost 13.2% to 20.3% of the orders are padded with the near elimination of bubble purchases. Counterfactual analysis indicates a potential loss of 13.2% in profits if this moderating role of ease-of-return experience is ignored while designing CFS policy. The authors recommend formulating lenient CFS terms when the return process is convenient, while stringent CFS terms should be applied when the return process is inconvenient. Applying uniform CFS policies to markets with different ease of returns can lead to a significant loss in profitability.

To Watch

Visit:
https://youtu.be/yAlEAp53WOg

5. Managing Product-reusability under Supply Disruptions

'**Managing Product-reusability under Supply Disruptions',** a Research Seminar by **Dr. Prashant Chintapalli**, Assistant Professor, Management Science, Ivey Business School at Western University, was held on August 7, 2023.

Research Theme: Freight transportation and logistics
No. of attendees: 63
Moderated by: Dr. Debjit Roy

Dr. Prashant Chintapalli is an Assistant Professor of Management Science, Ivey Business School, Western University, Canada. He holds a PhD from the UCLA Anderson School of Management. His research interests lie in analysing operational issues faced by businesses and policymakers in emerging economies, with a special focus on food supply chains.

Talk Summary

Dr. Prashant Chintapalli delivering a seminar on 'Managing Product-reusability under Supply Disruptions'

Dr. Prashant Chintapalli with Prof. Debjit Roy & Prof. Maya Ganesh alongside the on-campus attendees

Large-scale supply chain disruptions are becoming more frequent in contemporary times. Prof. Chintapalli explored the feasibility of product reusability in the presence of risk of such large-scale supply disruptions. Product reusability is determined through the ease of refurbishment due to innovations in product design The model involved allowing consumers to trade-in their used units for new ones with a trade-in fee being used by firms to entice consumers. The model provided for a firm to operate in either a state of normal supply (N) or a state of disrupted supply (D) and uses a discrete-time Markov chain model to determine the degree of product-reusability, price, and trade-in fee. The refurbishment happens through an external refurbishment facility. The results from the model showed that increasing product reusability is beneficial till the likelihood of supply disruption increases to a certain extent. However, when disruption probability is high, increasing reusability may lead to higher design costs and decreased revenues. He further discussed two strategies available to a firm in case of supply chain disruptions and sufficient trade-ins from customers, namely, risk absorption (increasing product reusability) and risk transfer (passing the increased cost to customers and abstention from product design changes for reusability). The results showed that firms should transfer risks when the probability of disruption is high irrespective of whether the trade-ins are high or low. It is also beneficial to increase the price premium for refurbished units in disrupted scenarios but only if the supply risk is high. Finally, a brief discussion on obtaining the optimal trade-in fee that a firm should offer to customers followed, and the study showed that it benefits the firm to increase the fee as the likelihood of the supply disruption increases.

To Watch

Visit:
https://youtu.be/sBvd17lr30s

6. Logistics Transformation with Humans and Intelligence

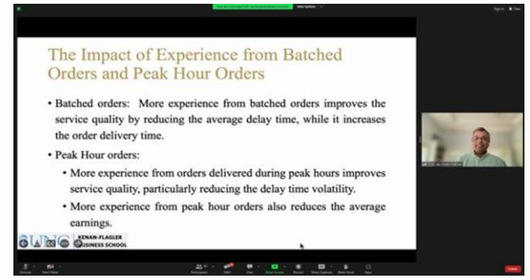
'**Logistics Transformation with Humans and Intelligence**', a Research Webinar by **Dr. Jayashankar Swaminathan**, GlaxoSmithKline Distinguished Professor of Operations, UNC Kenan-Flagler Business School, The University of North Carolina-Chapel, was hosted on August 18, 2023.

Research Theme: Freight transportation and logistics
No. of attendees: 52
Moderated by: Dr. Debjit Roy

Dr. Jayashankar (Jay) Swaminathan is the GlaxoSmithKline Distinguished Professor of Operations at the Kenan-Flagler Business School at University of North Carolina at Chapel Hill. An internationally recognized thought leader on productivity and innovation in business operations, he is an inducted Fellow of The Institute for Operations Research and Management Science (INFORMS), Manufacturing and Service Operations Management Society (MSOM) and Production and Operations Management Society (POMS). Dr. Swaminathan has published more than 70 scholarly journal articles and is the author of the edited volume "Indian Economic Superpower: Fiction or Future?"and co-author of the edited volume "Responsible Operations". He currently serves as a Department Editor for Management Science and Production and Operations Management journals.Recently, he was listed among the Top 10 Scholar in the world in terms of publications in major journals (MS, MSOM, POM, JOM) from 2000-2015 as well as Top 1%of scholars worldwide in Operations Research field and across all disciplines.He has received numerous awards for his work, including the National Science Foundation CAREER Award, George Nicholson Prize, Schwabacher Fellowship, Weatherspoon Distinguished Research, Weatherspoon Excellence in Teaching and Roy Holsten Award for Exceptional Service.He has consulted with numerous firms over the last 30 years, including AGCO, Agilent, IBM, Kaiser, Nokia, Public Health Institute, Railinc, Samsung,Siemens,Sara Lee, and UNICEF. He has served in various leadership roles at UNC Kenan-Flagler including Senior Associate Dean for Academic Affairs, Associate Dean for Global Executive MBA Programs, Director of UNC Global Business Center as well as Area Chair of Operations Faculty. Prior to joining UNC, he was a faculty at theHaas School of Business at UC Berkeley. He received his PhD and Master's degree in industrial administration from GSIA (now Tepper) at Carnegie Mellon University and his Bachelor's degree in computer science and engineering from the Indian Institute of Technology, Delhi.

The overall cost of logistics as a percentage of GDP in India is around 14%, almost double compared to the USA. Increased transportation costs, driver shortage, technological and business innovations, and financing for supply chains are some major challenges faced by the Indian logistics sector. In India, reducing the last mile delivery cost is extremely important since it drives

Talk Summary



Dr. Jayashankar Swaminathan delivering a webinar on 'Logistics Transformation with Humans and Intelligence'

the overall cost of logistics by 40%. Further, the gig economy in India is projected to employ 70 mn people over the next 10 years and research indicates a 40% rider churn with delivery agents. The study aims to understand how experience affects worker performance in gig worker settings where the effect is understood for experience obtained through batched orders, and through peak hour orders. The data for the study was collected from 23 groceries from Beijing CBD between 2018 and 19 involving 1066 gig workers. Using the Heckman selection model, the study modeled choice equation and level equation based on delivery experience and task variety. The results indicated that prior delivery experience reduces delivery time while task variety helps reduce delivery time till a level beyond which complexity in tasks increases delivery time. Mechanism study on exploration-exploitation revealed that in case of store exposure for region exploration, workers do not increase store exposure to seek new knowledge, while in case of customer region exposure, workers tend to explore new regions initially and later converge to deliver at their familiar areas. Delivery of batched orders tends to increase with workers' experience. The impact of experience gained from batched orders showed an increase in service quality indicated by a reduction in average delay time though an increase in average order delivery time was observed. Similarly, experience from operating in peak hours tends to improve service quality, reflected by reduction in average delay time but a reduction in average earnings was also observed. The talk ended with a brief discussion on an ongoing study by the speaker on improving packing efficiency at warehouses through AI and how availability of real time information about performance ranking affects workers' productivity and performance.

7. Bollywood Beats Boredom: Addressing Drivers' Limited Attention with Movie-Themed Alerts

'**Bollywood Beats Boredom: Addressing Drivers' Limited Attention with Movie-Themed Alerts**', a Research Seminar by **Dr. Anuj Kumar**, Associate Professor and Matherly Professor of Information Systems at the Warrington College of Business, University of Florida, was hosted on November 20, 2023.

Research Theme: Passenger transportation and sustainable urban mobility
No. of attendees: 53
Moderated by: Dr. Debjit Roy

Dr. Anuj Kumar is an Associate Professor and Matherly Professor of Information Systems at the Warrington College of Business, University of Florida. He holds a Ph.D. in Information Systems from Heinz School of Information Systems and Management, Carnegie Mellon University. He also holds a Bachelor's degree in Mechanical Engineering and a Master's degree in Thermal Engineering from the Indian Institute of Technology, India, and a Master's degree in Management from the Indian Institute of Management, India. Professor Kumar's research focuses on understanding how information technology affects the behavior of organizations, individuals, and the interactions between them. His research has been published in top-tier journals like Management Science, Information Systems Research, Manufacturing & Service Operations Management, and Management Information Systems Quarterly.

Talk Summary

Dr. Anuj Kumar delivering a seminar on 'Bollywood Beats Boredom: Addressing Drivers' Limited Attention with Movie-Themed Alerts'

Dr. Anuj Kumar with Prof. Debjit Roy

Behavioral economics and applied psychology identify the cognitive constraints in individuals due to finite attention and infinite information at any given point of time. Such limited attention may lead to suboptimal choices by individuals in varied areas like consumption, education, mobility or savings. Attention lapse happens in cases of repetitive work, leading to accidents and mishaps. Reminders are a way of overcoming limited attention and bring desired activity to the top of the mind. However, individuals may not pay attention to reminders due to boredom. Literature reveals that exposure to the same media signals can cause boredom and negate the entire purpose of these reminders.

The study explored the impact of varied Bollywood themed audio alerts for truck drivers in collaboration with a truck driver safety app in India. An alert was sent to drivers every 15 minutes. The field study was carried out on 18,510 truck drivers who made 707, 338 trips, divided into a control group and treatment group where the treatment group received Bollywood themed alerts. The study revealed an increase of 104% in distance per trip and 76% increase in duration per trip for treatment group drivers. The study found that new alerts have a significantly higher effect on app engagement than monetary rewards. The findings reveal that drivers react more negatively to old alerts after experiencing new alerts. Interestingly, no evidence of attenuation of the effect of new alerts was found with the passage of time. The study reveals that novel delivery mechanisms for reminders can counter drivers' boredom. The advent of new technologies like GenAI can further enhance efficiency of these initiatives through personalized and context specific variations in repetitive alerts.

To Watch

Visit:
https://youtu.be/1HNFZQiWc2g

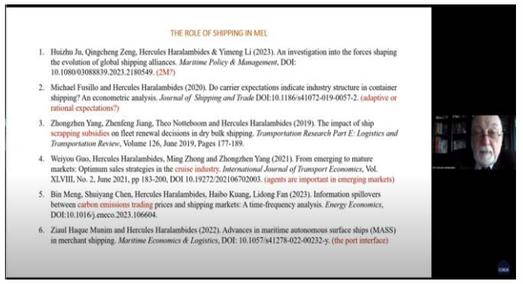
8. MEL: Pioneering new avenues in Maritime Economics & Logistics research

'**MEL: Pioneering new avenues in Maritime Economics & Logistics research**', a Research Webinar by **Dr. Hercules Haralambides**, Professor of Maritime Economics and Logistics (MEL), was hosted on January 11, 2024.

Research Theme: Freight transportation and logistics
No. of attendees: 55
Moderated by: Dr. Debjit Roy

Dr. Hercules Haralambides has been a Professor of Maritime Economics and Logistics (MEL), since 1992, having taught at 9 universities (and in 7 different countries), most prominent of which being Erasmus University Rotterdam, National University of Singapore, and Singapore Management University. Currently, he is "Distinguished Chair Professor" at Dalian Maritime University (China), Visiting Professor at Erasmus University Rotterdam, and affiliated researcher with the Sorbonne Center for Economics - Sorbonne University.

Talk Summary


THE ROLE OF SHIPPING IN MEL

1. Huizhu Ju, Qingcheng Zeng, Hercules Haralambides & Yimeng Li (2023). An investigation into the forces shaping the evolution of global shipping alliances. *Maritime Policy & Management*, DOI: 10.1080/03088839.2023.2180549. (2M?)
2. Michael Fusillo and Hercules Haralambides (2020). Do carrier expectations indicate industry structure in container shipping? An econometric analysis. *Journal of Shipping and Trade* DOI:10.1186/s41072-019-0057-2. (adaptive or rational expectations?)
3. Zhongzhen Yang, Zhenfeng Jiang, Theo Notteboom and Hercules Haralambides (2019). The impact of ship scrapping subsidies on fleet renewal decisions in dry bulk shipping. *Transportation Research Part E: Logistics and Transportation Review*, Volume 126, June 2019, Pages 177-189.
4. Weiyou Guo, Hercules Haralambides, Ming Zhong and Zhongzhen Yang (2021). From emerging to mature markets: Optimum sales strategies in the cruise industry. *International Journal of Transport Economics*, Vol. XLVIII, No. 2, June 2021, pp 183-200, DOI 10.19272/202106702003. (agents are important in emerging markets)
5. Bin Meng, Shuiyang Chen, Hercules Haralambides, Haibo Kuang, Lidong Fan (2023). Information spillovers between carbon emissions trading prices and shipping markets: A time-frequency analysis. *Energy Economics*, DOI:10.1016/j.eneco.2023.106604.
6. Ziaul Haque Munim and Hercules Haralambides (2022). Advances in maritime autonomous surface ships (MASS) in merchant shipping. *Maritime Economics & Logistics*, DOI: 10.1057/s41278-022-00232-y. (the port interface)

Dr. Hercules Haralambides delivering a webinar on 'MEL: Pioneering new avenues in Maritime Economics & Logistics research'

Prof. Haralambides started the webinar with a brief description of his pioneering work in maritime economics and logistics across Asia, Africa and Europe. He discussed topics of topical relevance in MEL like shipping alliances, port integration, port connectivity and centrality, sustainable port development, carrier expectations, port interface, shipping market structures and network among others.

Prof. Haralambides covered the entire gamut of MEL and categorized it into three broad categories of ports, shipping, and network and global logistics. In the ports category, he highlighted the significance of determining hinterlands for container ports in order to determine optimal port size. He argued for integration of closely located ports. He discussed the role of economic factors in shaping the evolution of port systems, using HongKong port as an example. His research showed the importance of port centrality, and not just connectivity in enhancing the attractiveness of hub port. He discussed how trade flows are important in determining port O-D pairs to ensure sustainable port development. He also touched upon the opportunities and challenges in making seaports a hub for green hydrogen.

In shipping, Prof. Haralambides discussed the forces shaping global shipping alliances. He discussed adaptive and rational expectations in the context of container shipping for carriers. His research revealed that adaptive expectations guide investment decisions in the Atlantic ocean while rational expectations guide decisions for players operating in the Pacific ocean. He also discussed how ship scrapping subsidies by governments may help propel fleet renewal and emergence of the shipbuilding industry in a country. His research revealed that the major hindrances in introduction of Maritime Autonomous Surface Ships is caused by the port design, port interface and navigation rather than the nature of the ship itself. In the networks and global logistics category, Prof. Haralambides discussed his work surrounding port networks in Asia and Africa, port clusters, dual transactions in container terminals and shipping alliances.

Prof. Haralambides left the audience with exciting developments in maritime logistics and interesting research questions for students and scholars to explore and solve.

To Watch

Visit:
https://youtu.be/vM5hN-5AXuU

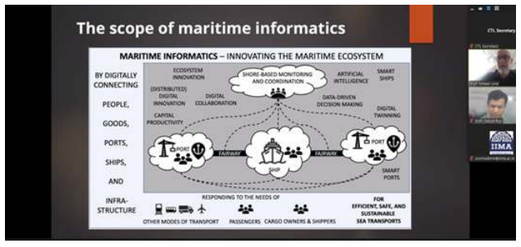
9. Maritime Informatics for a High-Performing and Sustainable Transportation and Logistics Industry

'**Maritime Informatics for a High-Performing and Sustainable Transportation and Logistics Industry**', a Research Webinar by **Dr. Mikael Lind**, Professor of Maritime Informatics at Chalmers University and Research Institutes of Sweden (RISE), was hosted on March 11, 2024.

Research Theme: Freight transportation and logistics
No. of attendees: 51
Moderated by: Dr. Debjit Roy

Dr. Mikael Lind is the world's first (adjunct) Professor of Maritime Informatics engaged at Chalmers and Research Institutes of Sweden (RISE) and well-known expert in the field of digital collaboration and innovation frequently surfaced in international trade press. He is an expert contributor at World Economic Forum, Europe's Digital Transport Logistic Forum (DTLF), and UN/CEFACT. He is co-editor of the first two books on Maritime Informatics, co-author of the Practical Playbook for Maritime Decarbonisation, co-editor of the book Maritime Decarbonization, and co-initiator and sponsor of the Virtual Watch Tower (VWT) network initiative. He has also been instrumental in setting up international ecosystem collaborations as well as co-founding collaborative decision making (CDM) initiatives for different transport and logistics settings.

Talk Summary



Dr. Mikael Lind delivering a webinar on 'Maritime Informatics for a High-Performing and Sustainable Transportation and Logistics Industry'

Maritime sector carries 90% of the world's trade and emits 2.2% of global emissions. Emphasizing large-scale collaboration for large-scale digitization for generation of economic and social value, Prof. Lind explained maritime informatics as the digitalization of sea transport rooted in information systems and relying on eclectic foundations. Maritime ecosystem is unique since it is the oldest and largest sharing economy which is self-organized in nature with no single keystone organization and distributed control. The sector is evolving from fragmented, low-quality information and sub optimized operation sector to one with standardized data exchange and high IT maturity. It encompasses digital innovation, digital collaborations, digital twinning, data driven decision making, smart ports, AI, smart ships, ecosystem innovation and capital productivity. Prof. Lind explained the three focus areas of maritime informatics, which are digital collaboration, digital data sharing and decision making and data analytics. He also advocated for a system-oriented perspective for maritime informatics, which involves systems of engagement, production, framing, record and inquiry, each of which bring attention to different concerns.

Maritime informatics can be applied in bringing information sharing communities together, fostering an appointment and collaborative economy and promoting standardization through smart and sustainable ports, smart ships, intelligent cargo to generate capital productivity gains. Prof. Lind also explained the application of maritime informatics in tackling key global challenges of enhancing predictability of maritime operations, managing supply chain risks and decarbonizing maritime transportation. Collaborative decision making can help enhance predictability of operations through standard data sharing, improved situational awareness and data driven decision making. Shipper driven terminal centric virtual watchtower (VWT) network aims to create a global community for enhanced visibility and supply chain risk management through private and public data driven analytics and collaboration. He emphasized on the need to look at digitalization and collaboration as a powerful duo that generate economic and social value, failing which the maritime ecosystem would get suboptimal results.

To Watch

Visit:
https://youtu.be/MLM98ODIsjE

Practitioner Seminar

Transforming Transport: Lessons from London in integrating institutions and services

'**Transforming Transport: Lessons from London in integrating institutions and services**', a Practitioner Seminar by **Mr. Shashi Verma**, Chief Technology Officer, Transport for London, was hosted on April 21, 2023.

Research Theme: Passenger transportation and sustainable urban mobility
No. of attendees: 53
Moderated by: Prof. Sundaravalli Narayanaswami

Mr. Shashi Verma is a member of Transport for London's Executive Committee. As Director of Strategy, he is responsible for TfL's overall corporate direction. Mr. Verma established the Technology and Data team in 2017 and has been Chief Technology Officer since then. Upon joining TfL in 2002 Mr. Verma established the Corporate Finance team with responsibility for major projects and for the development of corporate strategy. He led on the development of Crossrail, a £16 billion project to build the next railway line in London. The work on Crossrail led to a new theory of agglomeration economics that is now central in the analysis of urbanization. Innovative methods of funding the project brought about two-thirds of the project's capital from local sources. Mr. Verma also worked on other projects such as the East London Line and White City, which resulted in the building of the Westfield shopping mall, the UK's largest. Since 2006 he has been responsible for the operation of TfL's revenue collection system including the Oyster card, the largest smartcard-based ticketing system in the world; and, advising the Mayor of London on fares and ticketing policy. In 2011 he added responsibility for integrating all customer facing activities and for running TfL's customer service operations. Mr. Verma has led the development of contactless payments since 2007 and implemented this successfully on TfL's systems starting in 2012. Contactless payments remain the most successful FinTech innovation anywhere in the world. In the process he has developed capability for technology development and globally leading innovation in a public sector organisation. The creation of the Technology and Data team in 2017 led to further improvements in TfL's technology delivery. He came to TfL from consultants McKinsey and Company, where he worked with clients in the heavy industrial, mining, and petroleum sectors. Mr. Verma has a Bachelor of Technology degree from the Indian Institute of Technology, Kharagpur, and a Master in Public Policy from the Kennedy School of Government at Harvard University. He taught at the Kennedy School for a year and received an award for excellence in teaching.

Mr. Shashi Verma delivering a seminar on 'Transforming Transport: Lessons from London in integrating institutions and services'

Mr. Shashi Verma with Prof. Sundaravalli Narayanaswami

Talk Summary

Mr. Verma delivered a highly insightful presentation on Transport for London (TfL) and its journey of transforming the city of London's public transport system. He strongly emphasised upon the need for adopting public transport and incentivising its use over private vehicles. He demonstrated the on-ground impact of institutional integration and policy changes upon a range of factors including better air quality, efficient land use, improved public health statistics, accident reduction, greater accessibility, etc.

Panel Discussion

Digitizing Logistics Services

An online panel discussion titled '**Digitizing Logistics Services**' was organized on March 26, 2024.

Moderated by: Dr. Debjit Roy
Discussion Theme: Freight transportation and logistics
No. of attendees: 113

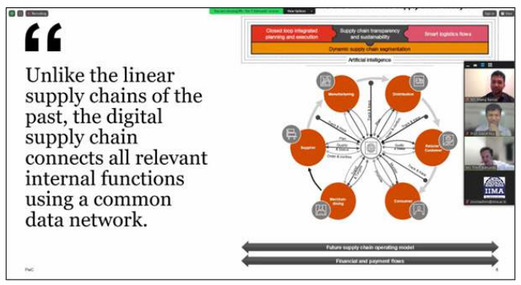
Panelists:

Mr. Tim T Edmunds
Partner,
Sustainable Value Chain
Strategy & Transformation
PwC

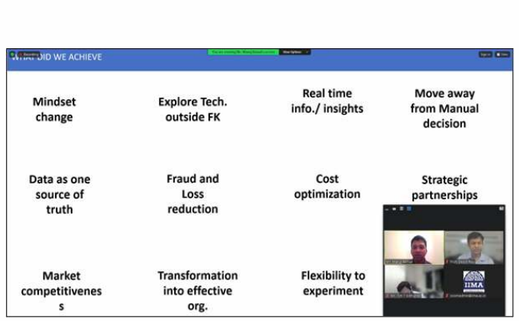
Mr. Manuj Bansal
Senior Director,
Supply Chain Network Design,
Flipkart

Discussion Summary

Dr. Debjit Roy joined by the distinguished panelists Mr. Tim Edmunds & Mr. Manuj Bansal for the panel discussion



Panelist, Mr. Tim Edmunds, delivering his presentation and keynote for the discussion



Panelist, Mr. Manuj Bansal, delivering his presentation and keynote for the discussion

The cost of logistics is a major concern for many low and middle income countries like India, China and Vietnam. Recent times have seen many disruptions in the supply chain, like, Covid-19 pandemic, Suez canal crisis and Russia-Ukraine war which has forced supply chain managers to look at ways to make supply chain resilient, one of which is digitization. The boom in e-commerce and rising customer expectations of same day zero cost delivery has put further pressure on businesses. In light of these circumstances, certain questions emerge like - How to digitize and who should initiate that? What should be the focus of such digitization?

Mr Tim Edmunds started the discussion with his views on connected supply chains. He underlined the key challenges faced by the industry which include high market volatility, regulatory pressure towards sustainable and socially responsible supply chains, challenging economic conditions and increasing customer expectations. Underlying the importance of improving visibility as the core goal of digitalization, he emphasized on a need to look at supply chains from linear to circular ecosystems where technology is implemented holistically to enable end-to-end connectivity. The four key components of a connected supply chain include integrated supply chain partners, data driven decision making, responsive to customer needs and ability to take smart decisions. He further explained how digital leaders are driving digital transformation in supply chains and presented a five step starting approach towards building a connected supply chain. He also showcased two cases where digitization helped achieve cost optimization.

Mr. Manuj Bansal started by explaining the difference between digitization, digitalization and digital transformation. Digital transformation aims to improve efficiency and effectiveness through data availability, elimination of subjectivity and data driven decision making. The three major barriers in digital transformation are organizational culture, resistance to change and legacy infrastructure. He further explained the process of digital transformation through the digital transformation journey at eKart which enabled significant savings.

The ensuing discussion yielded many important takeaways, some of which are-

1. The increased pressure on topline and bottomline along with increased customer expectations has forced businesses to optimize cost and digital transformation is an enabler of such optimization.

2. Logistics industry needs to understand the needs of other businesses and design their supply chains accordingly.

3. There is a clear two stage approach towards understanding the digitization needs. The first stage involves value stream mapping through internal consultations to identify the pain points in existing systems and processes. The second stage involves finding solutions to such pain points, which in some cases may not even need digitization.

4. Digital transformation makes sense for business uses for all players, irrespective of scale. Scale can drive the magnitude of digitization.

5. Digitizing the supply chain should start from a process, followed by people and then technologies.

6. Digitizing should be looked at as an enabler for humans, and not displacement. It helps improve the quality of work and add to the skills of the people.

7. Digitization should be done in a manner that creates value for all players of the supply chain to facilitate information sharing.

8. The biggest benefit of digitization lies in its potential in optimizing cost.

Knowledge Session on - ‘Grant Proposal Writing’

The Centre organised a knowledge session on '**Grant Proposal Writing**' by **Dr. Subhrajit "Subhro" Guhathakurta**, Professor, Georgia Tech School of City & Regional Planning, on December 16, 2023.

Dr. Subhrajit "Subhro" Guhathakurta delivered a knowledge session on 'Grant Proposal Writing'

Description:

Prof. Guhathakurta provided valuable insights from his rich experience of receiving several grants from prominent funding agencies of the US. Following are the key takeaways from the session:

1. It is important to understand and align one's research interests and goals with that of the funding agency. Reviewers in funding agencies use multiple factors while making a decision about accepting or rejecting a grant request.

2. Prof. Guhathakurta emphasized on the need to explore hard problems for research and create innovative solutions for the same. A thorough review of the literature is essential to attain clarity about how the problem has been dealt with.

3. While applying for a grant, it is important for the applicant to highlight the element of novelty in their approach and its potential in generating better results.

4. Articulation of the idea within limited words is the key for a successful application. It is better to receive feedback from a diverse pool of peers to ensure the message is conveyed in a persuasive manner and revisions can be made, wherever necessary.

5. Justification of funds is another crucial component of proposal writing.

6. Proposal writing varies according to the type of research and an applicant should read successful proposals to get a flavor of what makes a proposal engaging and persuasive.

7. In cases of unsolicited proposal submission, the main focus should be understanding pain points and issues that the funding agency cares about, and conveying the benefit of funding research to tackle those problems.

One must note that there is always an element of uncertainty in securing a grant and there is no predetermined approach for a favorable decision.

Dr. Subhrajit "Subhro" Guhathakurta with Prof. Sandip Chakrabarti alongside the on-campus attendees

Workshop on Electric Vehicles and Smart Mobility

One-Day Workshop on 'Electric Vehicles and Smart Mobility' organised by CTL

CTL IIMA organized a one-day workshop on the topic 'Electric Vehicles and Smart Mobility' on August 12, 2023 at the IIMA campus. The workshop examined the market structure, emerging trends, policy and regulatory environment, opportunities and challenges for the EV industry, EV supply chain resilience, digital technologies for smart mobility, consumer adoption and hesitation, low-carbon solutions for smart cities and shared mobility solutions among others.

The workshop consisted of keynote talk, panel discussions, policy presentation, breakout discussion and research talks by a panel of distinguished guests from industry, academia and government. The audience gained a lot from the discussions surrounding smart and shared mobility, environmental enthusiasm, micromarketing and customer segmentation, behavioral nudges and innovative business models.

The workshop schedule was structured as follows:

Sr. No.	Workshop Activities	Key Speakers/Moderators
1.	**Inauguration & Welcome Address**	Dr. Satish Deodhar, Dean (Faculty), IIMA
2.	**Keynote Speech**	Ms. Suman Mishra, CEO, Mahindra Last-Mile Mobility
3.	**Panel Discussion: Electric Vehicle Supply Chain**	**Moderators:** Prof. Debjit Roy and Prof. Sandip Chakrabarti, Co-Chairpersons, CTL **Panelists:** Ms. Suman Mishra, CEO Mahindra Last-Mile Mobility Mr. Divya Chandra, Program Director - Atul Auto Ltd. Mr. Arun Pratap Singh, Founder & COO - Matter Representative from MG Motor Dr. Ranga Srinivas Gunti, Head of Talent Development and General Manager at Tata Passenger Electric Mobility Limited, Tata Motors
4.	**Research Talk**	Prof. C. S. Shankar Ram, IIT Madras Prof. Prahalad Venkateshan, IIMA
5.	**Presentation: AMTS BRTS Sustainable Transport System**	Mr. Vishal Khanama, General Manager-BRTS and Senior Assistant Commissioner, AMC
6.	**Research Talk**	Prof. Debjit Roy, IIMA Prof. Sandip Chakrabarti, IIMA
7.	**Panel Discussion : Smart Mobility, Technology and Sustainability**	**Moderators:** Prof. Debjit Roy and Prof. Sandip Chakrabarti, Co-Chairpersons, CTL **Panelists:** Dr. Ashish Verma, Professor, Indian Institute of Science, Bangalore Dr. Neha Sharma, Assistant Professor, The Wharton School, University of Pennsylvania Mr. Ram Divedi, Board Member, Pravaig Dynamics Pvt. Ltd. Mr. Divay Pranav, Director of Policy & Partnerships, Yulu

Background:

Lighting of the lamp by Dr. Satish Deodhar (Dean-Faculty), Prof. Debjit Roy, Prof. Sandip Chakrabarti & Prof. Prahalad Venkateshan

Prof. Satish Deodhar inaugurated the workshop by lighting the lamp and delivered the inaugural address. It was followed by the Keynote Talk by Ms. Suman Mishra where she shared insights from her rich industry experience and provided exciting research questions. The panel discussion on 'EV supply chain' helped the participants understand the opportunities, challenges and innovations happening in the EV ecosystem in India. Our panelists, Ms. Suman Mishra, Mr. Divya Chandra, Mr. Arun Pratap Singh and Dr. Ranga Srinivas Gunti made the discussion insightful. The panel discussion was followed by a presentation by Mr. Vishal Khanama where he discussed how AMTS-BRTS is making mass transit in the city smarter and greener. The research talks by Prof. Shankar Ram Coimbatore Subramanian , Prof. Prahalad Venkateshan, Prof. Debjit Roy, and Prof. Sandip Chakrabarti covering vehicle dynamics, facility location choice problem, dynamic allocation policy and critical evaluation of EV, respectively, added depth to the discussions of the workshop. The breakout discussions after lunch helped participants brainstorm on pressing EV issues and engage in a free flow of ideas among themselves. Dr. Ashish Verma, Mr. Ram Divedi, Dr. Neha Sharma, and Mr. Divay Pranav were the panelists for the second panel discussion of the day on 'Smart Mobility, Technology and Sustainability'.

The participants of the workshop included faculty, students and research scholars from IIMA and outside IIMA, representatives from industry and startups and other related stakeholders. The following topics were discussed in the workshop:

1. EV supply chain: challenges and opportunities
2. Drivers of electrification in India
3. Total cost of ownership of ICEVs vs EVs
4. Policy framework surrounding EVs in India
5. Electrification and integration of public transport systems
6. Resilience of EV Supply Chains
7. Adoption of EVs by Businesses and Consumers
8. Production Capacity Building for EVs
9. Role of vehicle dynamics in EV
10. Location of EV charging stations amidst service level constraints
11. Performance analysis framework for shared electric mobility systems
12. Critical analysis of EVs in meeting global pathways to net zero
13. Systems approach for Sustainable Transportation
14. Behavioural nudges to promote shared mobility
15. Key challenges in mobility and sustainability in India

Synopsis of Sessions held during the Workshop

Introduction

Welcome Address by Dr. Satish Deodhar, Dean (Faculty), IIMA

The global spotlight on the transportation industry, which emits around 25% of total emissions (Transport, n.d.), has generated a significant interest in developing alternative pathways and technologies for the decarbonization of the transportation industry. While research on developing alternatives to Internal Combustion Engine Vehicles (ICEVs) is mostly technology agnostic, Electric Vehicles (EVs) are emerging as the most compelling solution to reduce carbon emissions and combat the growing threat of climate change. The Indian EV industry will grow at 49% CAGR between 2022-30, and the annual sales of EV units in India is estimated to hit 10mn by 2030 (Ministry of Finance, 2023). The growth in the EV ecosystem is also steered by reduced consumer hesitance for EVs, policy support for EV manufacturing and the institution of stringent regulatory requirements to curb automotive emissions. India has pledged to achieve carbon neutrality by 2070, reduce the carbon intensity of GDP by 45% by 2030 and cut down projected carbon emissions for 2030 by 1 billion tonnes. A study by ICCT reveals that the transport sector contributes 14% of the total emissions in India and continues to grow at a worrying pace. Road transport contributes to more than 90% of India's total transport sector emissions, making it essential to decarbonize road transport through zero-emission vehicles like EVs. Government push for fostering a favorable EV ecosystem for EV manufacturers include schemes like FAME, PLI for Advanced Cell Chemistry, semiconductors and auto components, Voluntary Vehicle Fleet Modernization Programme (V-VMP), EV30@30 and state EV policies. The industry also plays a big role in transitioning towards an EV-oriented ecosystem through commitments, collaborations and consortiums.

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Increasing internet penetration, smartphone access and technological innovations improving interconnectedness are driving monumental shifts in mobility infrastructure and customer expectations in search for solutions that make urban travel more efficient, accessible, convenient, sustainable and faster through a single, eco-friendly platform. By integrating technology, data, and transportation systems, urban planners and the transport industry aim to improve the overall transportation experience for individuals and communities in urban areas through smart mobility solutions while reducing congestion, lowering emissions, and enhancing safety. The growing interest in this segment is demonstrated by the increasing number of startups exploring smart mobility solutions like intelligent transportation systems, telematics, connected vehicles, autonomous vehicles, shared mobility, multimodal integration and smart infrastructure.

The growth in the EV sector also comes with its own set of technological, infrastructural, regulatory, operational, sourcing and strategic challenges. Academic research in facility location, network optimization, battery technology, grid integration, smart mobility and autonomous vehicles, range and efficiency optimization, and policy impact assessment are some of the many ways in which academia may help solve many real-world India class problems in increasing EV adoption in India and promoting smart and sustainable road transport systems. The government can incentivize EVs and shared mobility and disincentivize conventional ICEVs and private mobility. Finally, customers need to actively adopt sustainable and responsible mobility solutions to help the industry grow and achieve scale, thereby enabling a virtuous cycle of growth. The proceedings are divided into two sections based on the larger theme of the workshop, namely, 'EV Supply Chain' and 'Smart Mobility, Technology and Sustainability'.

Section 1 : Electric Vehicle Supply Chain

Overview of the Indian Automotive Industry

The Indian automotive sector is a driver of growth in the country and contributes to around 7.1% of the total GDP of India, which is expected to rise to 12% by 2026. It contributes to 49% of the manufacturing GDP and employs 40 million people in India (Ministry of Finance, 2023). The industry generates an annual revenue of $108 billion (Indian Auto Industry Grows to ₹8.7 Lakh Crore in FY23: Report, 2023). It is also a major driver of R&D in the country with the industry alone responsible for 8.1% of national R&D expenditure (Auto Components Industry in India - Investment Opportunities, n.d.). India is a global leader in automobile manufacturing and is the 4th largest manufacturer of passenger and CVs, the largest producer of tractors and 2&3Ws. The industry contributes to 4.1% of total merchandise exports (Ministry of Heavy Industries, 2023). Automotive component exports amounted to $20 bn in FY 2023 (ACMA, 2023). The industry plays a pivotal role in making Make in India successful through the support of various incentives and policies encouraging domestic production of automobiles.

However, the industry poses the triple challenge of energy security, import dependency and carbon emission. India imports around 87% of its oil, costing the economy $158 bn (FY 2023). The transportation sector consumes around 60% of the total oil. Import bills for spare parts and components for manufacturing stood at $16.5 bn in 2023. The transport sector is also the fourth largest carbon emitter in India, contributing to around 13.5% of the total CO2 emissions in India.

Rising concerns around sustainability have led to a boost in the EV sector. According to the VAHAN dashboard by MoRTH, FY 2022-23 saw registration of 7.46 lakh units of EVs and 1.85 lakh units of Petrol-Hybrid vehicles. EV-India dashboard predicts a CAGR of 45.5% between 2022 and 2030. The EV industry has the potential of 5 crore direct and indirect job creation by 2030. While EVs currently constitute 2% of the total vehicle sales, Jain et al. (2022) estimate that 35-40% would be EVs by 2030. The drivers of EV adoption in India would be 2&3Ws, with an estimated 45% sales to be electric by 2030. LCVs, 4W PVs and buses are expected to reach 20–25% EV penetration by 2030, while HCVs would remain a challenge to electrify.

The following sections would discuss the potential of EVs in solving the problem of sustainability through domestic production of EVs, making EV supply chain resilient by indigenization and accelerate energy transition to green grid.

Keynote Speech by Ms. Suman Mishra

Benefits Of Transition To E-Mobility

The electrification of the Indian road transport presents many benefits and opportunities for the Indian automotive sector. Some of them are listed below:

Environmental benefits-

1. Emissions savings from e-mobility

The global transition to electric is driven by emissions savings from such transition. Emissions from vehicles can be classified into tailpipe emissions and non-tailpipe emissions. Tailpipe emissions refer to exhaust released from a vehicle's tailpipe in gaseous form due to combustion of fossil fuel used in driving the vehicle. Harmful gases include carbon, sulfur, nitrous oxides, hydrocarbons, and particulate matter. EVs discharge zero tailpipe emissions since no fossil fuel is used in their operation. Undoubtedly, the source of electricity used in EV charging needs to be generated from renewable means, and efforts are being made globally to power national grids through renewable sources, as envisioned in the 2015 Paris Agreement.

Non-tailpipe emissions arise from wear and tear of vehicle components, evaporative emissions from fuel tanks and fueling process and PM released due to usage of roads in the form of dust. Emissions from energy-intensive mining activities for battery manufacture lead to a higher initial carbon footprint vis a vis ICEVs. However, the life cycle emissions savings from zero tailpipe during operations make EVs a better alternative for a sustainable future. The below figure compares the lifecycle emissions of EVs and ICEVs across Europe, the US, China and India.

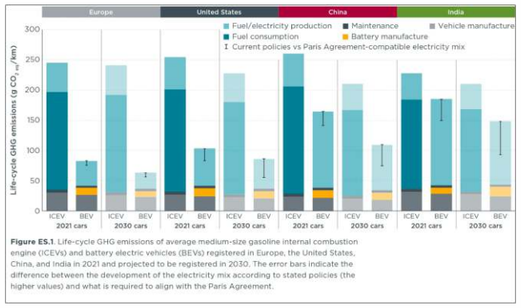

Figure ES.1 Life-cycle GHG emissions of average medium-size gasoline internal combustion engine (ICEVs) and battery electric vehicles (BEVs) registered in Europe, the United States, China, and India in 2021 and projected to be registered in 2030. The error bars indicate the difference between the development of the electricity mix according to stated policies (the higher values) and what is required to align with the Paris Agreement.

Lifecycle emissions comparison across different regions (Source:Troskie 2023)

2. Pollution control and reduction

Indian urban areas suffer from the problem of severe pollution. 39 Indian cities featured in the IQAir list of the 50 most polluted cities worldwide. As a major contributor of pollution (92% of the total emissions by the transport sector), the decarbonization of road transport not only leads to reduced GHG emissions but also helps improve air quality across India. CO2, PM 2.5 and PM 10 generated from road transport operations degrade air quality, leading to a higher incidence of respiratory disease and hindering mobility due to lower visibility caused by smog formation. With zero tailpipe emissions, EVs are a potent tool in the fight against air pollution. A study by Ibarra et al. (2017) revealed that EVs can reduce noise emissions by 10 dBA compared to ICEVs, making roads quieter. However, the silence of EVs has generated concerns regarding road safety for pedestrians and riders of 2Ws due to an increase in the propensity of accidents on noisy Indian roads.

3.Accelerate grid transition

Ensuring EVs truly achieve their objective of zero emissions would involve ensuring the source of electricity that powers them is also carbon neutral. Scope 2 emissions refers to the carbon emissions released by the source of electricity and heating. In the case of EVs, scope 2 emissions would be calculated by looking at the source of electricity of their charging stations. This robust and clear system of emissions calculation motivates grid transition from non-renewable to renewable sources.

Economic benefits-

1. Energy security

There exists a huge deficit between domestic oil production and consumption in India. Almost 85% of India's oil is imported and the transport sector alone is responsible for 50% of its consumption. Further, the sector consumed 4 EJ of energy in 2020, amounting to a fifth of the national energy consumption (Kamboj et al., 2022). In the passenger segment, 2Ws are the largest consumers of energy (31%), followed by 4Ws (27%), while trucks are responsible for almost 80% of freight segment energy consumption. By electrifying India's road transport fleet, India can reduce its dependency on oil imports for energy consumption and slash India's burgeoning oil import bill. Oil prices and supplies are not affected by just demand and supply dynamics but also by other factors like economic blockades, sanctions, geopolitical problems, cartelization and natural and manmade calamities. Further, the savings from oil imports can be effectively diverted to promoting R&D innovation and adopting EVs in India.

2. Enhanced operational efficiency in transportation system

ICEVs face many problems like low fuel efficiency, noise and air pollution, high maintenance costs and regulatory instability due to changing emissions mitigation norms. ICEVs are inefficient in converting fuel energy into vehicle movement, leading to the wastage of a significant amount of energy as heat. Further, regenerative braking in EVs helps recover energy during braking by converting kinetic energy back into electricity to recharge the battery. Unlike ICEVs, EVs require a simplified cooling system to regulate engine temperature since electric motors generate less heat. EVs are also embedded with advanced sensors that collect real-time data and help diagnose and predict vehicle health and performance. The enhanced efficiency helps lower operational costs, increase vehicle lifespan and reduce vehicle maintenance costs.

3. Employment creation

ICEV manufacturing ecosystem has an established market, known technologies, a skilled workforce, standardized practices, a widely followed imitation game and a widespread fueling network. EV manufacturing ecosystem directly competes with ICEV manufacturing since it renders many parts of the traditional vehicle manufacturing supply chain obsolete while simultaneously introducing new dynamics. This change is brought by cutting-edge research in EV design, manufacturing and charging infrastructure. With the emergence of new skills requirements, EV manufacturers are bound to create immense job opportunities, especially for highly skilled workers since specialized knowledge and training are required to handle automated, connected and digitized operations of EVs. The expansion of battery manufacturing also presents a vast scope for job creation for engineering graduates with knowledge of cell chemistry. Constant R&D to optimize and refine vehicular performance and manufacturing process would require a team of highly skilled engineers, scientists, and technicians. Software engineers would be required to work on troubleshooting, cybersecurity and enhancement of user interface of applications in EVs. Finally, the thrust on end-of-life management of batteries would help formalize India's fragmented recycling industry and spur entrepreneurs' entry into this domain.

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4. Create innovative economy

ICEVs have been in popular use for over a century, yet constant design, features and performance innovations are required to retain and attract customers. With EVs still in the nascent stage, there exists immense scope for R&D in EVs, leading to innovation across different domains of the value chain. India poses a unique set of challenges due to geographic, topographic and demographic diversity. Solutions to fleet electrification problems must be uniquely crafted for India through innovation and entrepreneurship. In fact, this characteristic of the EV ecosystem has led to the democratization of vehicle manufacturing, which was once considered a play area of select large oligopolists. Numerous startups have entered to transform the way Indian people move across all vehicle segments. This trend will continue to grow rapidly and provide impetus to entrepreneurs trying to enter the manufacturing space.

5. Macroeconomic benefits

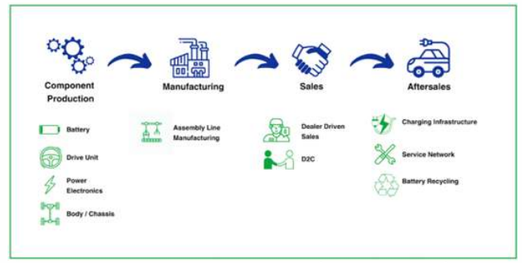
EVs also benefit the national economy in myriad ways. As discussed above, reduced dependency on oil would lead to a fall in India's import bill and save crucial foreign reserves while keeping India's current account deficit under control. Similarly, higher energy efficiency of EVs would reduce energy consumption and emissions. Simpler mechanics of EVs lower maintenance costs, leading to massive national savings and expanding vehicular lifespan. Zero tailpipe emissions are expected to save millions of rupees city administrations spend on pollution control and prevention measures. They are also expected to reduce treatment costs through a decrease in the incidence of respiratory health problems.

Before discussing the challenges faced by EV manufacturers and customers in India, it is important to understand the stages and levels in the supply chain of EVs. The following section discusses the value chain for EVs in detail.

Ms. Suman Mishra addressing the audience during her keynote speech

Understanding EV Supply Chain

Despite being very similar to the ICEV value chain, the EV supply chain has its own peculiarities and complexities that make it essential to understand the current state of the EV supply chain in India. While the four main stages of EV supply chain are similar to ICEVs, namely, component production, vehicle manufacturing, sales and after sales, the differences occur at the operational level in each stage. The below figure illustrates the different stages of the EV supply chain with important operational levels in each stage.



EV manufacturing supply chain (Author's Analysis)

1. At the stage of component production, the primary level involves battery production. Battery packs are the singular most essential component of an EV. Batteries for EVs can be lead-acid batteries or lithium-ion batteries. While lead acid batteries are cheaper, lithium-ion batteries have higher energy density and last longer leading to a better TCO advantage vis a vis lead acid. However, lithium-ion battery manufacturing requires rare earth metals like palladium, nickel, cobalt, manganese, platinum and lithium, among others (Goel et al., 2021). This requires mining and retaining of these metals, manufacturing cells for advanced automotive components and assembling battery packs for supply to OEMs. The drive unit level requires design and manufacture of EV-compatible powertrain components, their assembly and supply to OEMs. Power electronics like chipsets, cables, chargers, converters and VCUs are imported since the production capacity of most of these components has yet to be established in India. Finally, in-house chassis production completes EV value chain at the component level.

2. Manufacturing vehicles has been traditionally done through assembly and subassembly lines. EV manufacturing differs substantially from ICEVs due to differences in design, components and manufacturing process. Design alterations in car underbody, production lines and tools, battery management system, high-tech electronics and cyber safety measures need to be imbibed in EVs. In contrast, certain features like spare tires need to be eliminated since they no longer remain relevant. Assembly and subassembly lines for battery packs, traction systems, EV controllers, EV brakes and EV chargers need to be modified to ensure process efficiency in body assembly, paint shop, general assembly and quality. However, minimal wastage from the assembly factory and limited byproducts from the manufacturing process represents the brighter side of EV manufacturing.

3. The sales process in EVs is expected to be mainly similar to ICEVs, with the dominance of dealer-driven sales through the existing dealer network. Additionally, emerging startups and OEMs may follow the D2C model for retail customers and fleet owners. However, the upgradation of physical infrastructure at dealer showrooms and upskilling of sales staff requires investment of significant resources to generate considerable demand for EVs.

4. The stage of aftersales represents an enormous challenge for OEMs since it requires a complete overhaul of systems, processes and people. However, it represents an opportunity to grab the first mover advantage through groundbreaking innovations that streamline processes and optimize operations. The first level concerns establishing an expansive charging infrastructure in the country. The companies have to decide if they want to establish a company-owned charging station network or enter into partnerships with third party vendors for constructing and operating charging stations. Further, companies face the difficult choice of adopting the strategy of battery swapping or battery charging since both have their own set of merits and demerits. At the service network level, OEMs need people skilled in electronics and AI to tackle all mechanical and interface level problems. Finally, with concerns about the impact of obsolete batteries after the end of life on the environment, companies have to set an elaborate system for returning and recycling used batteries either through establishing their own recycling centers or partnering with authorized recyclers.

The readiness of the Indian automotive sector to transition towards e-mobility poses a significant challenge in expanding e-mobility in India. Since the Indian EV manufacturing ecosystem is nascent, its growth will depend on our ability to reconfigure existing capabilities and create innovative solutions that solve India-specific challenges. The following section discusses the drivers of electrification in India.

BOX: Are Hybrid EVs the solution for India?

In order to counter range anxiety and overcome scarcity of charging stations, Hybrid EVs are proposed as a viable alternative. Hybrid EVs combine the elements of EVs and ICEVs in a single vehicle that could be run on electric only mode, fuel only mode or a combination of both based on driving situation. It is argued that they help provide an extended driving range, function more efficiently due to regenerative braking and reduce fuel consumption and emissions. However, in the Indian context, promotion of Hybrid EVs would involve substantial diversion of funds from a permanent solution to a temporary and transitory solution. Net zero of road transport is a necessity, and while Hybrid EVs can seem a viable solution to the myriad challenges faced by EVs in India in the short run, they would effectively divert scarce Indian capital in a temporary solution and slow down Indian transition to net zero.

Interaction Session during the workshop

Drivers of Electrification in India

The growth of the automobile sector in India is based on a massive inflow of FDI, abundant manufacturing capacity, availability of skilled talent, cost-competitiveness, unsaturated domestic market and rising export potential (Miglani, 2019). The government has set numerous ambitious goals to decarbonize the Indian economy, foremost being net zero by 2070. Realizing the significant role of the transportation sector in leading such decarbonization efforts, India has joined the EV30@30 initiative that aims to transform 30% of the national fleet into electric by 2030.

However, EV adoption in India will be driven by first and last-mile connectivity in commercial and passenger segments. For HCVs, electrification needs further research for long-distance viability. While some use cases of e-HCVs exist, there are still substantial concerns regarding range anxiety, servicing, carrying capacity, charging time and high cost of operations. Hydrogen as an alternative fuel still needs more research. Also, the production of green hydrogen at the Indian scale is a huge challenge.

India is a cost-sensitive country, and with batteries comprising a significant part of the entire vehicle, the higher purchase price and subsequent replacement of battery packs in EVs make ICEVs more attractive to consumers. The gap widens in the case of 4W and HCVs compared to 2/3W vehicles, making 2/3Ws more suitable to transition to electric first. Moreover, the growth of e-commerce and food and grocery delivery businesses in urban areas help propel demand for electric scooters. With an expected internet penetration of 87% by 2025, the size of the e-commerce industry in India is expected to hit $350 bn in 2030 (India Brand Equity Foundation, 2023). The growing concern for sustainability has led to numerous companies announcing the complete electrification of their delivery fleet. For instance, Zomato plans to electrify 100% of its fleet by 2030 while Big Basket has targeted 70% electrification by 2024. A report by Janakiram et al. (2023) estimates that a quarter of EV sales would be driven by the business of last-mile delivery that uses 2 and 3/4W SCVs.

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Table: EV penetration estimates of the industry outlook on last mile electrification in India.

Segments	Market Size (FY '23) (in '000s)	Penetration estimates (by FY '27) (in %)
E-rickshaw/Car	340	100
3W Passenger (L5M)	360	35
3W Cargo (L5N)	97	40
4W Cargo (>2tn GVW)	154	15

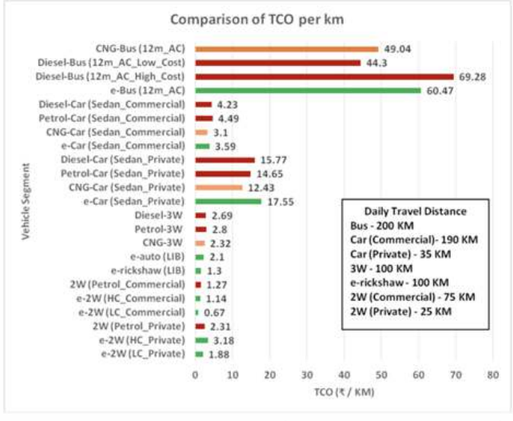
The 3W & 4W SCV (<2tn GVW) is estimated to reach $5 bn by 2027. Since the target to achieve 30% electrification by 2030 does not need to be equally spread across all vehicle categories, 2Ws and 3Ws would act as a catalyst since they are universally accepted and adapted to the specific use of first and last-mile connectivity.

Following are some of the drivers of last-mile electrification in India:

1. Total cost of ownership advantage

As an owner of a vehicle, a person has to incur numerous costs beyond the upfront cost of purchase. Operational and maintenance costs of vehicles include fuel, service, repairs and insurance costs. An efficient way of looking at them is through TCO, which considers the cost of purchase and subsequent operational costs of the vehicle during its lifetime. TCO is helpful for policymakers to design appropriate fiscal incentives in nudging EV adoption and aid fleet owners and consumers in deciding the financial viability of transitioning to EVs. According to Kumar and Chakrabarty (2020), the TCO per km of an e-2W is less than the corresponding ICEVs, even when the battery pack comprises more expensive lithium-ion batteries.

Similarly, e-3W SCVs used for last-mile deliveries can be more cost-efficient than ICEVs when daily usage is more than ~110 km. TCO of electric passenger cars and buses are much higher than ICEVs, making 2, 3 and 4W SCVs the ideal choice for initiating transition over the next few years. This TCO advantage is driving the electrification of the last mile at a rapid pace. Analysis by Atul Auto also reveals 87% annual running cost savings for e-rickshaws vis a vis diesel vehicles if operated for a minimum 100 kms daily since e-autos cost 0.2-0.4 per km.



TCO comparison for Indian vehicles (Source: Kumar & Kanuri, 2020)

2. Proactive policy framework

The efforts by the government to push for alternatives for ICEVs have led to proactive policy formulation for the promotion of EVs in India. With Hydrogen still in the nascent stage of development, EVs have emerged as the frontrunner in India's drive to decarbonize the transport sector. Policy support to EVs help in achieving the triple goal of promoting sustainable transportation, reducing oil import bill and incentivizing grid transition to renewable sources. By preceding electrification through a proactive policy push, the Indian policy outlook has been fairly stable and predictable. It firmly pushes for the electrification of road transport through demand generation incentives and EV production capacity enhancement schemes. Some of the major schemes, roadmaps and initiatives are the following:

(i) FAME I & II: EVs are an expensive choice for sustainability in a cost-sensitive country like India. FAME is a flagship scheme of the Government of India focusing on demand generation through subsidies. FAME is a multi-phased scheme that provides subsidies to EV customers based on battery capacity across all vehicular segments to reduce disparities in the upfront cost of EVs and ICEVs. The scheme was first launched in 2015 for a period of two years, following which it was extended into a second phase that also included funding support for charging infrastructure and R&D incentives. Several state governments also launched their EV policies to accelerate EV adoption by providing additional financial assistance to EV customers.

(ii) PMP: Phased Manufacturing Program was introduced in India in 2022 to promote localization of EV manufacturing through a chronologically distributed graded customs duty enhancement across EV manufacturing, assemblies/subassemblies and component manufacturing. It covers AC/DC chargers, AC/DC motors, AC/DC controllers, power control units, energy monitors, contractors, brake systems, battery packs, lithium-ion cells and electricity compressors, among others.

(iii) PLI: The PLI for Auto and Auto Components scheme intends to enhance the productive capacity of EV manufacturing in India through direct fiscal incentive to OEMs manufacturing EVs and EV components up to 18% of EV sales. OEMs could receive 13-18% of sales with scope for an additional 5% benefit if the components of BEVs and HFCVs are manufactured in India. Similarly, PLI ACC targets the establishment of 50 GWh ACC manufacturing capacity in India through direct fiscal support to reduce import dependence on cells for batteries. It also incentivizes manufacturing cell parts in India, localizing the EV supply chain and substituting imports.

Further initiatives include the formation of the National Mission on Transformative Mobility and Storage, a hike in FAME incentive on EVs, reduction of GST on EVs and EV chargers/charging stations from 12% and 18% respectively, to 5% and exemption of green-plated e-CVs from permit requirements. Such policy interventions drive industry growth by incentivizing EV adoption and ensuring long-term support from the government.

Timeline of key EV related initiatives (Source: e-AMRIT, n.d.)

3. Infrastructure setup and ease of charging for 2&3W

EV charging can be classified into three levels: Level 1 involves home-based charging through a standard 15 - 20 amp 120V socket found at home (6-8 hours), level 2 charging is done through a 240V socket (4 hours) while level 3 involves charging through a DC fast charger that can charge batteries within 30 minutes (Goel et al., 2021). 2 & 3W EVs charging is relatively hassle-free since they can be charged through a 120V socket at home due to lower battery capacity requirement of around 11.25 - 4 GWh. On the contrary, 4W EVs require specialized battery charging cords, sockets, and expensive DC fast chargers. Inadequate battery charging infrastructure in public spaces and the adverse impact of fast charging on the life cycle of expensive batteries also decelerate the adoption of 4W EVs. At the same time, such considerations do not affect 2 & 3W EV categories.

Despite government support, cutting-edge innovation and a clear understanding of environmental benefits that accrue due to electrification, the EV manufacturing industry faces numerous challenges at multiple levels of demand generation, supply chain resilience and physical infrastructure. The following section discusses the challenges faced by the EV industry in detail.

Panelists Mr. Divya Chandra, Ms. Suman Mishra, Mr. Arun Pratap Singh & Dr. Ranga Srinivas Gunti along with the moderators Prof. Sandip Chakrabarti & Prof. Debjit Roy, during the Panel Discussion on Electric Vehicle Supply Chain

Challenges in Electrifying Road Transport in India

There exists enough academic literature, industry consensus and policy push that make it clear that ICEVs are nearing their age and will soon become obsolete. Global warming, climate change and environmental degradation have propelled world leaders to pledge ambitious targets towards decarbonizing their economies, and the answer to most of their problems can be solved by going electric. Transportation has taken a lead in harnessing the true potential of electric. However, it is beset with challenges at numerous levels.

Consumer level-

Customers of 2,3 and 4Ws are well aware of how the market for ICEVs functions. EVs are still at a nascent stage in India and hence, consumers are yet to get in terms with how the EV ecosystem works. Following are some of the challenges in transition to e-mobility at the consumer level:

1. Explaining TCO to customers: The cost of a vehicle for an average Indian is the upfront payment made to the dealer. A huge disparity exists between the initial upfront cost between EVs and ICEVs. There has been little discussion on TCO in the past since operational costs have been considered to be directly dependent on the use of the vehicle by the customer. A holistic look at TCO may convince customers about the economic benefit of owning an EV. However, with a lack of any prior discourse on TCO, OEMs find it hard to explain TCO to customers and consequently miss out on the opportunity of converting a lead into a sale.

2. Demand generation: With a well-established ICEV market, it becomes difficult for EV manufacturers to generate demand for their limited number of models. Apprehensions regarding resale value, battery degradation, replacement cost and safety of EVs are a huge challenge for OEMs. Batteries represent around 40-50% of the total vehicle cost. Customers are apprehensive of the impact of battery obsolescence and degradation on the resale value of an EV. News regarding battery explosion or meltdown creates a negative perception among customers regarding the safety of EVs.

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3. Range anxiety: Customers hesitate in buying EVs because of a fear of mid-journey vehicle breakdown due to low battery. Further, customers are apprehensive about the range claimed by OEMs. An expansive fuel station network weighs heavily in the minds of customers when they decide to buy a vehicle. This is despite EVs providing enough range for daily intra-city travel.

4. Charging infrastructure: With the availability of home charging, fast charging and battery swapping, customers feel confused about which charging method should be used to extend battery life and attain maximum range. Different charging standards and multiple connectors also create confusion and inconvenience for customers. Inadequate charging infrastructure contributes to range anxiety.

Manufacturer's level-

Constant pressure from government, civil society and the general public has prompted OEMs to develop alternatives to ICEVs. The reasons include frequent regulatory changes in emissions standards, compulsion to align with global goals for decarbonization at the company level and protection from negative publicity in the media. Despite investing rigorously in the R&D of EVs, manufacturers face several challenges. Following are some of the challenges:

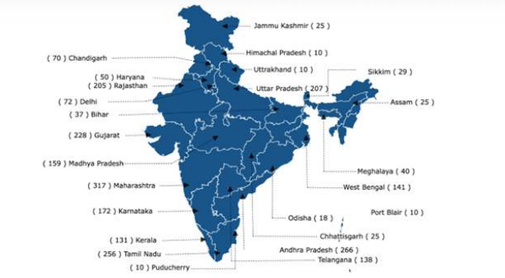
1. Supply Chain Resilience: As an emerging industry, the supply base for EV components in India is very small. Reliance on imports of many critical components like lithium-ion

Table : Level of localization of EV components in India

Component	Localization in India	Remarks
Cells	Very Low	Primary challenge is the availability of critical minerals. PLI ACC is expected to boost indigenization overtime.
BMS and VCU	Emerging	Software and manufacturing capability exists in India while design capability is emerging.
Motor and MCU	Emerging	Manufacturing capability of motors exists although improvement in efficiency is required. Magnets used in motors are currently imported and act as a hurdle in localization.
Chassis and Body	Very High	Manufacturing and design capabilities already exist. Already highly localized but body shell die tooling is still dependent on other countries.
Bare PCBs	Very Low	Multi layer manufacturing capability is not available and still imported. Only 30% of the demand is met by local manufacturers
Power electronics	Very Low	High potential of localization but requires heavy capital investment.
Others (Gearboxes, brakes, lights, tyres etc.)	High	Large supplier base already in India with technology and design expertise.

2. Charging infrastructure: A robust nationwide charging network is critical for promoting EVs in India. However, the current situation in India displays signs of a chicken and egg problem. Establishing a robust charging station network in a large country like India entails a huge investment. However, there needs to be more EVs on roads to make the business of charging stations financially viable. Similarly, customers hesitate to buy EVs because of a lack of expansive charging infrastructure. This vicious cycle leads to range anxiety and pulls down the EV adoption rate. The problem is particularly acute for 4W and CVs since 2 & 3Ws can be easily charged at home. The Model Building Bye-Laws for Electric Vehicle Charging Infrastructure released by the Ministry of Housing and Urban Affairs in 2019 mandated a charger density of one charger per 3 square km. Further, a charger station must be constructed every 25 km on both sides of the highways. Despite official plans and policies in place, India's public charging station density is poor.

In order to correct this, the government included the construction of charging infrastructure in its FAME II scheme. It would provide incentives to establish 2877 charging stations across India with a budgetary outlay of Rs, 10,000 cr.



Charging stations under FAME II (Source: e-AMRIT, n.d.)

3. Battery manufacturing and recycling: A battery pack is the lifeblood of an EV. They make up almost half of the total cost of an EV. Hence, their manufacturing, distribution and end-of-life treatment are essential for achieving a competitive advantage in the domestic and global markets. Lead acid batteries, in which India has manufacturing capability, are not used in EVs. Instead, lithium-ion batteries are used in EVs due to higher efficiency, compact size, lower weight, higher energy density, lower maintenance and longer life cycle. India is deficient in critical metals required to manufacture cells and battery packs. However, with a greater push for EV adoption, India needs to indigenize battery pack manufacturing by keeping Indian roads and local conditions in mind. It is essential to build the right cell chemistry for India through a detailed study of battery performance on Indian roads. This would require a huge investment in R&D, the establishment of testing facilities and the collaborative effort of all stakeholders.

Disposal of batteries is another area where investments are needed. The e-waste generated by depreciated batteries needs systematic management. Extraction of rare metals from such advanced batteries requires skilled people, while the current

recycling ecosystem is mainly informal and unskilled. Another challenge in battery recycling is the fixation of responsibility among customers, producers or third-party independent recycling vendors after the end of battery life. Such questions require consultative deliberations between policymakers and industry partners.

Other challenges

Numerous other challenges hindering the growth of EVs still need to be addressed. Some of them are:

1. Hesitation among financiers in financing EVs due to lack of any structured methodology for calculation of end of life value of the asset, or after battery degradation.

2. Range anxiety can be solved by increasing the charging capacity of battery packs. However, such an increase would make vehicles costlier and heavier. This tradeoff requires a better understanding of Indian road conditions and designing battery systems accordingly.

3. A huge skill gap exists in advanced automotive technologies like embedded systems, power electronics, and high-powered computing. A similar gap exists in battery recycling and vehicle servicing, where workers comfortable with technology are limited. OEMs would face a challenge in upskilling existing service workers to make them expert in handling advanced software and hardware issues like hacking, cybersecurity, troubleshooting and handling of automated tools.

4. Policy and regulatory stability are essential in building industry and consumer confidence to drive EV adoption. Frequent changes in the regulatory environment, like testing and AIS disrupt business operations and impose additional compliance costs. Also, a lack of clarity in regulations tends to create confusion. For instance, the criteria of determining localization levels need extensive detailing to avoid confusion and ensure compliance.

There are some unresolved issues regarding the aftersales market for EVs. Unlike ICEVs, which are highly standardized, EVs are a playground of innovation for every OEM and startup. In such a scenario, interoperability of spare parts and components may pose a challenge in the emergence of an aftersales market.

BOX: Is retrofitment of existing fleet a solution?

Retrofitment in vehicles refers to the addition, upgradation or modification of certain components or features of a vehicle that alters partly or wholly the vehicle's operations. Retrofitment is usually done through prefabricated kits. Interestingly, retrofitting of existing ICEVs into EVs can help in the rapid transformation of the road transport fleet. However, retrofitting ICEVs into EVs poses several serious challenges:

1. The cost of retrofitment would be extremely high since lithium-ion batteries would be required to be fitted in ICEVs.

2. Additional costs would be incurred in replacing components not geared towards thermal management, EV management, current flow or drainage. These problems are reflected in vehicular performance which does not attain the same efficiency level as new EVs.

There is a lack of consensus on who (OEM or kitmaker or kit fitter) would bear the liability in case of any damage to the vehicle after retrofitment.

Way Forward

The onset of the EV era has brought in new business models, strategies, technologies, sales models and factors affecting consumer behavior. The industry faces numerous challenges in establishing a stable supply chain for vehicle components and vehicles in India, which were discussed above. Following are some of the ways to overcome these challenges:

1. There is a need for better control over the EV supply chain in India. Localization is a must to prevent shocks from abrupt supply chain disruptions and leverage cost competitiveness in the Indian market if India wants to become a reliable exporter of EVs to the global market. Policy push to achieve localization through fiscal incentives is driving manufacturing activity but many regulations need further clarification. The government and the industry need to engage in deeper consultations over this issue.

2. EVs are hyper-competitive. They need constant improvement and updation in body design, vehicle dynamics, control systems and software. Operating systems, high-powered computers, automotive-grade microcontrollers, software and automotive-grade electronics are the future. Differentiating factors would be software capabilities. This requires the firm to adopt an innovation mindset involving long-term investment in R&D with patience and confidence in the team. There is a need to enable a framework that changes staff mindset from a delivery mindset to an innovation mindset.

3. EVs allow OEMs to collect massive data from vehicle operations through telematics. Such vehicular performance data presents scope for predictive maintenance, innovation in spare parts to extend their life, impact warranties and insurance, improve driver's safety and enhance efficiency. OEMs need to control networks and software completely to leverage data and achieve a competitive edge in manufacturing or sales. For this, substantial investment in developing hardware, software and data monitoring capabilities would be required.

4. It is essential to not only attain manufacturing capabilities but also develop expertise in design, testing and control to achieve benefits of cost, scale and performance across all levels of the supply chain. Collaboration among industry partners and government agencies is required to create an enabling environment in India.

5. New technologies and new business models require new skills. As discussed before, the knowledge gap in the industry is wide and must be bridged. Capacity building and talent management for EVs can happen through the engagement of OEMs with ITIs and universities to teach mechatronics, software engineering, industry 4.0 and EV systems. Sponsoring PhD programmes and labs would not only help in R&D but would also help in increasing general interest in these subjects among students.

6. Affordability is an essential factor that affects buyer's decisions, and financing can act as a catalyst in promoting the adoption of EVs. Numerous challenges related to financing make it difficult for customers to access finance for EVs vis a vis ICEVs. Accessible financing options like Vaas, BaaS, battery leasing, and pay-per-charge can help bring the upfront purchase price of EVs at par with ICEVs. The first loss risk sharing instrument of USD 300 mn by the World Bank is one such initiative. The government can also bring lending for ICEV alternatives in the priority sector to boost funding.

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7. Better battery technology reduces range anxiety and degradation worries, making EVs more appealing to buyers and boosting financier confidence. Therefore, efforts should be made to discover new chemistry more suited to Indian conditions. Battery performance data can be used to adjust chemistry and improve life expectancy. Battery chemistry should be developed in a manner that places minimal strain on natural resources. A way of minimizing such strain is recycling. Designing easy-to-dismantle batteries, recycling e-motors and establishing recycling plants closer to manufacturing units can help reduce the cost of battery manufacturing and consequently reduce the cost of EVs. Another way of increasing battery efficiency and performance is by reducing vehicle weight.

8. Some other solutions to challenges include permitting houses to provide commercial charging services, GST waiver on EV and EV components, incentivizing modal shift to public transport, switching to a greener grid and developing second life use case for depreciated Evs.

There is a clear need to boost battery and EV production, enable technology transitions, integrate EVs into urban, regional and national transportation grids and networks, build compatible infrastructure and initiate proactive and effective policymaking for rapid EV adoption across users and different modes.

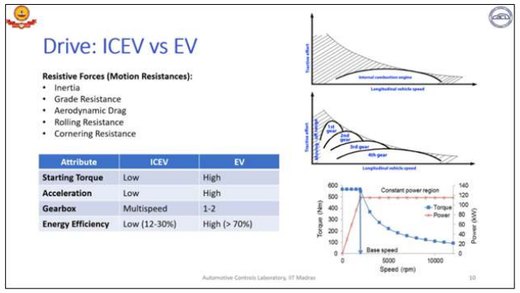
BOX: Is Sodium a viable cell chemistry vis a vis lithium?

The high cost of lithium-ion batteries has propelled the discovery of alternative cell chemistries that do not involve rare minerals. Sodium has emerged as one such alternative. Sodium ion (Na-ion) batteries are rechargeable batteries that use sodium ions to store and move electricity between anode and cathode materials. Sodium is abundant and less environmentally harmful due to the reduced environmental impact associated with sodium mining and extraction. However, sodium-ion batteries in their current state are suitable for stationary applications (like energy storage in grid or backup power) and not mobility applications. This is primarily because of low energy density and lesser Na-ion efficiency than Li-ion batteries. Lower energy density would require batteries of larger size, which would increase weight and reduce range.

Prof. Sandip Chakrabarti & Prof. Debjit Roy felicitating the Panelists Ms. Suman Mishra, Dr. Ranga Srinivas Gunti, Mr. Divya Chandra & Mr. Arun Pratap Singh (L-R)

Research Talk 1: Role of Vehicle Dynamics in Electric Vehicles and Smart Mobility

Delivered by Prof. C.S. Shankar Ram, IIT Madras



Key points:

- Vehicle dynamics refers to the study of forces acting on the vehicle and the corresponding vehicle motion/response. It can be grouped into longitudinal, lateral and vertical dynamics. Longitudinal dynamics for EVs consist of adaptive cruise control, autonomous braking, powertrain sizing and energy consumption. Lateral dynamics involve a lane-keeping system and yaw stability control. Finally, vertical dynamics consist of ride comfort and rollover detection and prevention.

- Dynamic system and models: Mathematical models are used to characterize system response. A system can be mathematically represented as a map and can be in the form of linear and nonlinear systems and time-variant and time-invariant systems. Most practical systems are nonlinear and time-varying. However, they are typically modeled as linear and time invariant to begin with. Dynamic models taking a systems approach help understand, predict and control the functioning of vehicle trajectory and motion.

- Braking in EVs: Braking is fundamentally a waste of energy, converted from kinetic energy to thermal energy through friction. In EVs, regenerative braking reconverts part of energy into electrical energy and stores it in the battery. However, regenerative braking alone cannot provide the desired braking demand/deceleration in all scenarios from the perspective of the vehicle's and occupants' safety. A blend of friction braking and regenerative braking, also called brake blending or cooperative braking, must be developed and integrated with active safety systems. Hence, driver training achieves significance in the case of EVs.

- Energy efficiency improvements in EVs: Research shows that energy consumption, efficiency and vehicular performance are sensitive to the driving style and specific operating scenarios (cities, highways or a combination of both). Academic discussions around improving energy efficiency and vehicle performance of EVs include

a. Platooning: Platooning is a form of cooperative driving where a group of trucks coordinate their driving pattern through intelligent applications.

b. Torque vectoring: It involves controlling the wheel torque between front/rear and left/right to reduce powertrain losses and generate direct yaw moment, leading to reduced slip.

c. Camber control: It involves managing the camber angle of the vehicle to reduce cornering resistance.

d. Regenerative braking

e. Regenerative suspension: It involves using regenerative dampers to reduce energy consumption in active/semi-active suspension.

f. Eco-driving: A mode that indicates driving practices/strategies that can lead to significant energy savings.

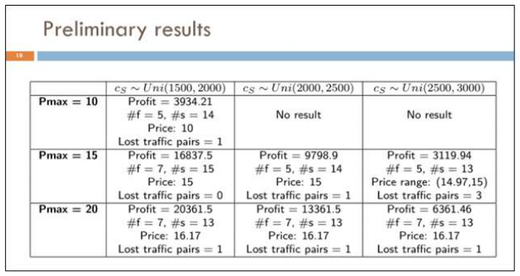
- Increasing adoption of EVs necessitates a clear understanding of their dynamics and control. However, the following challenges remain:

- Domain knowledge for characterizing systems
- Knowledge of sensor and actuator characteristics
- Effect of unmodeled dynamics
- Variations in system parameters.

Prof. C.S. Shankar Ram delivering his Research Talk on 'Role of Vehicle Dynamics in Electric Vehicles and Smart Mobility'

Research Talk 2: Optimal Location-Service-Pricing Models for EV Charging Centers

Delivered by Prof. Prahalad Venkateshan, IIM Ahmedabad



	$c_S \sim Uni(1500, 2000)$	$c_S \sim Uni(2000, 2500)$	$c_S \sim Uni(2500, 3000)$
Pmax = 10	Profit = 3934.21 #f = 5, #s = 14 Price: 10 Lost traffic pairs = 1	No result	No result
Pmax = 15	Profit = 16837.5 #f = 7, #s = 15 Price: 15 Lost traffic pairs = 0	Profit = 9798.9 #f = 5, #s = 14 Price: 15 Lost traffic pairs = 1	Profit = 3119.94 #f = 5, #s = 13 Price range: (14.97,15) Lost traffic pairs = 3
Pmax = 20	Profit = 20361.5 #f = 7, #s = 13 Price: 16.17 Lost traffic pairs = 1	Profit = 13361.5 #f = 7, #s = 13 Price: 16.17 Lost traffic pairs = 1	Profit = 6361.46 #f = 7, #s = 13 Price: 16.17 Lost traffic pairs = 1

Key points:

- The talk discussed facility location problems for EV charging centers. Facility location models for service operations is a well-researched topic in Operations Research and Operations Management. It seeks to optimize the location of a facility (factories, outlets, warehouses, DCs, etc.) to serve customers to achieve some balance between cost and service. Such problems usually have two decisions to make:

a. Where to locate a service facility? (fixed cost for the service provider)

b. Which customers are assigned/allocated to which facilities (transportation cost for customers)

- The problem in the talk involves determining the optimal number and location of EV charging centers, considering the tradeoff between having more charging stations to remain closer to the customers and the cost of establishing and operating such stations.

- Service quality in terms of coverage, density and staff (server operating costs) are important service level features characterized in the model by average weighting time by customers, arising due to variability and heterogeneity in the incoming stream of arrivals and service time, among others.

- Many server staffing costs exhibit economies of scale. Queuing theory provides a square root staffing principle that helps determine the optimal number of servers at the center if arrivals and average service time for each customer are known. However, it works best in situations with a captive audience, where the user has already paid an amount (subscription/premium) to receive the service.

- EV users exhibit features of a non-captive audience since they cannot use public charging stations and instead opt for an at-home charging facility. This makes the market non-captive, and the customer demand is endogenously linked to the service provider's decision to set up charging stations.

- Modeling such consumer choice using consumer surplus theory (surplus = utility - effort), the utility can be measured through range anxiety determined by the shortage of EV charging centers and limited battery capacity. Consumer effort can be determined by the detour a customer has to take vis a vis the shortest route to recharge at the EV station. It increases with the cost of charging and thus diminishes consumer surplus.

- However, an EV charging center service provider faces the following challenges today:

a. Establishing infrastructure for EV charging at the lowest cost amid uncertain demand

b. Inadequate number of EVs in market leading to tough break even situation

c. A higher price for charging may dissuade customers from arriving at the station

- The prescriptive model for locating an EV charging center needs to answer the following questions to help service providers arrive at decisions keeping the endogeneity of customer choice in mind:

a. Where in the network to locate an EV charging center

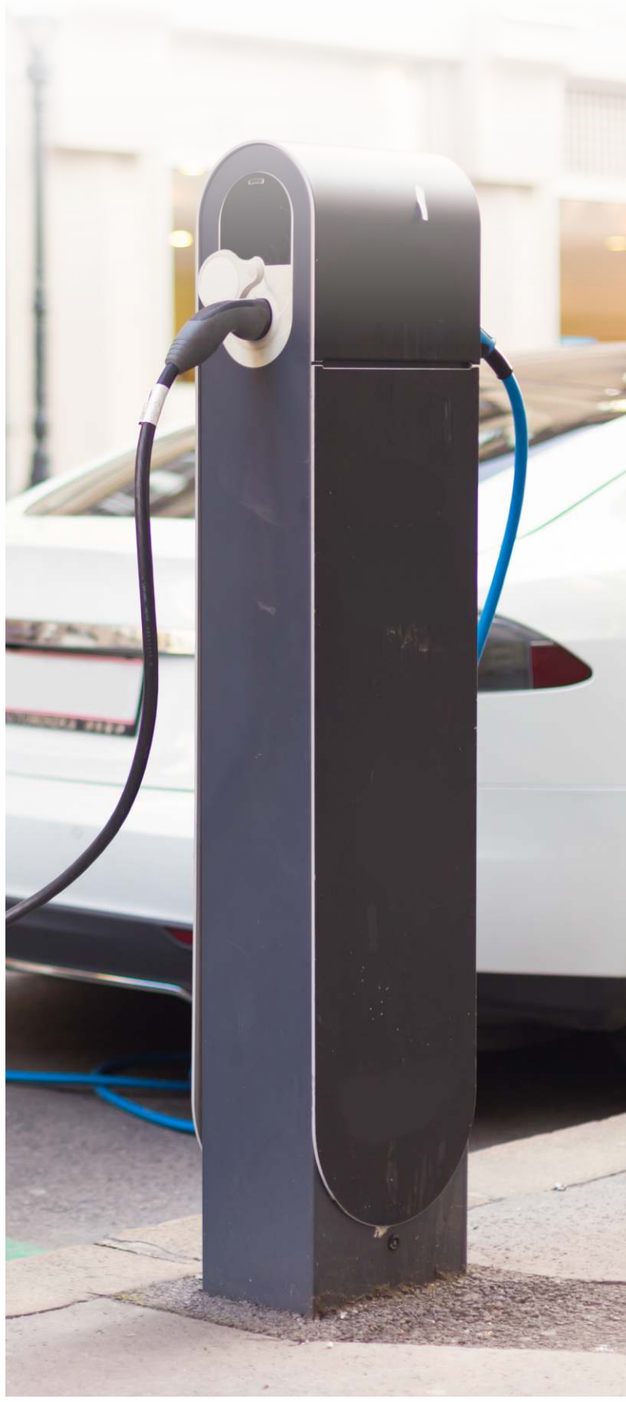
b. Number of charging stations at an EV charging center

c. Pricing for charging

d. Maximization of profits

It has been observed that with a very low price ceiling and high vehicular demand, the service provider will fail to break even and will decide not to invest in infrastructure. Higher price ceilings lead to more customers being served and greater service provider profit. Beyond a certain limit, service providers refuse to increase prices further even if they are allowed to since that might result in customers choosing not to charge.

Prof. Prahalad Venkateshan delivering his Research Talk on 'Optimal Location-Service-Pricing Models for EV Charging Centers'



Breakout Discussion

The workshop included a breakout session where participants and guest panelists brainstormed on issues of topical relevance related to EVs. The participants were divided into three segments where a guest panelist moderated the discussion. Each group was provided fifteen minutes to deliberate on the given topic following which the moderator presented the gist of the discussions. The activity involved:

a. Understanding the given topic from perspective of different stakeholders

b. Brainstorming the potential challenges that hinder EV ecosystem

c. Finding solutions to the challenges contextualized in Indian automotive space

d. Discussing key takeaways from the breakout session with rest of the audience

The table below summarizes the key takeaways from the breakout discussion:

Table: Breakout discussion summary

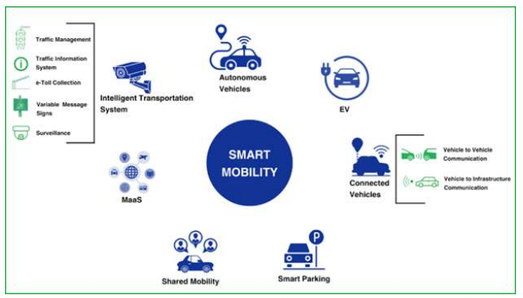
Resilience of EV Supply Chains	Adoption of EVs by Businesses and Consumers	Production Capacity Building for EVs
Challenges: - Unavailability of raw materials - Concentrated supply chains and geopolitical problems - Human resource gap - Manufacturing and freight costs - Trade partnerships - Policy instability	Challenges: - Segmented customer base and related behavior - Cost sensitivity of Indian customers - Charging infrastructure - Range anxiety - Indigenization of manufacturing	Challenges: - Abundant production capabilities in ICEV production - Unavailability of critical minerals reading to import dependency - Technology gap - Talent gap
Solutions: - Trade partnership with friendly countries to overcome supply chain disruptions due to geopolitical issues - Technology tie ups with developed world to enable tech-transfer - Introduction of training programmes at degree level for skilling in EV sector through active industry-academia interaction and partnership - Industry sponsored research in EV technology - Scale production to achieve economies of scale in manufacturing - Proactive tariff and non tariff policies based on international trade cycle	Solutions: - Target premium segment to create buzz around EV adoption - Customer centric innovation in EV - Improve affordability of EVs by bringing resiliency in supply chains and optimizing costs - Carbon credits to incentivize EV adoption - True range information - Awareness campaigns to build positivity around EV ownership	Solutions: - Effective implementation of government schemes like FAME, PLI etc. - Regulation and standardization of vehicle norms - Creating linkages between venture capitalists and startups to foster innovation in EV production capacity - Enable special industrial clusters focussing on EV manufacturing - Centre of Excellence in educational institutes in partnership with the industry to foster research in EV technology

Breakout session where participants and guest panelists brainstormed on issues of topical relevance related to Electric Vehicles & Smart Mobility

Section 2: Smart Mobility, Technology and Sustainability

Panelists Dr. Ashish Verma, Dr. Neha Sharma (appearing on screen), Mr. Ram Divedi & Mr. Divay Pranav (appearing on screen) along with moderators Prof. Debjit Roy & Prof. Sandip Chakrabarti during the Panel Discussion on 'Smart Mobility, Technology and Sustainability'

Transportation systems worldwide are becoming more complex, innovative and data-driven. Smart mobility is an approach to transportation that leverages data-driven, connected, autonomous and smart solutions to improve the efficiency and performance of transportation systems. It aims to enhance the experience of individuals and communities by minimizing and eliminating conventional transport inefficiencies. Its focus primarily lies on sustainability, accessibility and affordability. Smart mobility is dependent on technology integration between vehicles and infrastructure alike. It consists of intelligent transportation systems, autonomous vehicles, connected vehicles, smart parking, shared mobility, MaaS and electric and sustainable transportation, among others.



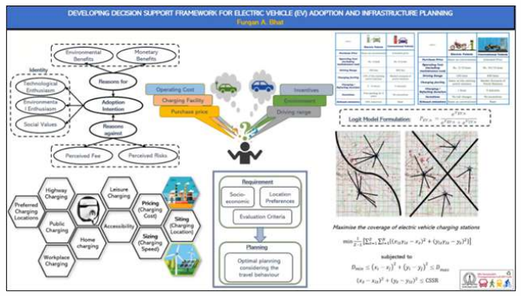
Components of smart mobility (Source: Author's analysis)

As a technology-intensive system, smart mobility involves high upfront costs. Significant investments in digitizing basic infrastructure is required. Poor road quality, lack of traffic management systems, conventional grid infrastructure, inefficient public transportation system, inadequate first and last mile connectivity, lack of smart parking solutions and integrating sensors and IoT infrastructure with the entire transportation system require immense capital, skills and technological capabilities. Electrification of transportation systems becomes difficult due to batteries, which comprise a significant vehicle cost. Uncertainties regarding battery life, supply chain disruptions and nascent replacement and recycling ecosystem make it difficult for financial institutions and banks to fund EV customers.

Further, charging infrastructure at city, state and national level is lacking. The phenomenon is not endemic to the country but exists globally. The global average for charging points per million population is less than 150, with just 20% of the charging points being fast charge points (Hall & Lutsey, 2017). Sustainability is at the core of smart mobility. The following section discusses the significance of adopting a systems approach for sustainable transportation.

Prof. Sachin Jayaswal & Prof. Maya Ganesh at the workshop

Systems Approach for Sustainable Transportation



- Research shows that car ownership significantly grows when the GDP per capita enters the bracket of $5,000 - $20,000, displaying an S-shaped growth curve. Congestion, travel time delays, unreliability of transport systems, inadequate road and rail infrastructure, lack of mass transit systems and poor traffic management approach are some of the issues that grapple India currently when it has not even entered the phase of rapid growth.

- Indian policymakers need to decide if India wants to follow a similar approach or saturate car ownership at a significantly lower level through innovative solutions to India's core transport system problems.

- Instead of a single strategy, a bundle of strategies can be adopted that maximizes benefits in the Indian context. A mix of planning, regulatory, economic and technological instruments that brings balance in modal choice and reduces inequity in transportation systems.

- In a BAU scenario, the macro simulation of the Bengaluru Metropolitan region shows an increase of 132% in VKT between 2030 and 2050. Such an increase would lead to a 580% increase in tailpipe emissions despite factoring in the modal shift to public transport. However, expanding coverage of public transit, notifying car-restricted zones, introducing congestion pricing, constructing cycling and walking infrastructure, encouraging carpooling, promoting high-density mix building use along main transport corridors and electrifying the entire vehicular fleet can drastically reduce VKT (16-18%) and tailpipe emissions (8–94%) by 2050 compared to BAU (Verma et al., 2018).

Each stakeholder (government, industry and customers) needs to actively contribute to promoting and adopting smart and sustainable mobility. The industry needs to develop innovative business models that promote the adoption of smart mobility solutions. Peer-to-peer asset sharing model, BaaS, centralized EV fleets and buyback guarantees from OEMs are some business models that can be applied in India after extensive market research and India-centric changes. Extensive research is required in battery development, alternative cell chemistry discovery, battery depreciation and battery life optimization to reduce battery costs and develop secondary life use cases for depreciated vehicle batteries. This requires a partnership between academia, government and industry.

In India, owning a car is an aspiration for many. Such an aspiration directly hinders efforts at promoting alternative transportation systems that are more sustainable and smart. Regulatory, economic and technological changes are required to nudge customers towards smart mobility. Following are some of the ways through which a behavioral change can be achieved in the Indian market:

- Nudges for end users of smart mobility boil down to cost and quality. Thus, all services have to keep affordability and accessibility in mind. This would require innovative business models, optimization of value chain processes and indigenization of the supply chain.

- Regulators can promote new use cases of smart mobility through policy changes. For instance, Delhi has now mandated all aggregators to induct EVs through its 'Aggregator's policy to mandate EV fleets' scheme. According to it, new vehicles inducted after March 2023 have to be electric (50% for 2Ws and 25% for 4Ws). Goa has also initiated a policy where all tourist rental vehicles (2,3&4Ws) must be electric from 2024 onwards. Such regulations not only provide a policy push to EVs but also act as a nudge for customers who are hesitant about EVs due to a lack of direct experience in riding EVs.

- There is a need for increasing synergy between public transport authorities, private EV customers and ridesharing service providers dealing with first and last-mile mobility. It includes making public transport more accessible, reserving parking lots at terminals for EVs and instituting other special incentives at the local level.

- Severe gaps exist in urban planning in India. Our cities lack the most basic infrastructure like sidewalks, pedestrian islands, bike lanes, green belts and intelligent signals on crossings. Such gaps necessitate the use of cars and other motorized vehicles due to safety concerns. We need to design our cities to support the adoption of sustainable and smart mobility solutions rather than necessitate the usage of cars.

- The aspirational nature of owning a car can be countered through a sustained educational and social campaign driven by the government and influential personalities. City authorities can incentivize non-motorized vehicles through the construction of infrastructure, providing free parking spaces for bikes, subsidizing bike-sharing systems and instituting public campaigns highlighting the negative impacts of conventional vehicles. Amsterdam has successfully projected itself as the bike capital of the world through a sustained campaign that made driving bikes 'cool'. In Paris, accessibility to public transport is so convenient that using 4Ws is frowned upon.

Dr. Ashish Verma interacting with the audience

Shared Mobility: What, Why and How?

Shared mobility is an integral component of smart mobility. It refers to a system where vehicle owners and commuters can rent, share and ride together in exchange for a payment. Figure 7 presents the various elements of shared mobility. A car owner uses a car for just 5% of the time they own that car. The idea of shared mobility is to either promote non-ownership of that car or enable sharing of that car to others to reduce car ownership. The sharing economy leverages technology to enable a free flow of information and develop a market for the sharing of such idle assets. This provides the twin benefits of reducing traffic congestion or roads and generating significant savings from expanding road infrastructure and parking spaces to fund infrastructure development for non-motorized transport systems.

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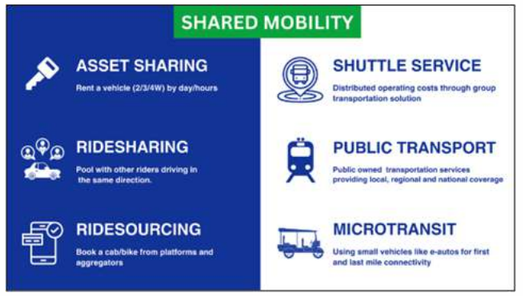


Elements of Shared Mobility

Public transport is the most commonly known element of shared mobility. A bus with a seating capacity of 50 passengers can reduce 50 cars from the road. Shared mobility can solve first, middle and last-mile mobility challenges in India. Integrating microtransit with public transport can help nudge commuters (specifically in urban areas) towards adopting shared mobility solutions (Oeschger et al., 2020). The growth of ridesharing and ride-sourcing service providers demonstrates the appeal of shared mobility to customers.

Many new ridesharing platforms like Yulu and BluSmart are driving a sustainability revolution in mobility by running entirely on EVs. As discussed before, affordability is a major hindrance in the adoption of EVs. These ridesharing platforms transform mobility by promoting a culture of usership and not ownership. The service provider takes care of high upfront costs, operating and maintenance costs in exchange for a fee. This not only makes EVs accessible and affordable but also provides customers with exposure to electric mobility. Ridesharing is particularly helpful in first and last-mile connectivity since Indian cities have larger sprawl and face inadequate public transport connectivity. Following are some of the core concepts and ideas that an e-ridesharing service provider keeps in mind:

1. Connectivity: Telematics technologies like sensors and IoT devices are essential to track the fleet and ensure vehicle upkeep. An app must act as a marketplace between service providers and commuters.

2. Design innovation: Service providers must ensure that their vehicles are designed for all weather city-wide operations. Further, they must include mechanisms for preventing theft and vandalism.

3. Data-oriented: The trackers installed in vehicles generate immense data. Not only does that data help in surveilling vehicles, but it can also help in day-to-day operations like repositioning of fleet, predictive maintenance, seasonal allocation of fleet, demand forecasting and dynamic pricing.

4. BasS: Battery swapping increases turnaround time by eliminating downtime lost in charging. BaaS can also be used to monetize operations from underutilized swapping stations.

However, e-ridesharing service providers face the following challenges in India:

1. Poor quality of Indian roads leading to safety concerns
2. Instances of theft and vandalism of vehicles
3. High operational and maintenance costs
4. ack of supporting infrastructure like walking and biking lanes
5. Price sensitivity of Indian customers
6. Seasonal and daily demand variability
7. Charging time impacting turnaround time and fleet repositioning
8. Low consumer demand

Mr. Ram Divedi engaging with the audience

There is a need to fix these challenges by boosting consumer demand. The growth of e-commerce provides a fertile ground for ridesharing service providers. They can partner with such aggregators and transform the delivery ecosystem, generating revenue from shared mobility business and ensuring zero tailpipe emission. Additionally, the following are some of the ways through which consumers can be nudged to adopt shared mobility:

- Build effective strategies to channelize environmental enthusiasm into the adoption of shared and public transport systems. This requires sustained and aggressive marketing that challenges the perceived superiority of one mode over another.

- The lack of safety measures for women is a big challenge in promoting shared mobility. Service providers need to make their vehicles safe by embedding vehicles with advanced safety features, establishing 24/7 women's safety helpline, providing emergency buttons, partnering with local authorities for illumination of dark spots and enhancing police patrolling during night time.

- Taking a cue from utility theory, service providers and city authorities can try to maximize the utility of shared mobility modes by making the use of other modes less attractive. This can happen either by incentivizing shared modes (priority toll lane, reserved parking places) or penalizing private conventional vehicles (congestion pricing, dynamic parking pricing, carbon tax etc.).

- There is a need to understand the dynamics of driving better and train drivers of shared mobility solutions and public transport systems to drive safely and abide by the traffic laws.

- The cost-sensitive Indian market finds it difficult to connect EVs with the larger problem of climate change. It becomes even more acute when shared mobility is promoted since it aims at a non-car lifestyle. Quality of life benefits due to shared mobility, like socialization and networking opportunities, must be communicated to commuters.

- Research shows that countries with a gap in the industrial and digital revolution (for instance, the European countries) tend to be more receptive to the shared economy. In contrast, countries that observe the industrial and digital revolution simultaneously (like India and China) tend to attach high social value to ownership rather than sharing. This requires special focus from the government to promote shared mobility and public transport through their vast financial, regulatory and technological resources. Fixing infrastructure for shared mobility by focussing on the safety and design of roads, increasing the length of bike lanes and creating exclusive lanes for sustainable modes can be a start.

- Service providers must identify their target segment and develop unique solutions for these micro markets. Youths can be their target audience since they are most open to using shared mobility platforms and attract importance to responsible mobility. Migrants are another target audience.

- Comfort, predictivity and accessibility remain key challenges which constant improvements in design and offerings can solve.

- Small pockets of use cases exist. For instance, shared mobility is used more in areas where office spaces and central business districts are near residential areas. Similarly, airport routes see great demand for these modes. Service providers need to leverage such corridors to the best by partnering with private developers and intermodal transport hubs to provide space for the creation of facilities for vehicle sharing.

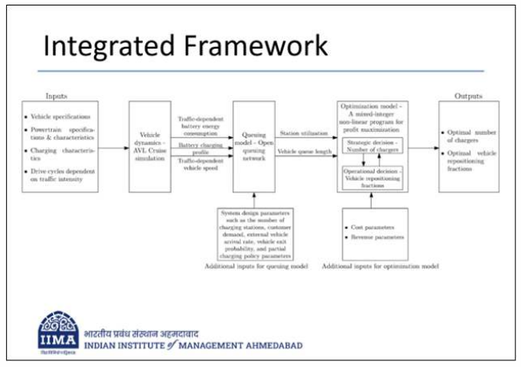
- Techno-optimism should be promoted to instill confidence among the public that mobility requires transformation through science-based solutions in the global fight against climate change.

Undoubtedly, shared mobility will continue to grow as conversations around climate change and sustainable mobility become more intense. However, it requires active collaboration among all stakeholders to accelerate the adoption of shared mobility through innovations in business models, the creation of adequate infrastructure, change in urban planning and city design, fiscal incentives that promote the use of shared mobility and consumer behavior pivoting towards responsible mobility.

Prof. Debjit Roy & Prof. Sandip Chakrabarti felicitating the Panelists, Dr. Ashish Verma & Mr. Ram Divedi, while Dr. Neha Sharma & Mr. Divay Pranav joined the session virtually

Research Talk 3: Analyzing Performance of Electric Car Sharing Systems

Delivered by Prof. Debjit Roy, IIM Ahmedabad



Key points:

- The talk was based on the operational aspect of car-sharing systems, giving an idea about how to analyze car-sharing systems and the nuances to consider while modeling such analysis.

- The global car-sharing market amounts to $13 bn in 2023 and will grow at ~6% CAGR between 2023-27. Globally, Zipcar and Getaround are the only two major car-sharing companies with a substantial market share of 13% and 10%, respectively, leaving a lot of scope for new entrants to explore the market.

- Car-sharing systems can be of two types:

  - Station-based systems: This system allows for pickup and drop-off cars at designated stations. Examples include EVCARD in China and Envoy in the US.

  - Free-floating systems: This system allows for commencing and terminating trips at any free parking spot in the operational area. Car2Go of the US is one such car-sharing company

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Station-based one-way system:

- The functional mechanism in a station-based one-way system involves the arrival of a vehicle at a charging station, waiting for customer requests upon charging and departure to the desired destination upon a booking. Notably, the vehicle is available only after charging and waits for the customer's request after charging. Rebalancing vehicles in the network upon completing a one-way trip is a major challenge in this system.

- Design parameters that affect the performance at the strategic level include the number and location of charging centers, the number of charging stations per center, parking capacity and parking locations. At the operational level, customer vehicle allocation, distribution of vehicles to the stations, charging policies, threshold energy levels for recharge and vehicle relocation, among others, affect the system's operational performance (Bansal et al., 2022).

- The dynamic model discussed in the talk integrates strategic and operational levels to solve the integrated problem. Dynamic modeling of the operational performance of a station-based one-way system needs to include charging infrastructure cost, vehicle waiting cost and vehicle repositioning cost (Bansal et al., 2022).

- The result indicated a reduction in the number of chargers required when the probability of partial charging increases. This is due to the reduced turnaround time and fulfillment of most consumer demand. Further, an increased probability of partial charging leads to higher profitability.

Free-float autonomous EV sharing system:

- In this mechanism, a customer requests a car and waits for the arrival of a vehicle, or a car waits for a request. The matching leads to travel to the destination, and the vehicle is charged only if necessary. The problem of vehicle allocation becomes complex due to variability in distances sought for the trip by the customer and in charging levels of each vehicle.

- Modeling vehicle allocation and charging based on charging levels and customer requests helps develop dynamic policies.

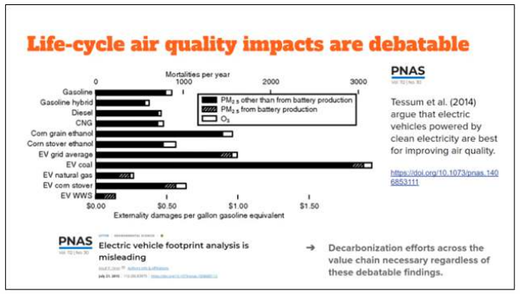
- Results from the Markov decision process reveal that it is better to reserve some idle vehicles for short-distance customers despite demand from long-distance customers since it reduces turnaround time and increases revenue.

- Hence, the dynamic allocation of vehicles based on real-time information benefits service providers. It is also important to consider the implicit costs while serving long distance customers.

Prof. Debjit Roy delivering a Research Talk on 'Analyzing Performance of Electric Car Sharing Systems'

Research Talk 4: (How) Can Electric Vehicles Contribute to Sustainability Goals?

Delivered by Prof. Sandip Chakrabarti, IIM Ahmedabad



Key points:

- Globally, EV sales have seen a CAGR of 45% between 2016-23, primarily driven by China. In order to achieve global net zero by 2050, a CAGR of 25% is required between 2023 and 2030, with the annual sales share of EVs rising from 14% to 65% by 2030. Such a scenario would require an average global charger density of a charger per 500 persons.

- Public and private sector entities, including ICE manufacturers, have announced their own plans to turn electric and announced deadlines to achieve such targets. However, there is no harmony between these targets due to a lack of clear pathways and an integrated approach.

- India has also announced ambitious targets like 15% of EV sales by 2025, 30% of the fleet to be electric by 2030, electrification of the entire commercial and logistic fleet by 2028 and a million EVs in stock across all segments by 2030, among others. Similarly, multiple legislations exist regarding the establishment and funding for charging infrastructure, PLI schemes for manufacturing EV components, vehicle scrappage policy, public transport fleet transition, demand-side fiscal incentives and state-level policies for promotion of EVs.

- But, the fundamental question of EVs' ability to solve India's core transportation-related problem needs to be explored. In this context, it is important to understand the limitations and impact of electric mobility in exacerbating environmental and social inequities.

- Critiques argue that EVs require massive investments and public subsidies despite car and battery manufacturing involving environmental and human rights concerns. Further, their benefits occur only when the source of electricity is renewable.

- Transportation policies promoting EVs ignore the alternative tools available to mitigate the impact of transportation on emissions and bring social equity. For instance, strengthening clean public transport systems and emphasizing their mass adoption can pull millions of cars out of roads, electric or whatever.

- Such an approach would require an emphasis on not just the electrification of private vehicles but also the cultivation of a culture of shared mobility to ensure as much reduction of cars off the roads as possible. A model of car usership rather than car ownership can help reorient the mobility scenario.

- However, research shows that EVs have a lower carbon footprint across their life cycle; hence, decarbonization efforts across the value chain are necessary regardless of these debatable findings.

- There exists a need to activate the circular economy for EVs involving extension of EVs useful lifetime by repair, reuse, refurbishment and remanufacturing.

- Research shows that the increased cost of acquiring EVs vis-a-vis petrol vehicles could never be matched if the batteries are replaceable every eight years or after running 200000 km. This requires debate on whether EVs need to be cost-effective since ownership of cars is not a basic human right.

- Some of the strategies to boost EV adoption include:

  - Cross-subsidization through the imposition of Pigouvian taxes can help make EVs cheaper.

  - The density of charging infrastructure tends to boost adoption. Monetary incentives to service providers may help. Policy focus on home charging facilitation through changes in building bylaws is needed to improve charging infrastructure.

  - Geographic differentiation of subsidies based on the severity of climate change and air pollution can be a creative way of promoting subsidies in a fiscally balanced way. Demography also plays a role in the adoption favorability of EVs.

  - Priority in parking, areas of congestion and tollways can boat adoption.

  - Promoting shared e-mobility can help car users get familiar with EVs and dissipate hesitancy due to lack of exposure.

  - Public programmes towards transitioning to EVs play a role. It can be in the form of electrification of government vehicles and bus systems.

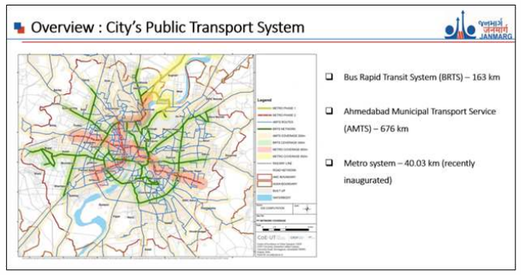
BOX: Compact city to curb range anxiety?

Compact cities are designed with limited urban sprawl and efficient land use to bring people and places nearer and eliminate the need for long-distance travel within cities. Such cities reduce the need for private vehicles and promote either non-motorized modes of travel or public transport. Compact cities may help the adoption of EVs since shorter distances reduce range anxiety among customers. Further, a robust public transit system reduces the need to use private vehicles. However, limited sprawl evokes concerns like traffic congestion, unsustainable natural resource usage, infrastructure breakdown and affordability issues for residents.

Prof. Sandip Chakrabarti delivering a Research Talk on '(How) Can Electric Vehicles Contribute to Sustainability Goals?'

Presentation: AMTS BRTS Sustainable Transport System

Delivered by Mr. Vishal Khanama, BRTS



Key points:

- The public transportation system in Ahmedabad consists of Ahmedabad Municipal Transport Service (AMTS), serving 676 km, Bus Rapid Transit Service (BRTS), serving 163 km and Ahmedabad Metro spanning a length of 40 km. BRTS currently uses ~ 200 electric buses in its network, becoming the country's first BRT system to use electric buses.

- All three systems observe a daily ridership of ~7 lakhs, which is approximately 9-10% of the city's population. Connectivity to all regions is essential to nudge commuters to move towards public transport systems.

- Route rationalization, last mile connectivity, single and smart ticketing and common mobility cards are some of the strategies AMC is considering to integrate the city's public transport system into a single entity to facilitate seamless, hassle-free travel for commuters. The current objectives of the authorities for the public transport system in the city are:

a. Reduce carbon emissions by lowering dependency on conventional fuels.

b. Make bus depots energy efficient to reduce power consumption.

c. Improve first and last-mile connectivity across the city.

- An initiative towards integrated fare management and allowing multi-modal transit took shape in the form of the Common Card Payment System (CCPS), also known as the Janamitra card. It is an open-loop card that can be used to make payments for transit systems, parking lots, AMC taxes, retail outlets and general utilities.

- The Integrated Transit Management System was launched in 2018. It consisted of an automated process of bus fleet scheduling, an automated data-driven process for billing of bus operators and optimized usage of paper rolls. IT-enabled devices, analytical platforms and central monitoring systems help adopt a data-driven approach for managing bus operations from the perspective of serviceability, accessibility and safety.

- Digital initiatives to ease user experience include dedicated mobile apps for AMTS, BRTS and Ahmedabad Metro, web ticketing, partnership with payment apps and QR-based ticketing. It is planned to integrate mobile applications of all three transport systems into a single application. Revenue and ticketing data show user interest in adopting these digital services provided by the transport authorities.

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- The operations and innovations in AMTS-BRTS would be guided by the 7Cs of mobility: Common, Connected, Convenient, Congestion free, Charged, Clean, and Cutting edge.

- In order to improve last-mile connectivity, the authorities plan on introducing e-rickshaws in the city to replace the existing fleet of fuel-powered rickshaws and provide single ticketing for MyByk and e-rickshaws in the city. MyByk is a bike-sharing platform in the city operating on a PPP model.

- The above-mentioned initiatives by the transport authorities have helped improve vehicle productivity, improvement in occupancy ratio, enhance the efficiency of fleet utilization, improve commuter satisfaction, increase earnings per km and reduce the turnaround time of incident resolution.

- The authorities plan to make transport system operations in the city sustainable by implementing the following strategy:

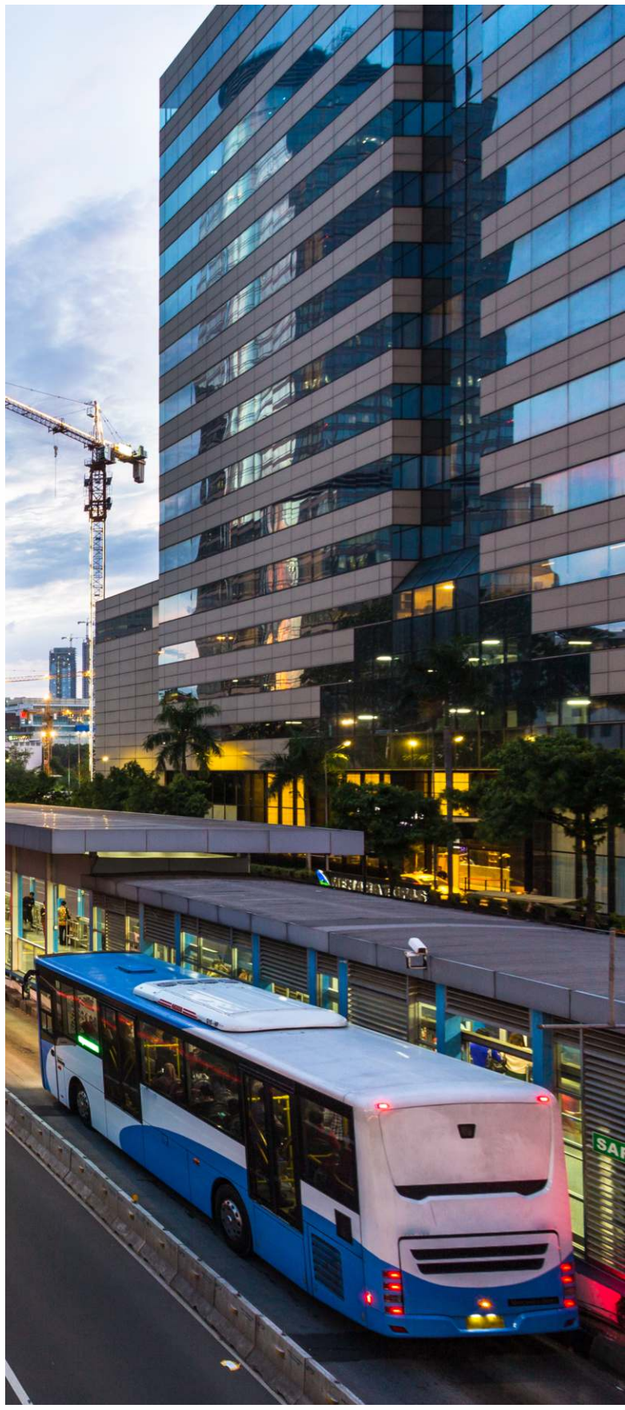
a. Net zero through complete electrification of the bus fleet

b. Solar-powered bus stations and bus depots

c. Electrification of last-mile transportation modes

d.Establishment of on-route charging stations for buses and EV charging stations for private vehicles in the city

Presentation on 'AMTS BRTS Sustainable Transport System' by Mr. Vishal Khanama



Conclusion

India is witnessing a period of rapid growth, and concerns about increasing usage of private vehicles continue to grow. The national target of net zero by 2070 requires rapid decarbonization of the transportation industry, especially the road transport sector. While many technologies are emerging, EVs are becoming more popular due to substantial investments, decreasing battery prices, higher energy efficiency, government push and smooth driving experience. However, their promotion and adoption is dependent on the resilience of the EV supply chain. TCO is an important consideration for customers, which has made 2&3Ws the drivers of electrification in India since 4Ws are more expensive than ICEVs. EVs provide economic and environmental benefits at different levels. A proactive policy framework has helped drive electrification. However, EVs face their own challenges at the consumer and manufacturer levels. Charging infrastructure acts as a big hindrance in the adoption of EVs and contributes to range anxiety. Battery swapping centers, home charging and rapid charging stations can help. While the growth of the EV ecosystem provides scope for job creation, it also faces a huge skill gap in India. Shared mobility solutions can partially solve affordability and accessibility-related challenges. They need to be promoted through innovative business models, cutting-edge technological innovations and micro-level customer targeting. Data would play a big role in both electric and shared mobility. Data-driven decision making, smart and connected solutions, innovation in vehicle design, processes and services, primacy to affordability and developing creative use cases of depreciated batteries, conventional vehicles and shared mobility are the key to promoting electric, sustainable and shared mobility in India.

Successful wrap-up of the One-Day Workshop on 'Electric Vehicles and Smart Mobility'

This synopsis note was prepared by :

Mr. Shubham
Research Associate, Centre for Transportation and Logistics,
Indian Institute of Management Ahmedabad

Scan here to read the detailed proceedings of the workshop

or
visit : https://www01.iima.ac.in/ctl/

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CTL Snippets

Continuing its rich tradition of thought leadership, the Centre initiated 'CTL Snippets' an interview series showcasing insightful conversations with leading academicians and practitioners of the transportation and logistics sector. The series aims to provide the audience with insightful discussions exploring topical issues, developing research problems, and finding innovative solutions within the realm of transportation and logistics.

CTL Snippets E1: Behavioral Interventions in Operations Management and its Impact on Society

Interaction with:

Dr. Vivek Choudhary
Assistant Professor, IT & Operations Management,
Nanyang Technological University, Singapore

Key Highlights:

Prof. Choudhary spoke about his work on behavioral interventions in operations management and its impact on society, the future of service platforms and human-AI interactions, and the potential impact of transportation and logistics research with a focus on the Indian scenario.

He further addressed the community of Indian PhD students in the OM area about effectively choosing their field of research.

Please visit to catch more:
https://www.youtube.com/watch?v=GnoHFYj_DDE

CTL Snippets E2: Link between Electric Vehicle Charging Locations and the Electricity Distribution Network

Interaction with:

Dr. Sriram Sankaranarayanan
Assistant Professor, Operations and Decision Sciences
Indian Institute of Management Ahmedabad

Key Highlights:

Prof. Sankaranarayanan discussed his work on transportation systems, specifically on the link between electric vehicle charging locations and the electricity distribution network.

He discussed the emerging new areas of interest pertaining to dynamic pricing and ridesharing services optimization within the domain of transportation research.

He also addressed the community of Indian management PhD students about the necessary skill sets and tools which would help them succeed as academics in the OM area.

Please visit to catch more:
https://www.youtube.com/watch?v=eKnuhgLdPAE

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CTL Snippets E3: Tackling Contemporary Urban Challenges through Public Transport

Interaction with:

Mr. Shashi Verma
Chief Technology Officer
Transport for London

Key Highlights:

Mr. Shashi Verma gave his insights about the role of public transport in tackling contemporary urban challenges like climate change, air pollution, road safety and public health.

Mr. Verma discussed the transformational work done by him in TfL, especially in building a business case for Elizabeth Line using agglomeration economics and developing innovative funding mechanisms for public transport in London. He spoke about the significance of bringing multiple stakeholders and institutions together to create an integrated public transport system. He explained how the unplanned growth of Indian cities is acting as a barrier in enhancing productivity of our urban economies.

He further discussed the importance of modal shift to public transport in decongesting our cities and improving air quality. He advised PhD students and aspiring researchers to understand the needs of the industry and policymakers in order to come up with high impact, actionable research output.

Please visit to catch more:

https://www.youtube.com/watch?v=e01rUggefFc

CTL Snippets E4: A Guide to Solving Real World Problems through Applied Research

Interaction with:

Dr. Sundaravalli Narayanaswami
Associate Professor, Public Systems Group
Indian Institute of Management Ahmedabad

Key Highlights:

Dr. Narayanaswami spoke about the need to uphold stakeholder centricity while defining research problems to bridge the gap between research and practice. She discussed the role of management, policy, and science in creating technologies and processes that can be applied to the Indian context to solve problems unique to our system. She explained how sequential decision-making, which utilizes machine learning and decision-making techniques, helps solve contextually different applied decision-making problems under uncertainty due to a combination of dynamic and stochastic optimization at each echelon of decision-making.

Further, she emphasized that researchers need to engage deeper with the industry and understand their problems better to develop relevant tools to solve those problems instead of solving problems using a single tool limited by unrealistic assumptions, rendering the research inapplicable in real life.

Finally, she shared her views on what lies ahead for the Centre and laid out different research areas.

Please visit to catch more:

https://www.youtube.com/watch?v=yNbotEjdkdg

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CTL Snippets E5: Boosting productivity of Indian Artisanal Supply Chains

Interaction with:

Dr. Somya Singhvi
Assistant Professor
Data Sciences and Operations Department
USC Marshall School of Business

Key Highlights:

Prof. Singhvi gave a detailed insight into his work related to artisanal supply chain in India based on field work with a rug manufacturer from Rajasthan.

Displaying the setting of a disaggregated resource constrained supply chain, Indian artisanal (weaving) supply chain predominantly employs women who work from their home due to social constraints. The raw materials are provided by the rug trader and frequent supervisory visits by a designated supervisor help ensure the work is done according to the standard quality parameters. Geographical isolation, infrequent supervision and labor-intensive nature involving intricacies of design lead to productivity inefficiency. Their study showed a 3-14% decrease in weaving time and a 15-17% improvement in weaver's income due to additional supervisory visits.

Further, frequency of supervisor visits helps in picking out mistakes in design early and reduces duplication of efforts.

Please visit to catch more:

https://www.youtube.com/watch?v=JibcbCtJYIA

CTL Snippets E6: Understanding Indian Food Security Program: Design, Interventions, and Innovations

Interaction with:

Prof. Maya Ganesh
Assistant Professor of Operations and Decision Sciences
Indian Institute of Management Ahmedabad

Key Highlights:

Prof. Ganesh discussed the approach to modernize the Indian food security program. She spoke in detail about the design of the Indian public distribution system (PDS) and related inefficiencies. Prof. Ganesh answered questions related to the introduction of portability (agent choice), a demand side intervention, in the PDS. Her work specializes in the impact of demand side intervention using differences in differences approach on sub district level data from the states of Andhra Pradesh and Telangana. Further, the work draws attention to how absence of complementary supply side modifications to address demand variability can prevent the realization of the interventions' full benefits. She advocates the use of micro level data and predictive analytics to improve demand management for food supply chains to reduce wastage and other inefficiencies. Furthermore, she stressed the availability of dynamic weather and traffic data that can be used to make real time vehicle routing decisions. The active usage of the IoT sensors that determine the freshness/shelf life of produce can also help retailers make dynamic pricing decisions and determine the logistics pricing of the product.

Please visit to catch more:

https://www.youtube.com/watch?v=gMBBiGgIDk8

Views from Select CTL Faculty Members

Dr. Prahalad Venkateshan
Associate Professor,
Operations and Decision Sciences

1. Digitalization in retail is driving retailers to adopt omnichannel retail strategy to provide customers a seamless shopping experience. What are the different strategies for order fulfillment under omnichannel retail?

Omnichannel retailing refers to cases where a single retail outlet can serve both physical as well as online customers. There are different strategies that can be employed in this context. A fully pooled strategy is where all online demand is satisfied from the single retail outlet that also caters to physical customers. At the other extreme, a fully decentralized strategy is where the retail outlet is exclusively used for physical customers only. Possibilities of satisfying some fraction of online customer demand via stores is also possible.

2. What are the benefits associated with 'ship-from-store' strategy for omnichannel retail fulfillment?

Some of the benefits of the ship-from-store strategy relate to being able to satisfy customer demand quicker since in many cases the retail stores are closer to customers. Apart from this, pooling leads to being able to provide better customer service at lower inventory levels. This can lead to better customer service at lower overall costs as well.

3. What are some of the important inventory management decisions that a 'ship from store' omni channel retailer must make?

Some crucial questions to address include how much of online customers' demand to be satisfied directly from warehouses, and how much to satisfy from smaller retail outlets. Once this decision is made, a related decision is what type of inventory levels to maintain at both the warehouse as well as the retail outlets so that customers experience better service levels.

4. How can a 'ship from store' omnichannel retailer maximize profit through optimizing the critical inventory management decisions discussed earlier?

Depending on a variety of parameters, such decisions can be made. For example, there is usually lower cost to satisfy customer orders from retail outlets. On the other hand, warehouses are better at packaging and handling for online orders. Shipping from store allows for better inventory turnover at retail stores leading to lesser amount of loss due to markdowns, for instance. Taking all of these factors into account, along with the expected quantity of demand from the online channel and that from the physical channel, a retailer can make decisions regarding how to optimally split the online demand between the two channels.

5. What are the upcoming areas of research in the field of 'E-Commerce and Omnichannel Retail Strategy'?

The field is relatively new and many crucial questions remain to be explored. An immediate problem to study would be the case where a single warehouse serves multiple retailers as is common in many firms. Additionally, questions related to replenishment frequency and amount, last mile delivery planning to customers from the retail outlets, planning over multiple periods, amongst others remain to be studied.

Dr. Sundaravalli Narayanaswami
Associate Professor,
Public Systems Group

1. Intelligent Transportation Systems are vast in scope and encompass many technologies. Can you explain the scope of ITS and emerging innovations happening in ITS?

One of the major differentiators in any country's socio-economic growth is a superior connectivity and transportation system. It is been observed that a country with a good quality transportation network grows very rapidly. However, countries continue to be struggling with increasing urbanization, poorly connected sparse populated regions, imbalance between landscape growth and mobility choices. Irrespective of whether a country is developed, under-developed or developing, congestion in urban spaces, ports, airports are a common phenomenon.

One traditional approach to address all the above challenges was to build more transportation and logistics capacity. However, building more capacity, such as building roads, bridges and flyovers, increasing the frequency of services posed additional challenges in terms of huge capital expenses, very long developmental time, increasing pollution, and social inconvenience during construction phase. From a managerial notion, a mismatch between supply and demand was attempted to be resolved with additional fixed (static) capacity using infrastructural developments. Intelligent Transportation systems (ITS) attempt to resolve traffic issues with dynamic and flexi-capacity, where all stake-holders are able to make informed decisions. This could be by means of efficient signalling systems, technologies for rapid movements, good models (using OR, simulation, AI, data analytics, ML), and simple managerial attempts to streamline and prioritize movements. Summarily, the three facets of transportation systems, which are vehicles, infrastructure and systems (traffic planners and policy makers) communicate and coordinate with each other's so that decision making is informed and transparent. The purpose of ITS is to make mobility operations both efficient and effective, for all stakeholders (commuters, transport operators, planners and policy makers). The scope of ITS is worldwide, as every country and every transport mode attempt to improve their capacity utilization and improve quality of transport services.

2. What are the prerequisites of implementing Intelligent Transportation Systems in transportation systems? How can a developing country overcome the constraints and resource and manpower in adopting an expansive and cutting edge ITS?

ITS is multi-disciplinary; it warrants bringing together expertise of vehicular and construction engineering, signalling and communication systems, computational skills, very large data processing capabilities, operations research (OR) models, data analytics, financial acumen, and policy planning. Manpower development in multiple skillsets and bringing together multiple expertise on a collaborative system is very essential.

3. ITS generates vast amounts of data. What are the different types of data sets that get generated by ITS? How can they be used to improve our transportation systems? Can you provide a specific use for any?

Data generation and data analysis in ITS can be of two broad kinds. One is analysis of historic data for planning purposes and second is rapid processing of very large data collected in dynamic systems for real-time execution. Both are very essential for a good ITS implementation.

4. How do Intelligent Transportation Systems (ITS) contribute to enhancing safety for surface transportation? Furthermore, how do these safety benefits extend to different modes of transportation, including public transit, cycling, and pedestrian infrastructure?

Using ITS, it is possible to bring in lots of automation in processing, implementation and execution. Because of which, human fatigue related errors, and subjective decision making are eliminated. This is one reason for improved safety in ITS as against manual systems. Apart from that, systems capacity utilization can be well optimized. Improved safety and capacity utilization enables better quality. Particularly in urban areas, an efficient transportation system means ease of operating multiple modes of transportation including non-motorized transit (NMT such as cycling and pedestrian movements), which is non-polluting and environment friendly.

5. The use of surveillance and tracking systems in ITS has created concerns about privacy among commuters. What measures should be implemented to mitigate potential privacy risks associated with the collection, storage, and use of Personal Identifiable Information in ITS, ensuring transparency, consent, and accountability?

Security threats are one of the major challenges in this digital age. Specific to transportation, we need stringent enforcement of rules and regulation, law abidance against any violation of privacy. Severe punitive measures also help prevent misuse of private data. Stakeholders have to commit to ensure transparency and fairness of business processes.

6. What are the upcoming areas of research in the field of 'Intelligent Transportation Systems'? How can the Centre contribute in advancing research for the same?

Upcoming areas in ITS are blockchain, E-vehicles and their entire ecosystem, hydrogen fuels, Industry 4.0 standard, non-motorized transportation, transit oriented development (TOD), data analytics and machine learning. From the centre perspective, there is a great scope of pursuing research in each of the above areas of work. Some of them are reasonably represented in current literature; but there is a huge gap. Therefore, there is huge scope of focused, application based research in the field of ITS.

CTL Faculty Research Accomplishments

1. Capacitated multiple allocation hub location problems under the risk of interdiction: Model formulations and solution approaches

Prof. Sachin Jayaswal published a research article with Prof. Vishal Bansal and Prof. Ankur Sinha titled 'Capacitated multiple allocation hub location problems under the risk of interdiction: model formulations and solution approaches'.

Abstract:

Hub-and-spoke networks play a critical role in reducing cost and enhancing service levels in various infrastructural sectors since hubs act as the consolidation and transshipment points of the flows. The failure of hubs in such a network can cause severe disruptions. While disruptions can be natural or man-made, a disruption by a rational individual or entity can be significantly detrimental to the network and is often studied as an interdiction problem. It is important to take interdiction effects at the design stage; therefore, we study the three-level capacitated hub-and-spoke network design problem from the perspective of a defender who considers the risk of interdiction by a rational attacker. Within the three levels, the upper level represents the network design level, and the lower two levels represent the bi-level hub interdiction problem. The introduction of capacity constraints within an interdiction model dramatically increases the complexity of the problem, as there can be some unfulfilled flows post-interdiction. Moreover, a flow may or may not be fulfilled through the least-cost route using the nearest hubs. This work makes two major contributions: the first contribution is on the efficient handling of the bi-level hub interdiction problem using the Dual-based approach and the Penalty-based approach, and the second contribution is on solving the overall three-level problem using a super valid inequality. These two contributions allow us to solve large-scale versions of the capacitated multiple allocation p-median hub location problem under the risk of interdiction, which is otherwise mathematically intractable and can be handled only using complete enumeration techniques.

To read the complete research paper

Visit:
https://doi.org/10.1007/s10479-023-05563-4

2. A dynamic pricing strategy model for Indian Railways

Prof. Sundaravalli Narayanaswami, along with IIMA students Karthikeya Singh and Pushkaraj Dhake, authored a research paper titled 'A dynamic pricing strategy model for Indian Railways'.

Abstract:

The Indian Railways has adopted a dynamic pricing mechanism for its premium trains like Shatabdi, Rajdhani, and Duronto. This led to an increase in its revenue but also a fall in passenger traffic. In this paper, we have analyzed the existing dynamic pricing model. A major flaw in the existing system is that the present system is only a fare hike system rather than a dynamic pricing system as there is no provision for a decrease in prices when the demand is low. Considering this, we have developed a new model that incorporates both inter-temporal pricing and demand-based pricing to come up with the dynamic fares along with the provision of having a downside in case of low demand. We developed a route selection criteria based on the key parameters identified by us where dynamic pricing would yield good results. The model was then tested on these routes using real-time data to determine the feasibility of the dynamic pricing system.

To read the complete research paper

Visit:
https://doi.org/10.1057/s41272-023-00450-w

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3. Zoning strategies for human–robot collaborative picking

Prof. Debjit Roy published a research paper with Dr. Kaveh Azadeh, Prof. René de Koster and Prof. Seyyed Mahdi Ghorashi Khalilabadi titled 'Zoning strategies for human–robot collaborative picking'.

Abstract:

During the last decade, several retailers have started to combine traditional store deliveries with the fulfillment of online sales to consumers from omni-channel warehouses, which are increasingly being automated. A popular option is to use autonomous mobile robots (AMRs) in collaboration with human pickers. In this approach, the pickers' unproductive walking time can be reduced even further by zoning the storage system, where the pickers stay within their zone periphery and robots transport order totes between the zones. However, the robotic systems' optimal zoning strategy is unclear: few zones are particularly good for large store orders, while many zones are particularly good for small online orders. We study the effect of no zoning (NZ) and progressive zoning strategies on throughput capacity for balanced zone configurations with both fixed and dynamic order profiles. We first develop queuing network models to estimate pick throughput capacity that correspond to a given number of AMRs and picking with a fixed number of zones. We demonstrate that the throughput capacity is dependent on the chosen zoning strategy. However, the magnitude of the gains achieved is influenced by the size of the orders being processed. We also show that using a dynamic switching strategy has little effect on throughput performance. In contrast, a fixed switching strategy benefiting from changes in the order profile has the potential to increase throughput performance by 17% compared to the NZ strategy, albeit at a higher robot cost.

To read the complete research paper

Visit:
https://doi.org/10.1111/deci.12620

4. Assessment of marketing channel choice and its impacts: The case of paddy smallholders in India

Prof. Poornima Varma, published a research paper with Dr. Sonalee Chauhan & Prof. Sukhpal Singh titled 'Assessment of Marketing Channel Choice and its Impacts: The Case of Paddy Smallholders in India'.

Abstract:

Market access for smallholders is a key policy issue in developing economies. However, smallholders often face barriers in accessing remunerative marketing channels. Combining the theoretical framework drawn from resource-based view, social exchange, and transaction cost theory, we jointly estimate the determinants of marketing channel choice and the impact of channel choice in a joint framework. Results show that households' resource endowments and social capital influence channel selection decisions. Paddy sales through government agencies help farmers realize higher prices because of the higher government support prices and proximity to farms, whereas sales through licensed traders operating in the regulated markets (APMC) results in reduced paddy prices due to high transportation costs. Furthermore, smallholders preferring government agencies, processors, and licensed traders over village traders realize greater farm income. Reasons for such findings can be deduced to be the result of low marketable surplus for smallholders selling to village traders.

To read the complete research paper

Visit:
https://doi.org/10.1080/08974438.2023.2291812

5. Integrated inventory replenishment and online demand allocation decisions for an omnichannel retailer with ship-from-store strategy


Prof. Debjit Roy and **Prof. Prahalad Venkateshan** published a research paper along with Prof. Vishal Bansal and Prof. Arnab Bisi, titled 'Integrated inventory replenishment and online demand allocation decisions for an omnichannel retailer with ship-from-store strategy'.


Innovative applications of O.R.

Integrated inventory replenishment and online demand allocation decisions for an omnichannel retailer with ship-from-store strategy

Vishal Bansal [a], Arnab Bisi [b], Debjit Roy [c], Prahalad Venkateshan [c]

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Abstract:

Retailing has changed dramatically from single-channel brick-and-mortar stores to multi-channel and omnichannel retailers over the last few decades. Omnichannel retailers employ different strategies to integrate online and offline sales channels as well as order fulfillment processes. Among these strategies, the ship-from-store is the most popular and widely accepted among retailers. It enables retailers to use inventory from store locations to fulfill online demand. An omnichannel retailer with a distribution center and a retail store has to make important, interlinked decisions — (1) how much inventory to keep at the retail store, and (2) where to fulfill the online demand from and how much. In this work, we model the integrated inventory replenishment and online demand allocation decisions for an omnichannel retailer employing the ship-from-store strategy. We analyze this problem for both single-period and multi-period settings. We extend the analytical framework of the single-period problem by providing a finite-horizon Markov decision process (MDP) formulation for the multi-period problem. Our findings suggest that for a single-period setting, decentralized inventory replenishment and demand allocation system maximizes the profit of the omnichannel retailer for low values of the incentive for fulfilling the online demand through store inventory, while for sufficiently high values of the incentive, a pooled system provides the optimal profit. An increment in the discount factor has the same effect on the optimal decisions in a multi-period setting as that of salvage value in a single-period setting for a given value of the incentive for the ship-from-store strategy. We also provide several extensions (such as cross selling, endogenous and correlated demand streams) of our analytical framework for the multi-period problem.

To read the complete research paper

Visit:
https://doi.org/10.1016/j.ejor.2024.02.027

6. The capacitated r-hub interdiction problem with congestion: Models and solution approaches

Prof. Sachin Jayaswal published a research article with Prof. Sneha Dhyani Bhatt & Prof. Ankur Sinha titled 'The capacitated r-hub interdiction problem with congestion: Models and solution approaches'.


Transportation Research Part E: Logistics and Transportation Review
Volume 185, May 2024, 103482

The capacitated r-hub interdiction problem with congestion: Models and solution approaches

Sneha Dhyani Bhatt [a], Ankur Sinha [b], Sachin Jayaswal [b]

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Abstract:

We study the r-hub interdiction problem under the case of possible congestion. Hub interdiction problems are modeled as attacker-defender problems to identify a set of r critical hubs from a set of p hubs, which when attacked, causes maximum damage to network restoration activities of the defender. In this work we consider that in addition to the routing cost, the defender also aims to minimize the congestion cost. Incorporating the congestion cost in the problem introduces non-linearity in the objective function of the interdiction problem, which makes the problem challenging to solve. To address this, we propose two alternate exact solution approaches. The first approach is an inner-approximation-based approach (IBA), which overestimates the convex non-linear objective function and provides an upper bound. A lower bound is obtained from solving the lower-level problem exactly corresponding to the upper bound solution. The upper bound is tightened using improved approximation with new points generated in successive iterations. In the second approach (referred to as SBA), the problem is reformulated as a second-order conic program, which can be solved using an off-the-shelf solver. From our computational experiments on benchmark datasets (CAB and AP), we demonstrate the efficacy of both the proposed methods. However, IBA consistently outperforms SBA by a significant margin.

To read the complete research paper

Visit:
https://doi.org/10.1016/j.tre.2024.103482

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7. Stochastic modeling of integrated order fulfillment processes with delivery time promise: Order picking, batching, and last-mile delivery

Prof. Debjit Roy published a research paper with Dr. Gyanesh Raj, Prof. René de Koster and Prof. Vishal Bansal titled 'Stochastic modeling of integrated order fulfillment processes with delivery time promise: Order picking, batching, and last-mile delivery'.


Innovative Applications of O.R.

Stochastic modeling of integrated order fulfillment processes with delivery time promise: Order picking, batching, and last-mile delivery

G. Raj [c], D. Roy [b], R. de Koster [c], V. Bansal [d]

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Abstract:

To guarantee high customer service and short and accurate lead times, many e-commerce retailers have started to home deliver their customer orders within a few hours or even minutes, also known as quick-commerce order fulfillment. Quick-commerce order fulfillment consists of three main processes: order picking in the warehouse, order batching for delivery, and last-mile delivery. The ultimate delivery performance depends on managing all three processes, which are highly stochastic, and interdependent. We capture this stochasticity and interdependency in an integrated analytical framework and derive approximate analytical expressions for the mean and variance of the total order fulfillment time. We validate the analytical expressions with both in-house detailed process simulations and external-party output measures. We then analyze the delivery cost-service quality trade-offs using an optimization model that minimizes the expected order fulfillment cost with a delivery probability (DP) constraint, focusing on meeting delivery time deadlines. The optimization model determines the number of pickers, the optimal delivery batch size, and the number of vehicles required to deliver the customer orders. Achieving a high delivery reliability comes at a cost. In comparison to the model with DP constraints, we observe that the expected order fulfillment cost averaged over all data parameter settings obtained from the model without DP constraints is 8.9% lower; however, the mean and standard deviation of order fulfillment time increase by 44.1% and 18.6%, respectively, which results in low delivery reliability. We further demonstrate that an integrated analysis of the order fulfillment process is essential to set reliable fulfillment due times.

To read the complete research paper

Visit:
https://doi.org/10.1016/j.ejor.2024.03.003

8. Bilevel Optimization: Applications, Models and Solution Approaches

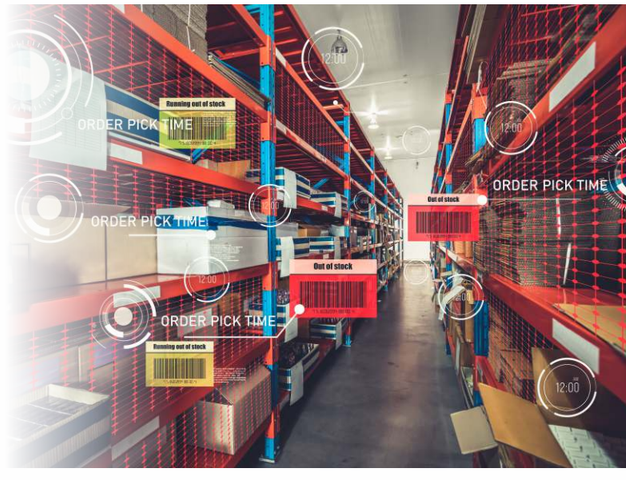
'Bilevel Optimization: Applications, Models and Solution Approaches', a research paper co-authored by **Prof. Sachin Jayaswal** and Prof. Ankur Sinha, has been featured in a book titled 'Optimization Essentials: Theory, Tools, and Applications', which is a part of the book series 'International Series in Operations Research & Management Science'.

Abstract:

Bilevel optimization is a difficult class of optimization problems, which contain an inner optimization problem as a constraint to an outer optimization problem. Such optimization problems are commonly referred to as Stackelberg games in the area of game theory, where a hierarchical interaction between a leader and a follower is modeled. This chapter presents several examples of bilevel optimization problems arising in various contexts, e.g., the product line selection problem and the shortest path interdiction problem. Depending on the context of the problem, the leader and the follower may have the same objective function but with conflicting objectives (max-min in the shortest path interdiction), or may have different objective functions (as in the product line selection problem). Under this hierarchical setting, the leader tries to optimize its own decision by taking into account the rational response of the follower. A bilevel optimization problem is NP-hard even in the simplest case in which the problems of the leader and the follower are both simple linear programs. This chapter discusses classical solution approaches that are based on the reformulation of the bilevel problem into a single level. It also discusses several alternate single-level reformulations for the application problems considered in this chapter.

To know more

Visit:
https://link.springer.com/book/9789819954902



Thought Leadership Articles

1. India has better options than banning rice exports

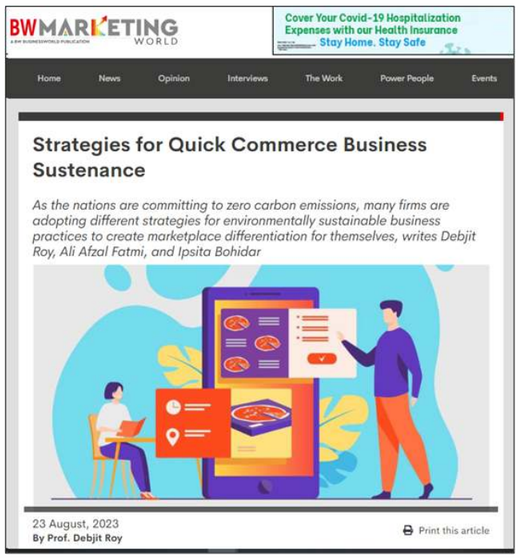
Opinion article titled 'India has better options than banning rice exports' authored by **Dr. Poornima Varma** was featured in Nikkei Asia, on August 17, 2023.

To read the complete article

Visit:
https://asia.nikkei.com/Opinion/India-has-better-options-than-banning-rice-exports

2. Strategies for Quick Commerce Business Sustenance

Opinion article titled 'Strategies for Quick Commerce Business Sustenance' authored by **Dr. Debjit Roy** along with PGPX participants Mr. Ali Afzal Fatmi and Ms. Ipsita Bohidar was published in BW Marketing World, on August 23, 2023.



To read the complete article

Visit:
https://bwmarketingworld.businessworld.in/article/Strategies-for-Quick-Commerce-Business-Sustenance/23-08-2023-488702/

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3. India's metro rail system should become financially sustainable

Opinion article titled 'India's metro rail system should become financially sustainable' authored by **Dr. Sandip Chakrabarti**, along with Mr. Nitin Zamre, CEO, The Infravision Foundation was featured in Mint, on October 04, 2023.

To read the complete article

Visit:
https://www.livemint.com/opinion/online-views/indias-metro-rail-systems-should-become-financially-sustainable-11696429843913.html

4. Land Value Capture: A self-financing and sustainable model for infrastructure development

Opinion article titled 'Land Value Capture: A self-financing and sustainable model for infrastructure development' authored by **Dr. Prashant Das** along with IIMA PGPX participants Mr. Yash Choudhary and Ms. Anchal Agarwal was published in Financial Express, on November 27,2023.

To read the complete article

Visit:
https://www.financialexpress.com/money/land-value-capture-a-self-financing-and-sustainable-model-for-infrastructure-development-3318701/

CTL Planned Activities for 2024-25

1. Logistics Leaders Summit:

A high-level gathering of industry executives and decision-makers to discuss strategic challenges and opportunities shaping the future of transportation and logistics. Keynote presentations, panel discussions, and networking sessions will drive collaboration and innovation.

2. Research and Practitioner Symposiums:

Efforts will be made to ensure that CTL will conduct research and practitioners symposiums contributing to the institute of learning.

3. Future Trends in Transportation Panel Discussion:

A forward-looking session examining emerging trends and disruptive forces shaping the future of transportation, considering India's foray into arranging the Olympics in the year 2036.

4. Sustainability in Transport Forum:

Addressing the urgent need for sustainable practices in transportation and logistics. Industry leaders, policymakers, and sustainability experts will explore strategies for reducing carbon emissions, optimizing energy efficiency, and promoting eco-friendly initiatives throughout the supply chain.

5. Last-Mile Delivery Symposium:

Examining challenges and innovations in the final stage of the delivery process. Topics include urban logistics, customer experience, delivery optimization technologies, and sustainable last-mile solutions, with a focus on enhancing efficiency and customer satisfaction.

6. Industry Consulting Assignments:

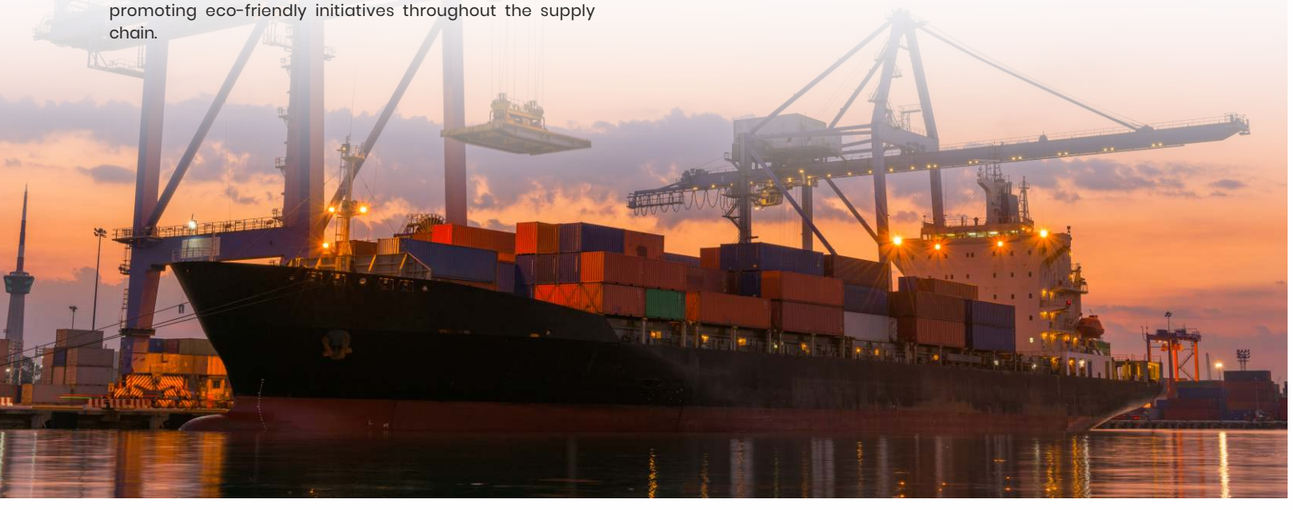
CTL will reach out to industry in a need of scientific management practices to optimize the existing operations for the purpose of betterment

7. Development of Index:

CTL will be releasing industry sought after indices that would benefit its operations as a function of the total operational logistics cost. The index will give a clear understanding of the steps to be taken by the respective industry for optimizing its operational cost.

8. Industry Executive Programs:

CTL will strive to arrange an executive cohort programme for the industry leaders in the transportation and logistics space, for a duration of 2 - 3 days.



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Appendix

A. CTL Faculty Highlights

1. Summer School on Large Scale Optimization by IIT Kanpur

Prof. Sachin Jayaswal was invited to be a part of the third edition of the Large Scale Optimization (LSO) Summer School and Conference held at Indian Institute of Technology Kanpur, from April 01-09, 2023.

Prof. Sachin Jayaswal alongside other esteemed guests and participants of the workshop

2. Masterclass on 'Emerging technologies for operational and strategic interventions in supply chains'

Prof. Debjit Roy delivered a masterclass on 'Emerging technologies for operational and strategic interventions in supply chains' at The Economic Times Supply Chain Management & Logistics Summit 2023 presented by Mahindra Logistics and co-powered by Amazon Web Services on June 28, 2023, at Delhi, India.

Key Highlights:
- Prof. Roy spoke about the role of digitization in reshaping supply chain management, intralogistics, transportation, and procurement systems.
- Further, he discussed the various use-cases of emerging technologies in streamlining supply chains and logistics operations to improve productivity and operational efficiency.

Masterclass on 'Emerging technologies for operational and strategic interventions in supply chains' by Prof. Debjit Roy

3. Paper Presentation at Transportation Science & Logistics (TSL) Conference

Prof. Sachin Jayaswal presented his work on 'A cutting-plane based approach for fixed-charge transportation problems' at the Transportation Science & Logistics (TSL) Conference, Chicago, USA, held from July 23-26, 2023.

4. Research Seminar on 'A cutting-plane based approach for fixed-charge transportation problems'

Prof. Sachin Jayaswal delivered a Research Seminar on 'A cutting-plane based approach for fixed-charge transportation problems' at IIM Bangalore on October 17, 2023.

Prof. Sachin Jayaswal with the organisers and attendees of the Research Seminar at IIM Bangalore

5. 2023 Transportation Science Meritorious Service Awards

Prof. Debjit Roy received the prestigious 2023 Transportation Science Meritorious Service Award. The award recognizes associate editors, special issue guest editors, and reviewers who have offered exceptional service in the review process.

Prof. Debjit Roy honored with the prestigious '2023 Transportation Science Meritorious Service Award'

Visit to know more:
https://pubsonline.informs.org/doi/10.1287/trsc.2023.servawards.V57.n6

6. Paper Presentation at the 2023 INFORMS Annual Meeting

Prof. Sundaravalli Narayanaswami presented a paper titled, 'A Study Of Cold Chain Practices Across Four Sectors' at the 2023 INFORMS Annual Meeting in Phoenix, USA from October 15-18, 2023.

7. Workshop on 'The analysis and optimization of warehouse performance'

Prof. Debjit Roy delivered a keynote on 'Stochastic Models for Integrated Warehousing Systems: Modeling Constructs and Research Opportunities in Order Fulfillment' as a part of the three-day workshop on 'The analysis and optimization of warehouse performance' held by Eindhoven University of Technology from November 28 to 30, 2023.

8. Conference organised by Confederation of Indian Industry and The Infravision Foundation

Prof. Sandip Chakrabarti discussed innovative and practical strategies for improving the financial sustainability of metro rail systems across India in a conference jointly organized by Confederation of Indian Industry and The Infravision Foundation in New Delhi on December 4, 2023.

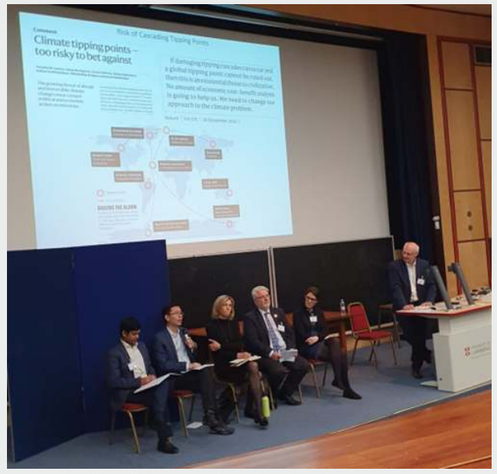
The theme for the conference was 'Urban Mobility: Towards Seamless Integration'. Dr. Chakrabarti also joined a panel discussion on 'Investing in Future Ready Systems' along with other renowned industry leaders.

Prof. Sandip Chakrabarti alongside distinguished panelists at the conference 'Urban Mobility: Advancing Towards Seamless Integration.'

Read Professor Chakrabarti's article titled 'India's metro rail system should become financially sustainable' accessible at the following link: https://www.livemint.com/opinion/online-views/indias-metro-rail-systems-should-become-financially-sustainable-11696429843913.html

9. 10th Sustainable Road Freight Conference

Prof. Debjit Roy was a part of the International Scientific Committee for the 10th International Workshop on Sustainable Road Freight held in Cambridge, UK on 4th-5th December 2023.
The theme for the workshop was 'Robust decarbonization and resilient logistics: Progress in the last decade and a roadmap to 2035'.



Prof. Debjit Roy contributed to the discourse at the '10th International Workshop on Sustainable Road Freight Transport 2023' held in Cambridge, UK

Visit to know more: https://www.csrf.ac.uk/events/10th-international-workshop-on-sustainable-road-freight/

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10.Research Seminar on 'Stochastic Models for Integrated Warehousing Systems: Modeling Constructs and Research Opportunities in Order Fulfillment'

Prof. Debjit Roy visited IIM Ranchi on December 7, 2023, to deliver a seminar on 'Stochastic Models for Integrated Warehousing Systems: Modeling Constructs and Research Opportunities in Order Fulfillment'.

Key Highlights:
- The seminar delved into stochastic models and further explored integrated warehousing systems in depth.
- The seminar also discussed prospective future research paths in order fulfillment.

Prof. Debjit Roy delivered a Research Seminar on 'Stochastic Models for Integrated Warehousing Systems: Modeling Constructs and Research Opportunities in Order Fulfillment'at IIM Ranchi

11. International Convention on 'Digital Transformation of Indian Railways: Track to Train & Operations to Maintenance, by IRSE

Prof. Sundaravalli Narayanaswami was a distinguished Guest of honor and keynote speaker at the International Convention organized by the IRSE on the subject of 'Digital Transformation of Indian Railways: Track to Train & Operations to Maintenance' held at Manekshaw Convention Center, Dhaula Kuan from December 11-13, 2023.

Prof. Sundaravalli Narayanaswami alongside other esteemed guests of the International Convention by IRSE

12. 7th Conference of the Transportation Research Group of India

Centre for Transportation and Logistics, IIMA was a supporting knowledge partner of the 7th Conference of the Transportation Research Group of India, along with Indian Institute of Technology, Bombay, Gati Shakti Vishwavidyalaya, Technical University of Munich, and other prominent Indian and international institutions. The conference, held in Surat, Gujarat from 17th-20th December, 2023, featured cutting edge research in passenger and freight transportation from researchers around the world.

Prof. Sandip Chakrabarti was an Organizing Committee and Scientific Committee member of the conference, chaired the Technical Track on Mobility Networks, and was the Session Chair of the Freight and Mobility session at the conference.

IIMA CTL was represented prominently at the conference. CTL Research Advisory Committee members **Prof. Chandra Bhat** of The University of Texas at Austin and **Prof. Geetam Tiwari** of Indian Institute of Technology, Delhi delivered keynote addresses.

Prof. Sandip Chakrabarti with other esteemed guests at the 7th Conference of the Transportation Research Group of India

13. Empowered Committee for Industry and International Collaboration, Ministry of Education, Government of India

The Ministry of Education, Government of India has created a special task force named 'Empowered Committee for Industry and International Collaboration' along 12 verticals of 'Critical and Emerging Technologies.' One of the verticals is 'Smart Cities and Mobility,' and the vertical comprises an expert sub-committee composed of top researchers in the field drawn from premier Indian institutes. **Prof. Sandip Chakrabarti** has been selected to serve on this sub-committee. The members of the sub-committee are Prof. Geetam Tiwari (IIT Delhi), Prof. Sandip Chakrabarti (IIMA), Prof. Arnab Jana (IIT Bombay), and Prof. P Rajalakshmi (IIT Hyderabad). Their mandate is to develop a report to identify future research agendas and strategies in India under the smart cities and mobility theme.

14. Research Presentation at IIMA Research & Publications Seminar

Professor Subhrajit "Subhro" Guhathakurta, Georgia Institute of Technology and member of CTL Research Advisory Committee presented his research on spatial equity and equality implications of on-demand multimodal transit service, using data from Atlanta, as part of Research and Publications at IIM Ahmedabad's Seminar Series. Technology facilitated on-demand transportation services are relevant for India's cities as well. With appropriate designs and policies, such systems have the potential to promote sustainable development and equitable access. Urban analytics offers great opportunities for exploring innovative solutions to a wide range of mobility challenges.

Prof. Subhrajit "Subhro" Guhathakurta with the attendees of his Research Presentation at IIMA

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15. Workshop on 'Modelling Resource Synchronization Delays'

An online workshop on 'Modelling Resource Synchronization Delays' led by **Prof. Debjit Roy** was organized by IIMA on January 05, 2024.

Key Highlights:
- The workshop focused on three key areas- Understanding of constructs for modelling resource synchronization, identifying application areas, and learning solution methods with potential research opportunities.
- The discussions further delved into the concept of Semi-Open Queuing Networks (SOQNs) and several stochastic models for manufacturing, logistics, and service systems were discussed in depth.

Prof. Debjit Roy led an online workshop on 'Modelling Resource Synchronization Delays' at IIMA

16. Research Webinar on 'Emerging Technologies for Operational & Strategic Interventions in Supply Chain'

A webinar on 'Emerging Technologies for Operational & Strategic Interventions in Supply Chain' was conducted by **Prof. Debjit Roy** on January 08, 2024, at IIM Kashipur.

Prof. Debjit Roy delivered a Research Webinar on 'Emerging Technologies for Operational & Strategic Interventions in Supply Chain' at IIM Kashipur

17. Autonomous Drone Logistics Systems to Automate Last-Mile Healthcare Supply Chains

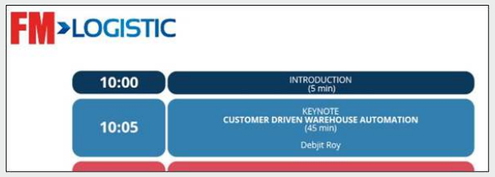
REDWING LABS

Prof. Maya Ganesh along with Prof. Namrata Chindarkar (JSW School of Public Policy) have initiated a collaborative project with Redwing Labs, a company that designs and operates autonomous drone logistics systems to automate last-mile healthcare supply chains. Redwing recently established drone hubs in the Kandhamal and Rayagada districts of Odisha to support delivery of emergency medicines, vaccines, and diagnostic services. The objective of this project is to evaluate the impact of Redwing's intervention on various health indicators in these districts.

Abstract:
Rural areas continue to face challenges in accessing good quality healthcare services. Many parts of rural India still lack timely access to medical services such as diagnostics and vaccines. The absence of efficient and agile supply-chains at the last mile poses a significant problem, resulting in the unavailability of essential medicines, increased out-of-pocket expenses for patients, and loss of lives. Drone-based autonomous systems have shown great promise and success in addressing last-mile delivery challenges in healthcare systems worldwide. Although drones hold the potential to overcome this challenge, there is a need for evidence to understand and quantify their impact. The Government of India has been actively encouraging public and private stakeholders to utilize drones to enhance healthcare access and equity. Considering that a substantial section of the rural population must travel more than 100 kilometers to access basic healthcare, drones offer immense potential in improving access to quality healthcare. An academic lens will enable policymakers to understand the cost-effectiveness, replicability, and scalability of this intervention.

18. Keynote on 'Customer Driven Warehouse Automation'

Prof. Debjit Roy delivered a keynote on the topic titled 'Customer Driven Warehouse Automation' to the global leaders at FM Logistic.



19. CTL at Vibrant Gujarat Global Trade Show 2024 at Gandhinagar, Gujarat

The Centre for Transportation and Logistics, IIM Ahmedabad participated in the **Vibrant Gujarat Global Trade Show 2024** as part of the IIMA booth, which was held in Gandhinagar from January 11 to 13, 2024. The Centre showcased its research projects, products, activities, and events to the audience which included thought leaders, industry experts, startup founders, research scholars and students among others.

The Centre was represented by team members **Mr. Subodh Patrikar** and **Mr. Shubham**. They held insightful discussions, exchanged ideas, and explored collaborative opportunities with stakeholders from various transportation & logistics sectors like e-mobility, warehousing and industrial real estate, industry 4.0, port logistics, last mile connectivity and autonomous vehicles among others.

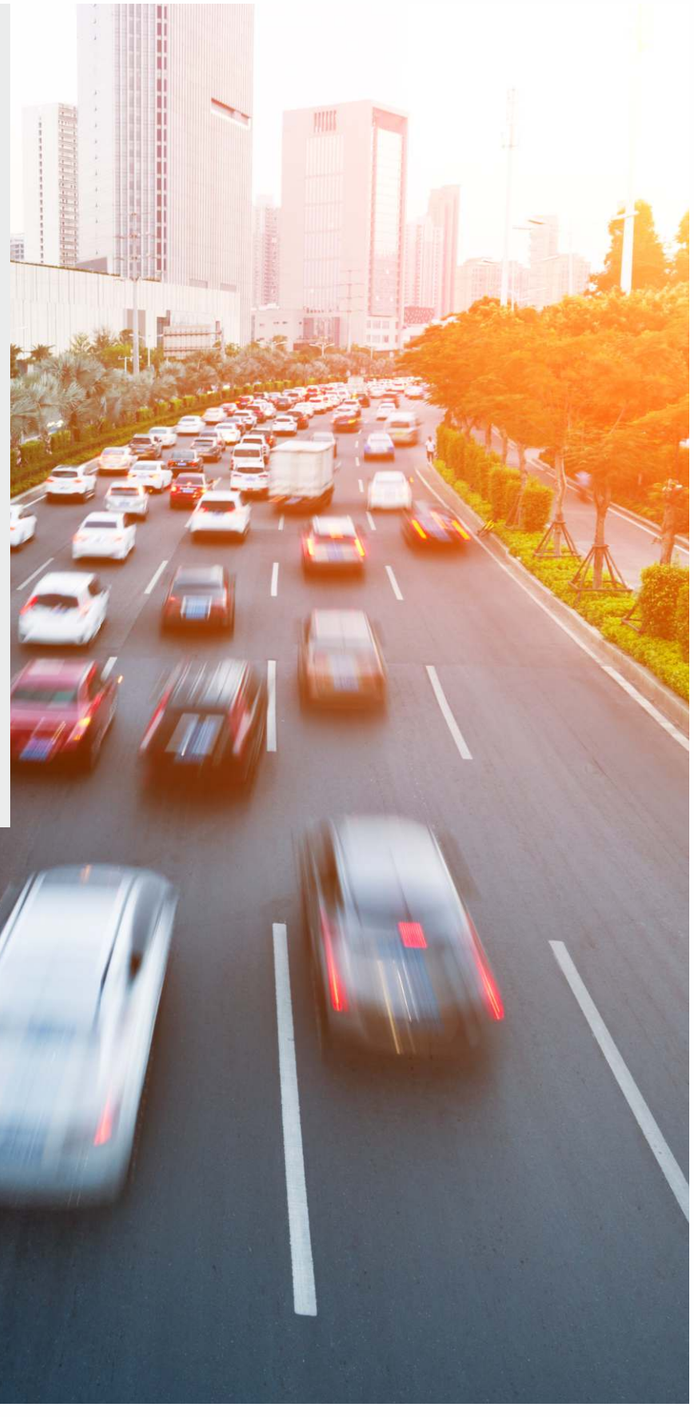
CTL Team Members, alongside other representatives from IIMA, at the Vibrant Gujarat Global Trade Show 2024

20. Workshop on 'Freight Emission Index developed for the Walled City of Ahmedabad'

Prof. Debjit Roy was one of the esteemed panelists for the knowledge dissemination workshop on the 'Freight Emission Index developed for the Walled City of Ahmedabad' that addressed challenges and opportunities in implementing emission reduction strategies. The workshop was held at the Ahmedabad Management Association on February 24, 2024.

Key Highlights:
- Dr. Debjit Roy provided insights on the role of the market in optimizing the supply chain and promoting an aggregated freight movement through government mandates.
- Further, he also discussed capacity building of private freight operators as driver behaviour plays a key role in vehicle emissions.

Prof. Debjit Roy alongside other esteemed guests and attendees of the workshop



21. Research Talk at International Conference on Computations and Data Science, IIT Roorkee

Prof. Sachin Jayaswal was invited to deliver a research talk on 'Old polytopes, new valid inequalities for cutting-plane methods' at the International Conference on Computations and Data Science organised by Indian Institute of Technology Roorkee on March 08, 2024.

Prof. Sachin Jayaswal presenting his research talk at the International Conference on Computations and Data Science held at IIT Roorkee

22.Conference Presentation at International Network Optimization Conference (INOC)

Prof. Sachin Jayaswal participated in the International Network Optimization Conference (INOC), presenting his work titled 'A cutting-plane-based method for solving fixed-charge transportation problems using new valid inequalities for single-node flow polytope'. The conference took place from March 11-13, 2024, at University College Dublin, Ireland.

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वस्त्रापुर, अहमदाबाद ३८०००१५, भारत | Vastrapur, Ahmedabad 380015, India.

+91 79 7152 7022 ctl@iima.ac.in

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