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PAPER ID:02

ASSESSING TURKISH AIRLINES' OPERATIONAL EFFICIENCY POSITION IN THE GLOBAL AVIATION INDUSTRY: DATA ENVELOPMENT ANALYSIS

Oya ÖZTÜRK, Zehra Vildan SERİN

Hasan Kalyoncu University, Department of International Trade and Logistics, Gaziantep, Turkiye, oya.ozturk@hku.edu.tr
Hasan Kalyoncu University, Department of International Trade and Logistics, Gaziantep, Turkiye, zvildan.serin@hku.edu.tr

ABSTRACT:

The aviation industry makes a significant contribution to the global economy by creating employment opportunities and driving economic growth. Hence, the aviation sector is characterized by intense competition. The operational efficiency of airlines provides them with a competitive advantage. Therefore, there is a need to conduct multidimensional performance measurements that consider both financial and non-financial perspectives to improve airline performance. The aim of this study is to determine Turkish Airlines' position among a total of 19 airlines implementing different business models by conducting operational efficiency measurement using the Data Envelopment Analysis technique for the period 2017-2021. In the study, an input-oriented (BCC-I) model was constructed, and technical efficiency (VRS) measurement was performed. Turkish Airlines has been identified to be placed 16th among 19 companies, with an average efficiency score of VRS=0.884.

KEYWORDS
Aviation, Data Envelopment Analysis, Efficiency, Turkish Airlines.
RELATED TOPICS
Sustainability in logistics and supply chains, Transportation and warehouse management

Paper ID:04

AIRLINE FLEET ANALYSIS AND OPTIMIZATION THROUGH RESPONSE SURFACE METHODOLOGY

Metehan ATAY, Serap ULUSAM SECKINER, Yunus EROGLU

Hasan Kalyoncu University, Department of UAV Technology and Operation, Gaziantep, Turkiye metehan.atay@hku.edu.tr
Gaziantep University, Industrial Engineering Department, Gaziantep, Turkiye
seckiner@gantep.edu.tr
Iskenderun Technical University, Industrial Engineering Department, Hatay, Turkiye
yunus.eroglu@iste.edu.tr

ABSTRACT:

With the fleet analysis using the Response surface methodology method, the purposes served by the fleet structures of the existing airline companies were examined and the ideas that should be carried out in order to establish a fleet were discussed. The main reason for making all these discussions is to choose the most realistic parameters to be used in the mathematical model to be established and to ensure that the model can serve real life and maintain its dynamism. It is possible to say that air transport has brought many changes with the recent changes in the world. It is also true that there is a great demand intensity in the civil aviation industry, especially with the increasing speed demand and rapid transportation trends. On the other hand, the reasons affecting the whole world such as the pandemic and disrupting the air transport have not only affected the operations on a sectorial basis but also the global economy and made the operations expensive. It is known that while many airline companies go bankrupt under these conditions, new airline companies are also established.

KEYWORDS
Fleet Analysis, Sustainability, Airline, RSM, Optimization.

RELATED TOPICS
Sustainability in logistics and supply chains, Green logistics and supply chain management

Paper ID:05

SUSTAINABLE LOGISTICS OPERATIONS IN DISASTER MANAGEMENT: A LITERATURE REVIEW

Cansu Akçiçek, Yücel Öztürkoğlu

Yasar University, Graduate School, İzmir, Turkiye, cansu.akcicek@yasar.edu.tr
Yasar University, Department of Logistics Management, İzmir, Turkiye
yucel.ozturkoglu@yasar.edu.tr

ABSTRACT:

Sustainable and innovative disaster logistics in the supply chain is a developing field that adopts sustainable and innovative principles to ensure that the processes and operations handled at every phase of disaster management can be carried out in an efficient and resilient manner. Unlike traditional approaches, sustainable and innovative disaster logistics represent a paradigm shift in disaster management by considering long-term environmental, social and economic impacts. By leveraging innovative technologies such as remote sensing, geographic information systems (GIS), real-time and big data analytics, a sustainable and holistic approach is provided to key actions such as optimizing the allocation of resources, better decision making, better collaboration and partnerships among various stakeholders. When the disaster logistics literature is examined, there are studies on disaster logistics activities that include the coordination and movement of resources, personnel and information in pre-disaster and post-disaster stages, it is recognized that there is a need for more sustainable and innovative approaches to disaster logistics in line with the sustainable development goals (SDGs). Therefore, this study aims to examine a wide range of scientific articles on sustainable and innovative disaster logistics under the theme of supply chain and humanitarian logistics published in recent years. As a result of the examinations, it is seen that there is limited empirical research on the implementation and effectiveness of sustainable practices in disaster logistics. Finally, gaps in the existing literature are identified and research direction is determined for future work that will also address sustainable development goals (SDGs).

KEYWORDS
Disaster management, sustainable development goals, humanitarian logistics, literature review
RELATED TOPICS
Emergencies and crisis logistics, Sustainability in logistics and supply chains, Humanitarian logistics

Paper ID:06

NUTRITION LOGISTICS IN DISASTERS "THE CASE OF KAHRAMANMARAS"

Prof. Dr. Mehmet TANYAŞ, İpek TEZEL

Maltepe University, International Trade&Logistics Department, Istanbul-Turkey,
mehmettanyas@maltepe.edu.tr
ipektezel@gantep.edu.tr

ABSTRACT:

Since the formation of the Earth, the world has witnessed many disasters. Although the general formation of disasters is due to the natural structure of the earth, many of them are caused by the damage caused by humanity to nature, especially after the industrial revolution. The biggest negative consequence of this damage is climate change. Disasters are actually a normal part of life. Disasters are defined as events and situations that cause great loss of life and property due to the emergence of expected or unexpected risks, that cause major and minor disruptions in the daily lives of people, that local governments are insufficient to combat alone, and that require national and international cooperation. National and international cooperation is the most important element of combating a disaster. In recent years, especially the earthquake that occurred in the Republic of Turkey on February 6, 2023, covering 11 provinces has revealed the importance of this cooperation and coordination. One of the most important issues in disaster organization is the need for nutrition and clean water, which is one of the most basic needs of human beings. In disasters, regardless of language, religion, race, certain priorities (search and rescue teams, infants, elderly, disabled, etc.) should be made to meet the nutritional needs within the first 72 hours. Under the leadership of the Disaster and Emergency Management Presidency (AFAD) established in Turkey, the responsibility of the "National Disaster Nutrition" group was given to the Turkish Red Crescent in accordance with the relevant articles of the Turkish Red Crescent Organization Regulation. In this study, the nutrition model of the Turkish Red Crescent and the duties and responsibilities of the "National Disaster Nutrition" group under its responsibility were examined, and a "Disaster Nutrition Logistics Model" based on the literature and semi-structured interviews was proposed.

KEYWORDS
Disaster Logistics, Disaster Management System, Nutrition Logistics, Turkish Red Crescent.

RELATED TOPICS
Social responsibility in logistics and supply chains, Humanitarian logistics, Health care logistics

Paper ID:07

HOW DID ORGANIZATIONS REACT TO THE SUPPLY CHAIN BREAKDOWN DURING THE COVID-19 PANDEMIC? THE SAMPLE OF FOREIGN TRADE COMPANIES IN MERSIN

Dr. Tülin Özbahar, Asst. Prof. Dr. Ender Gürgen, Assoc. Prof. Dr. Mehmet Nasih Tağ

Independent Researcher, tulinozbahar@gmail.com
Mersin University-Department of Business, Mersin, Turkiye gurgen@mersin.edu.tr
Mersin University-Department of Business, Mersin, Turkiye, tag@mersin.edu.tr

ABSTRACT:

One of the main objectives of supply chain management is planning the logistics activities to achieve uninterrupted flows of goods, finance, and information in the supply chain. However, unexpected distruptions of these flows may occur during a crisis period, such as the Covid-19 pandemic, which caused massive distruptions in production operations, container supply, port operations, and staff availabilities. Then the main question that arises is how does the top management in affected organizations react to minimize losses due to supply chain interruptions. In this study, we first aim to document the disruptions that businesses of global supply chains have experienced during the pandemic. Second, we explore how these businesses responded to the disruptions in their supply chains. For this purpose, we collected data by interviewing top managers of large businesses registered in the Mersin Chamber of Commerce and Industry. The businesses in our sample were all involved in foreign trade and had sales exceeding 10 million dollars in 2019. Our qualitative analysis shows that while the businesses in our sample have implemented several tactical-level adaptations to the disruptions in their environment, overall they did not enact major changes in their business strategy. A key reason for the apparent inertia seems to be the significant, nonetheless unexpected, increase in profitability that came with the pandemic.

KEYWORDS
Organizational Change, Supply Chain Strategy, Strategy Change, The Covid-19 Pandemic.

RELATED TOPICS
Special topics in logistics and supply chains, Best practices in logistics and supply chains.

Paper ID:13

A CIRCULAR ECONOMY MODEL FOR HOUSEHOLD MEDICAL WASTE MANAGEMENT: A CONCEPTUAL FRAMEWORK

Gizem HALİL UTMA, Semra TUNALI

İzmir University of Economics, Faculty of Business, Department of Business Administration, İzmir, Turkey, gizem.halil@ieu.edu.tr
İzmir University of Economics, Faculty of Business, Department of Business Administration, İzmir, Turkey, semra.tunali@ieu.edu.tr

ABSTRACT:

The pharmaceutical industry generates nearly 100 million tons of waste annually, posing health risks and environmental concerns. Effective management of household medical waste (HMW) is crucial in addressing these issues. Traditional disposal methods harm the environment and waste resources, highlighting the need for sustainable practices. Circular economy (CE) offers a solution by transforming waste into valuable resources and paving the way for a sustainable future. However, the sector has not widely implemented CE due to the absence of regularity policies involving quality and safety. This study aims to develop a comprehensive conceptual framework for managing HMW within the context of CE. By reviewing relevant literature and theoretical frameworks, we identify essential elements and their interconnections. Through adopting CE principles, our goal is to optimize waste collection, promote the reuse of unused medicines, recover valuable resources, and minimize waste generation.

KEYWORDS
Circular economy, Conceptual framework, Household medical waste, Waste management
RELATED TOPICS
Green logistics and supply chain management, Sustainability in logistics and supply chains

Paper ID:21

REWEIGHTING THE LOGISTICS PERFORMANCE INDEX THROUGH THE MULTI-CRITERIA DECISION MAKING METHODS

Betül Çetiner, Önder İnce, Tuğrul Bayat, Mehmet Tanyaş

Afyon Kocatepe University, Afyon, Turkiye, betul.kocaturk@usr.aku.edu.tr
Afyon Kocatepe University, Afyon, Turkiye, onderince_03@hotmail.com
Afyon Kocatepe University, Afyon, Turkiye, tbayat@aku.edu.tr
Maltepe University, Istanbul, Turkiye, mehmettanyas@maltepe.edu.tr

ABSTRACT:

The logistics performance index (LPI) is an international index published by the World Bank at irregular intervals and reveals the logistics performance level of countries depending on six sub-variables by experts in the logistics industry. However, overall logistics performance scores are generated by the equal weighting of the sub-variables. The weighting of the variables in the index should be objectively re-evaluated by academicians working in the field of logistics and relevant sector representatives for policymakers, practitioners, and researchers to benefit more from the overall logistics performance index score of the countries. The main motivation of the research is the re-weighting and ranking of the criteria in the index through the MCDM methods. In this direction, interviews were conducted with 15 experts in the logistics sector. The data obtained as a result of the interviews were analyzed with the Best - Worst Method (BWM), which is one of the CRM methods. According to the results of the analysis, the weights of logistics performance criteria are calculated as Infrastructure (0.308), Timeliness (0.199), Logistics Competence (0.135), Tracking and Tracing (0.131), Customs (0.129) and International Shipments (0.095).

KEYWORDS
Logistics, Logistics Performance Index (LPI), Multi-Criteria Decision-Making Methods (MCDM), BWM

RELATED TOPICS
Best practices in logistics and supply chains, Special topics in logistics and supply chains

PAPER ID:26

OPTIMIZING POST-DISASTER RELIEF OPERATIONS: INTEGRATING UNMANNED AERIAL VEHICLES IN VEHICLE ROUTING PROBLEM

Zeynep Yüksel, Dursun Emre Epcim, Süleyman Mete

Gaziantep University, Faculty of Engineering, Department of Industrial Engineering, Gaziantep Turkey,zeynpyukselll@gmail.com
Gaziantep University, Faculty of Engineering, Department of Industrial Engineering, Gaziantep Turkey,dursunemreepcim@gmail.com
Gaziantep University, Faculty of Engineering, Department of Industrial Engineering, Gaziantep Turkey, smete@gantep.edu.tr

ABSTRACT:

Natural disasters are inevitable as a part of life and therefore it is critical to take precautions against disasters. When a natural disaster occurs in a country, urgent needs must be met within the first 72 hours. During this time, especially fundamental needs such as health supplies, food, water and medicine should be delivered to the disaster victims. In order to do this in the most efficient way, vehicle routing studies have been conducted in the literature for use after natural disasters. The classical vehicle routing aims to reach the destination in the shortest way. However, natural disasters may cause road collapses. This makes vehicle routing problems difficult and thus causes a delay in the delivery of aid to the disaster victims. The literature review for this problem's solution revealed a deficiency in the field of multi-depot UAV routing problem. Therefore, in this study, by integrating UAVs into traditional vehicle routing, it is possible to eliminate the delay caused by road collapse after a disaster and enable fast and safe delivery of supplies to disaster victims. The proposed model aims to minimize the time it takes to deliver the supplies. The mathematical model is solved using GAMS-CPLEX package.

KEYWORDS
Unmanned aerial vehicles, multi-depot vehicle routing problem, post-disaster

RELATED TOPICS
Disaster logistic, routing

Paper ID:27

DRONE ROUTING PROBLEM FOR MONITORING

Emine Eş Yürek

Department of Industrial Engineering, Bursa Uludag University, Bursa, Turkiye,
esyurek@uludag.edu.tr

ABSTRACT:

Recent developments in drone technology have led to the emergence of drone deployment in various areas. One of these areas is monitoring. Drones are highly preferred because they can move quickly and easily under challenging terrains and are not life-threatening. Some areas where drones are used for monitoring are wildlife, geological and environmental surveys, filming or image acquisition, and traffic. For this aerial monitoring, in some cases, it is necessary to approach the target sufficiently to obtain the required resolution or to collect data at specific distances from the sensors. These restrictions require considering the height when determining the drone routes because the monitoring time and accuracy depend on the height at which the drone monitors the target area. This study proposes a mathematical model to solve this problem. A computational study is conducted to analyze the results.

KEYWORDS
Drone, drone routing, monitoring
RELATED TOPICS
Autonomous vehicles in logistics, special topics in logistics and supply chains

Paper ID:28

STRATEGIC EVALUATION OF RESILIENT URBANLOGISTICS

Gülçin Büyüközkan, Öykü Ilıcak

Galatasaray University, Istanbul, Turkiye, gbuyukozkan@gsu.edu.tr
Galatasaray University, Istanbul, Turkiye,oykuilicak12@gmail.com

ABSTRACT:

Urban resilience is an important concept that enables cities to be prepared for disasters and unexpected events arising from climate change. In order to ensure urban resilience, important infrastructure and systems of cities should be strengthened. One of the most important is urban logistics (UL). UL is the optimization of logistics services carried out by different companies by taking into consideration the traffic conditions, environmental impact and energy consumption within the city. UL activities are of great importance in ensuring the sustainability of cities, in their economic development and in improving the quality of life. Resilient UL will contribute to cities becoming more resilient places. In this study, UL strategies were created for Istanbul, and the results obtained were interpreted by applying the Interpretive Structural Modeling method. With this study, both researchers and managers will be able to develop and use resilience strategies for UL.

KEYWORDS
ISM, MCDM, Resilient urban logistics, Strategy evaluation

RELATED TOPICS
Smart and durable city logistics, Special topics in logistics and supply chains

Paper ID:29

LITERATURE REVIEW ON SUSTAINABLE RENEWABLE ENERGY SUPPLY CHAIN OPTIMIZATION: A FOCUS ON HEURISTIC AND METAHEURISTIC METHODS

Gürkan Güven Güner

University of Turkish Aeronautical Association, Faculty of Engineering, Department of Industrial Engineering, Ankara, Türkiye, gguner@thk.edu.tr

ABSTRACT:

The transition towards sustainable energy systems has necessitated the optimization of renewable energy supply chains. This literature review aims to explore the state-of-the-art approaches, with a specific focus on heuristic and metaheuristic methods, employed for optimizing sustainable renewable energy supply chains. Metaheuristics, which are higher-level strategies for guiding search processes, have demonstrated great potential in tackling complex optimization problems with diverse constraints and objectives. Genetic algorithms, simulated annealing, ant colony optimization and particle swarm optimization are some of the examples for the metaheuristic methods. The review emphasizes their ability to provide near-optimal solutions, handle uncertainties, and optimize multiple conflicting objectives. This literature review synthesizes and analyzes the existing research on heuristic and metaheuristic methods for optimizing sustainable renewable energy supply chains.

KEYWORDS
Metaheuristic techniques, optimization, renewable energy, sustainable supply chain.
RELATED TOPICS
Best practices in logistics and supply chains, green logistics and supply chain management, sustainability in logistics and supply chains.

Paper ID:31

THE ENVIRONMENTAL IMPACTS OF LOGISTICS TRANSPORTATION IN TÜRKIYE: PROVINCIAL LEVEL ANALYSIS

Hülya Saygılı

Atılım University, School of Business, International Trade and Logistics, Ankara, Turkiye, hulya.saygili@atilim.edu.tr

ABSTRACT:

The logistics sector plays an important role in the development of both domestic and international trade and leads economic growth. However, it is also one of the important sources of air pollution. Air pollution caused by road transportation and aviation not only has a greenhouse effect, but also causes lung and cardiovascular diseases and even premature deaths by emitting toxic gases and particles that directly affect human health. This study examines the impact of road transport on human health due to air pollution from vehicle use, using Turkey's provincial level data. In other words, the study applies a variety of statistical techniques, including analysis of covariance and impulse response analysis, to a set of variables that include income, exports, imports, road transport infrastructure, vehicle use per capita, air pollution, and mortality due to respiratory and circulatory system diseases. The important findings of the study can be listed as follows. First, there is a positive relationship between the income, export and import performances of the provinces and their developments in the transportation sector. Secondly, there have been serious increases in the amount of nitrogen oxide (NO, NO2 NOX), ozone (O3) and particulate matter (PM10, PM2.5) resulting from transportation. Third, there is a statistically significant positive relationship between respiratory and circulatory system-related deaths and NOX.

KEYWORDS
Health impact, Provincia level data, Traffic-related air pollution, Türkiye

RELATED TOPICS
Transportation, Enviorenment, Health

Paper ID:32

USE OF NAVAL DISASTER RELIEF GROUP (NDRG) IN NATURAL DISASTERS WITHIN THE SCOPE OF CIVIL-MILITARY COOPERATION

H. Mücahit Şişlioğlu

Beykoz University, Istanbul, Turkey, mucahitsislioglu@beykoz.edu.tr

ABSTRACT:

Turkey has to fight effectively against natural disasters such as earthquakes, that cause loss of life and property, using all of the national power elements it has. We recently witnessed the devastating effects of the Kahramanmaraş earthquake. As seen in this disaster, it is of vital importance to establish systems that will ensure the timely arrival of search and rescue and survival equipment to the disaster area and that can effectively coordinate aid activities within the first seven days. The aim of this study is to examine the formation and working methods of the "Naval Disaster Relief Group (NDRG)", which will consist of the TCG Anadolu landing ship and two or three fast logistics support ships which can meet these requirements within the scope of civil-military cooperation (CIMIC) activities. NDRG will be able to serve as a field hospital while storing and distributing the humanitarian aid materials to the land by sea with the landing crafts or heavy load helicopters.

KEYWORDS
Civil-military cooperation (CIMIC), Humanitarian aid logistics, Naval Disaster Relief Group (NDRG)
RELATED TOPICS
Humanitarian logistics, Emergencies and crisis logistics

PAPER ID:33

CONVERGENCE ANALYSIS OF ECOLOGICAL FOOTPRINTS OF COUNTRIES SELECTED BY LOGISTICS PERFORMANCE INDEX (LPI)

Esra Hasdemir

Atılım University, International Trade and Logistics, Ankara, Turkey,
esra.hasdemir@atilim.edu.tr

ABSTRACT:

The aim of this study is to investigate the convergence of ecological footprints, specifically focusing on the impact of logistics activities on Sustainable Development Goals-13. Analyzing the convergence of ecological footprints helps policymakers assess progress in reducing the environmental impact associated with logistics activities. Therefore, we examine the stochastic convergence of ecological footprints in the first 11 countries with high Logistics Performance Index scores. The convergence implies that these countries are moving towards a similar level of environmental impact in terms of resource consumption and carbon emissions related to logistics activities. Hence, we utilize several nonlinear unit root tests to assess the convergence patterns in the 11 countries. These nonlinear tests account for potential nonlinearities in the data generating process, such as sign, size, and hybrid nonlinearities for the period of 1961-2018. The study findings reveal mixed results for the selected countries.

KEYWORDS
Convergence, Ecological Footprint, Nonlinear Unit Root Tests

RELATED TOPICS
Sustainability in logistics and supply chains, Special topics in logistics and supply chains

Paper ID:36

THE CONGESTION PROBLEM IN MARITIME INDUSTRY: A CASE OF THE U.S. CONTAINER PORTS

Süleyman Başpınar, Cansu Yıldırım

Team Product Sales Assistant, Nora Global Logistics, suleyman.baspinar@noraglobal.com.tr
Asst. Prof. Dr., Maritime Faculty, Dokuz Eylül University, Izmir, Turkey, cansu.yildirim@deu.edu.tr

ABSTRACT:

The maritime industry, backbone of global trade and economy, creates links between countries by integrating production centers and consumer markets. Ports, an important component of the industry, plays a key role in the economic and social development. As 80% of the global trade,35% of total volumes is carried by ships, and containers, respectively, ports are essential for both global supply chains, and economic growth. However, ports efficiency may diminish competitiveness and trade volume of a port. One of these inefficiencies, port congestion was faced by U.S.A ports in 2022, causing longer waiting times, lower service levels, income, risk, and further problems for global supply chains. As the effects of port congestion is critical, the problem has been gathering attention from both practitioners and academicians. Therefore, the aim of the study is to underline reasons and consequences of port congestion faced by U.S. ports and provide possible solutions and/or strategies for coping.

KEYWORDS
Congestion, maritime, ports, ports services
RELATED TOPICS
Emergencies and crisis logistics, special topics in logistics and supply chains, service supply chains

Paper ID:37

STRATEGIC ANALYSIS OF DIGITAL SERVICE QUALITY IN AVIATION 4.0

Orhan Feyzioğlu, Celal Alpay Havle, Gülçin Büyüközkan

Galatasaray University, Faculty of Engineering and Technology, Industrial Engineering Department, Istanbul, Turkey, orhanfeyzioglu@gmail.com
Özyeğin University, Faculty of Aviation and Aeronautical Sciences, Professional Flight Department, Istanbul, Turkey, celal.alpay.havle@gmail.com
Galatasaray University, Faculty of Engineering and Technology, Industrial Engineering Department, Istanbul, Turkey, gulcin.buyukozkan@gmail.com

ABSTRACT:

Aviation has undergone significant transformations. A new era called Aviation 4.0 has started through today's digital technologies, such as artificial intelligence and the Internet of Things. This has resulted in efficiency, security, lower cost, digitization, and improved operational performance and customer experience. Aviation 4.0, where digitalization and digital transformation prevail, has become a period of radical changes. One of these changes is seen in customers, who are the backbone of the industries. Digital technologies have completely changed customers' expectations, behavior patterns, and perceptions of service quality. Classic service quality has left its place for digital service quality (DSQ). Therefore, this study aims to analyze DSQ strategically from the perspective of Aviation 4.0. The fuzzy analytical hierarchy process (FAHP) is utilized to prioritize the criteria of DSQ. To validate the study, a case study is conducted in the Turkish aviation industry.

KEYWORDS

Aviation 4.0, aviation industry, digital transformation, service quality, digital service quality, fuzzy analytical hierarchy process

Paper ID:42

A LITERATURE REVIEW ON SUSTAINABLE AIRBORNE DELIVERY

Ece Arzu YILDIZ, Murat ŞAHİN

Department of Industrial Engineering Faculty of Engineering Gazi University Ankara, 06570, Turkiye, arzudemircan@gazi.edu.tr
Department of Industrial Engineering Faculty of Engineering Manisa Celal Bayar University Manisa, 45140, Turkiye, murat.sahin@gazi.edu.tr

ABSTRACT:

Recently, small, intelligent airborne autonomous systems, or drones, have become widely used in our daily lives. Surveillance, military operations, disaster relief logistics, and last-mile delivery can be given as examples of drones' application areas. Aside from the fact that drones are nature-friendly systems that use batteries, they are not affected by traffic jams, which allows for fast delivery even in crowded urban areas. They can also reach locations that are difficult to reach by road, which makes them very useful in disaster operations. The world's biggest retailers and cargo companies considered these and became pioneers in drone usage in last-mile delivery. In lockstep with the increased use of drones in logistics operations, researchers began to study sustainable ways of performing logistical tasks. This study presents a review of recent studies on the use of drones in logistics operations.

KEYWORDS
Drone Delivery, Literature Review, Logistic Operations, Sustainable Logistics
RELATED TOPICS
Sustainability in logistics and supply chains, Green logistics and supply chain management, Autonomous vehicles in logistics, Innovative and smart technologies in logistics

Paper ID:44

GREEN SUPPLY CHAIN ENVIRONMENTAL SUSTAINABILITY PERFORMANCE

Nevra Ölçer, Ebru Baştürk, Buse Fatoş Topalkara, Zülal Diri Kenger

Endüstri Mühendisliği, Hasan Kalyoncu Üniversitesi, Gaziantep, Türkiye,
nevra.olcer@std.hku.edu.tr
Endüstri Mühendisliği, Hasan Kalyoncu Üniversitesi, Gaziantep, Türkiye,
ebru.basturk@std.hku.edu.tr
Endüstri Mühendisliği, Hasan Kalyoncu Üniversitesi, Gaziantep, Türkiye,
bfatos.topalkara@std.hku.edu.tr
Endüstri Mühendisliği, Hasan Kalyoncu Üniversitesi, Gaziantep, Türkiye,
zulal.kenger@hku.edu.tr

ABSTRACT:

Supply chain management has become a crucial strategic element for businesses in today's world. Enhancing the contribution of sustainability is among the top priorities in supply chain management. Adopting a green (environmental) approach is necessary for experiencing changes that would enhance profitability and efficiency in supply chain processes. If the methods of sourcing, producing, delivering, using, recycling, and renewing products remain unchanged at current consumption levels, the world will face even greater challenges in the near future. Unlike traditional supply chain management, green supply chain management aims to minimize environmental impacts and support sustainability goals. A green supply chain aligns environmental sustainability and supply chain issues by incorporating an ecological approach at every stage. By improving efficiency, creating product and service quality, reducing energy consumption, and supporting environmental sustainability strategies and visions, a green supply chain provides significant benefits. The purpose of this study is to determine the effects of green supply chain practices on environmental sustainability performance. Additionally, a systematic review of existing literature is conducted to identify trends and results are analyzed.

KEYWORDS
environmental sustainability, green supply chain, supply chain management, sustainability
RELATED TOPICS
Sustainability in logistics and supply chains, green logistics and supply chain management

Paper ID:45

ASSESSMENT OF URBAN RESILIENCE IN THE CITIES AFFECTED BY YEDISU SEGMENT OF NORTH ANATOLIAN FAULT LINE BY INTEGRATED DEMATEL-VIKOR METHOD

Gökhan ÇAYBAŞI, Ramazan Eyüp GERGİN, Gülşah AYVAZOĞLU, İskender PEKER

Gümüşhane University, Gümüşhane, Turkey, gkhn.cybs@gmail.com,
gergin@gumushane.edu.tr , iskenderpeker@hotmail.com
Hatay Mustafa Kemal University, Hatay, Turkey, gulsahayvazoglu@mku.edu.tr

ABSTRACT:

Resilience is a fundamental strategy for building the capacity of societies and cities. Natural or man-made disasters have devastating effects on cities. In this study, it is aimed to examine the resilience of the provinces on the North Anatolian Fault Line Yedisu Basin, which is one of the important active fault lines of Turkey. In this direction, hybrid multi-criteria decision making technique was used. Criteria affecting urban resilience were identified through literature research and prioritised by DEMATEL method. Then, the provinces in the Yedisu Segment were ranked by VIKOR method in terms of their resilience. DEMATEL results show that Disasters and Natural Hazards (K1), Environmental pollutants (K3) and Topography (K4) are the most important criteria affecting urban resilience. VIKOR results show that Muş is the most resilient province. This research aims to provide new perspectives for urban planners and disaster managers by helping them understand the importance of resilience.

KEYWORDS
Urban resilience, Earthquake, DEMATEL, VIKOR
RELATED TOPICS
Humanitarian logistics, Emergencies and crisis logistics, Smart and durable city logistics

Paper ID:47

AN EVALUATION OF SECONDARY THREATS TO ARISE AFTER EARTHQUAKE WITH FAHP-FTOPSIS METHOD: THE CASE OF HATAY

Gülşah AYVAZOĞLU, Ramazan Eyüp GERGİN, Gökhan ÇAYBAŞI, İskender PEKER

Hatay Mustafa Kemal University, Hatay, Turkey, gulsahayvazoglu@mku.edu.tr
Gumushane University, Gumuşhane, Turkey, gergin@gumushane.edu.tr ,
gkhn.cybs@gmail.com, iskenderpeker@hotmail.com

ABSTRACT:

In this study, the causes of secondary threats following the earthquake event constitute the criteria in 13 items, while secondary threats (tsunami, landslide, slope-induced rupture, liquefaction, changes in ground level, fire, surface rupture, flood, dam collapse) symbolise alternatives. Fuzzy Analytic Hierarchy Process (Fuzzy AHP) was used to weight the criteria and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS) was used to rank the alternatives. The results of the study show that the most important criteria for the causes of secondary threats following the earthquake event are the depth of the earthquake, ground loading (fill ground), fracture size and proximity to the coastline. Among the secondary threats following the earthquake event, flood, dam failure (A7), surface rupture (A6) and tsunami (A1) were determined as the most effective secondary hazards respectively. The ongoing flooding on the İskenderun coast confirms these results for Hatay.

KEYWORDS
Earthquake, Secondary Threats, FAHP, FTOPSIS

RELATED TOPICS
Humanitarian logistics, Emergencies and crisis logistics, Smart and durable city logistics

PAPER ID:48

EVALUATION OF SOCIAL MARKETS IN GAZIANTEP BY INTEGRATED FUZZY AHP – TOPSIS METHODS

Nurcan ŞİMŞEK, Salih DOĞRU, Yasemin DENİZ ÖZTÜRK, İskender PEKER

Gumushane University, Graduate Education Institute, Department of Disaster Management, Gumushane, Turkey, 66.nurcansimsek@gmail.com
Gumushane University, Graduate Education Institute, Department of Disaster Management, Gumushane, Turkey, salihdogruakademi@gmail.com
Artvin Coruh University, Artvin Vocational School, Emergency and Disaster Management, Artvin, Turkey, yasemindenizozturk@artvin.edu.tr
Gumushane University, Faculty of Economics and Administrative Sciences, Department of Business Administration, Gumushane, Turkey, iskenderpeker@gumushane.edu.tr

ABSTRACT:

It is important for individuals to be able to reach their daily needs easily after a disaster, to overcome the trauma they have experienced and to adapt to social life. The "Social Market" project was initiated in disaster areas. When choosing a place for social market, criteria such as accessibility, proximity to tent cities, food distribution points, and central areas should be considered. The number of markets should consider heavily damaged buildings, affected persons, rural area access, and donated product stock. Our study evaluated Gaziantep's social markets after the February 6, 2023 earthquakes. Fuzzy Analytical Hierarchy Process weighted criteria, and Fuzzy TOPSIS ranked alternatives. Accessibility, affected persons, and proximity to the center were the most effective site selection criteria. Nurdağı Social Assistance and Solidarity Foundation Social Market was identified as the most suitable location.

KEYWORDS
Disaster Management, Fuzzy Logic, Multi-Criteria Decision Making, Social Market.

RELATED TOPICS
Emergencies and Crisis Logistics, Humanitarian Logistics

Paper ID:49

EVALUATION OF EARTHQUAKE DEBRIS DISPOSAL AREAS USING INTEGRATED FUZZY AHP-VIKOR METHOD: GAZİANTEP CASE STUDY

Salih DOĞRU, Yasemin DENİZ ÖZTÜRK, Nurcan ŞİMŞEK, İskender PEKER

Gumushane University, Graduate Education Institute, Department of Disaster Management, Gumushane, Turkey, salihdogruakademi@gmail.com
Artvin Coruh University, Artvin Vocational School, Emergency and Disaster Management, Artvin, Turkey, yasemindenizozturk@artvin.edu.tr
Gumushane University, Graduate Education Institute, Department of Disaster Management, Gumushane, Turkey, 66.nurcansimsek@gmail.com
Gumushane University, Faculty of Economics and Administrative Sciences, Department of Business Administration, Gumushane, Turkey, iskenderpeker@gumushane.edu.tr

ABSTRACT:

On February 6, 2023, two earthquakes occurred in Kahramanmaraş and after the earthquake 35,355 buildings collapsed, 17,491 buildings need to be urgently demolished, and 179,786 buildings have suffered severe damage. It has been reported that the total debris generated from the collapsed and planned demolition buildings will amount to 96,867,683 tons. The aim of the study is to determine the most suitable area in Gaziantep province where the debris from the collapsed buildings and those requiring demolition due to severe damage is disposed of or stored. For this purpose, the integrated fuzzy Analytic Hierarchy Process-VIKOR method was used. According to the study results, the distance to residential areas, distance to agricultural areas, and distance to water sources were identified as the most influential criteria in determining the locations where the debris is disposed of. Among the alternatives, Nizip- Fırat neighborhood, was determined as the most suitable debris disposal area.

KEYWORDS
Debris, Earthquake, Fuzy AHP, Vikor
RELATED TOPICS
Emergencies and crisis logistics, Humanitarian logistics, Transportation and warehouse management

Paper ID:52

IMPROVING RESOURCES ALLOCATION STRATEGIES FOR CONTAINER TERMINALS: A SIMULATION STUDY ON OPTIMIZED VESSEL ALLOCATION AND PRODUCTIVITY

Mehmet Sinan Yıldırım, Ziya Çakıcı
Manisa Celal Bayar University, Faculty of Engineering, Department of Civil Engineering, msyildirim35@gmail.com
Izmir Democracy University, Faculty of Engineering, Department of Civil Engineering, Izmir, Turkey, ziya.cakic@idu.edu.tr

ABSTRACT:

The Resources Allocation Problem is a well-known issue that ports face while dealing with limited berth resources and diverse vessel sizes and loads. Our solution to this problem involves simulation models considering not only the berth availability but the productivity in terms of variable handling speed. The first model uses a conventional berth allocation system, which follows a first-come-first-served priority rule. The second model uses an optimized allocation schedule, which considers the availability of berths and the efficiency of handling with variable crane allocation. We evaluated models using a hypothetical vessel traffic scenario with variable sizes and cargo. The microsimulation model was developed by combining agent-based simulation methodology with a discrete-event simulation approach. This model encompasses a standard peninsula-style terminal, featuring agents responsible for horizontal container transportation, yard and ship to shore gantry crane operations. Our assessment of the results shows that the optimized system leads to decreased vessel waiting times and increased terminal productivity. Moreover, the optimization of the resource allocation policies also increased overall terminal efficiency. Our proposed solution is a necessary step towards efficient and effective berth allocation for container terminals which lead to increased terminal competitiveness and decreased congestion costs.

KEYWORDS
Berth allocation, container terminal, microsimulation, optimization, discrete event

RELATED TOPICS
Transportation and warehouse management, Autonomous vehicles in logistics, Innovative and smart technologies in logistics

Paper ID:53

DOES IMPROVEMENT IN LOGISTICS SECTOR PERFORMANCE ABATE CARBON INTENSITY? FRESH EVIDENCE FROM EMERGING ECONOMIES

Elma Satrovic
Department of International Trade and Logistics, Faculty of Economics, Administrative and Social Sciences, Hasan Kalyoncu University, Gaziantep, Türkiye
elma.satrovic@hku.edu.tr

ABSTRACT:

The logistics sector is a core element of the modern economy, facilitating the circulation of freight. Pursuing the worldwide supply and demand, the logistics sector ameliorates causing a boom in the emission of pollutants associated with motor vehicles powered by non-renewable energy sources. Despite the fact that logistics sector is among the world's leading pollutant emitters, the literature on the interplay between logistics sector performance and environment is limited. To fill the void, this study uses the emerging economies (Brazil, China, India, Russia, South Africa and Türkiye - BRICST) as an investigative laboratory to scrutinize the impact of the logistics sector performance, financial involvement, renewable energy, energy consumption in transportation, and population on carbon intensity under the context of environmental Kuznets curve (EKC) hypothesis. Notwithstanding the direct impact of the logistics sector performance, this manuscript assess whether logistics sector performance moderates the impact of energy consumption in transportation on environment. This study adopts on the Method of Moments Quantile Regression (MMQR) from 2007 to 2020 and divulges that the direct impact of logistics sector performance, renewable energy, and financial involvement on environment proxied by carbon intensity is negative. However, population and energy consumption in transportation have strengthened the environmental pressure of BRICST economies. Our empirical findings also confirmed the presence of EKC phenomenon suggesting that economic prosperity strengthens the environmental pressure in the early stages of growth, whereas later stages of growth are accompanied with diminishing environmental pressure. Considering the moderating impact, logistics sector performance is helpful in reducing the harmful environmental impact of energy consumption in transportation. These findings suggest that further advancement of logistics sector performance opens up the way to achieve the objectives of Sustainable Development Goals (SDGs) by replacing the petroleum with renewable energy sources in logistics for sustainable future.

KEYWORDS
Logistics sector performance, Renewable energy, Energy consumption in transportation, Emerging economies

RELATED TOPICS
Sustainability in logistics and supply chains, Green logistics and supply chain management

Paper ID:54

IMPACT OF VOICE BEHAVIOR ON RELATIONSHIP WELLBEING: MEDIATION EFFECT OF SUPPLY CHAIN PERFORMANCE

Abdüssamet POLATER

Erzincan Binali Yıldırım University, Ali Cavit Çelebioğlu School of Civil Aviation, Department of Aviation Management, Erzincan, Turkey, apolater@erzincan.edu.tr

ABSTRACT:

Surviving and thriving in dynamic and competitive business environment requires that suppliers offer ideas and suggestions, which we name as suppliers' voice behavior. However, the extant literature has overlooked the significance of suggestion sharing on supply chain performance and relationship wellbeing. Thus, drawing on the relational view and social exchange theory this study investigates the interplay between supply chain performance, suppliers' voice behavior and relationship wellbeing. To test the hypotheses the data was obtained from manufacturing companies by using a survey instrument. The results highlight the significance of suppliers' voice behavior to increase supply chain performance and relationship wellbeing as well as mediation effect of supply chain performance in the suppliers' voice behavior and relationship wellbeing relationship. In this regard, this study contributes to the relational view and social exchange theory by offering a unique conceptual framework.

KEYWORDS
Relational view, relationship wellbeing, social exchange theory, supply chain performance, voice behavior.

RELATED TOPICS
Special topics in logistics and supply chains, Best practices in logistics and supply chains.

Paper ID:55

PANEL DATA ANALYSIS OF FOREIGN TRADE OF 10 COUNTRIES TO WHICH TURKEY MADE EXPORTS THE MOST IN 2022 BY USING THE GRAVITY MODEL

Emel Büyükbağrıaçık

Haliç University, Istanbul, Turkey, e-mail: emelbuyukbagriacik@halic.edu.tr

ABSTRACT:

There is a positive relationship between international trade and economic growth, which increases the importance given to international trade. Countries are increasing their initiatives to carry out more foreign trade transactions and to expand their trade volume. The reason why countries do this is to reach new markets, to carry out commercial activities with more countries and to grow in their foreign trade. Due to the positive relationship between international trade and economic growth, it is important to examine the factors affecting international trade. In this study, exports, gross national product, population, and distance variables between top ten exporting countries with Turkey in 2022 were examined with the gravity model. For panel data analysis, multicollinearity, unit effect and time effect tests were applied, and then Hausman test was performed and it was concluded that the model was a one-way random effects model. After this stage, tests that examine the econometric assumptions of the model were conducted and the final model was estimated with the PPML method, which removed the deviations from the resulting assumption. According to the findings obtained, it has been concluded that the distance and population variables significantly and negatively affect exports and the gross domestic product variable significantly and positively affects exports.

KEYWORDS
Gravity model, Panel Data Analysis, Poisson Pseudo Maximum Likelihood (PPML)

RELATED TOPICS
Big data analytics in logistics, Special topics in logistics

Paper ID:56

CHALLENGES IN INTERNATIONAL HUMANITARIAN LOGISTICS: PROBLEM AREAS

Ferhat Dinler, Derya Atlay Işık

Muğla Sıtkı Koçman Üniversitesi Fethiye İşletme Fakültesi, deryaatlay@mu.edu.tr
Muğla Sıtkı Koçman Üniversitesi Sosyal Bilimler Enstitüsü Uluslararası İşletmecilik ve Ticaret Doktora Öğrencisi, f_dinler@hotmail.com

ABSTRACT:

Although developing technological opportunities have improved the ability to provide natural disaster relief assistance more effectively and quickly, it still largely depends on the training and preparedness of the actors. Humanitarian logistics, which is the most intense and critical activity of the said humanitarian aid operations, is more complex and unpredictable than commercial or military logistics. Identifying the importance and frequency of problems to be encountered before they occur is the key to being prepared. This study has been written in order to present a perspective on the subject by identifying and compiling the most critical problem areas related to international humanitarian aid logistics by making use of the articles in the academic literature. It is aimed to present a focused approach to the difficulties experienced in humanitarian aid logistics, to provide a wider perspective to practitioners, especially humanitarian aid and public institutions, which will contribute to subsequent studies and especially the national literature on the subject as a qualitative compilation study. In the study, analysis and compilation were made with the data obtained from twenty scientific articles from qualitative studies written between 2000-2022. In international humanitarian aid logistics, which includes numerous variables and has a dynamic structure; 3 main problem areas that were emphasized the most were determined, and it was determined that the most common problem was "lack of cooperation and coordination between actors".

KEYWORDS

Humanitarian aid logistics, International humanitarian aid supply chain, Logistics problems in natural disasters, Natural disaster.

Paper ID:57

E-SERVICE QUALITY OF RETAILERS PROVIDING DELIVERY SERVICES AND ITS IMPACT ON SATISFACTION AND LOYALITY

Ayşe Doğa BULUT
Dr. Öğr. Üyesi Ahmet ÇETİNDAŞ

Hasan Kalyoncu University, Department of International Trade and Logistics, Gaziantep, Turkiye, ahmet.cetindas@hku.edu.tr

ABSTRACT

With the development of technology and the widespread use of the internet all over the world, access to information has become much easier. Thanks to mobile technologies, accessing the internet from smart devices has become a routine of daily life. The Internet has been used for shopping almost since its existence. However, in recent years, the internet has offered new solutions for supermarkets too, such as online ordering and home delivery services of fast-moving consumer goods. This facilitated and accelerated the daily shopping duty. Especially during and after the COVID-19 pandemic, consumers who preferred less to be physically in a supermarket used these services. This new online service created also new service quality expectations for satisfying consumers. The service process starts with ordering through an application and ends with the delivery of the ordered fast-moving consumer goods to the given address. Therefore, as a result of the literature review, application quality, product quality, and delivery quality are considered as the dimensions of e-service quality. Exploratory factor analysis also showed that the scales were validated as parts of a whole in this way. In line with the purpose of the study, the effects of these dimensions on customer satisfaction and loyalty were examined, and as a result of the structural equation model established with the data collected from 357 users, it was found that all dimensions of e-service quality affect customer satisfaction and loyalty.

KEYWORDS

E-Service Quality, Application Quality, Product Quality, Delivery Quality, Customer Satisfaction, Loyalty

Paper ID:61

NEW WAREHOUSE LOCATING SELECTION WITH KEMIRA: A MOTHER-CHILD RETAIL INDUSTRY APPLICATION

Nadircan Uca, Esma Birisci, PhD,

Bursa Uludağ University, Faculty of Economics and Administrative Sciences, Department of Econometrics. Bursa, Turkey. nadircan.uca@hotmail.com

Bursa Uludağ University, Faculty of Economics and Administrative Sciences, Department of Econometrics. Bursa, Turkey. esmabirisci@uludag.edu.tr

ABSTRACT:

Depending on the developing production conditions, the logistics and distribution chain have an important role in increasing the product and service quality. There is a need for space or storage for the products to be kept, stocked and preserved in the process until they reach the consumers. It is important to choose the location of the warehouse or distribution center in order to shorten the delivery time and maximize efficiency. Therefore, in this study, a warehouse location was determined in a retail company operating in the mother-child sector by using the recently popular KEMIRA (KEmeny Median Indicator Rank Accordance) approach, which is one of the Multi-Criteria Decision Making (MCDM) methods. KEMIRA divides the criteria into different groups and calculates the importance weights of each group. Decision makers can change the importance weights of the criteria according to the median priority component, which represents the expected order of the criteria importance weights, and see the effect of this variability on the ranking of the alternatives. Considering different criteria for the selection of warehouse location, it was aimed to choose the appropriate location, and 10 alternative warehouse locations were evaluated.

KEYWORDS
KEMIRA, Multi-Criteria Decision Making, Retail industry, Warehouse location,
RELATED TOPICS
Transportation and warehouse management, Best practices in logistics and supply chains

Paper ID:65

GREEN PRACTICES IN ROAD TRANSPORT: A RESEARCH ON TURKISH LOGISTICS COMPANIES

Merter Tümer
Dr. Öğr. Üyesi Ahmet ÇETİNDAŞ

Hasan Kalyoncu University, Department of International Trade and Logistics, Gaziantep, Turkiye, ahmet.cetindas@hku.edu.tr
Göksu Lojistik, merterus@gmail.com

ABSTRACT

The aim of this study is to draw attention to green logistics practices in Turkey and to determine how the green logistics practices of logistics companies differ according to their demographic characteristics. The green logistics activities of the companies providing road transportation have been identified in previous studies as logistics environment management, green storage and packaging, green transportation, fleet management, alternative fuel implementation, and logistics innovation. In the study, green logistics practices of enterprises providing road transport services in Gaziantep will be measured through a questionnaire with scales measuring these variables. The obtained data will be analysed with the SPSS program. After frequency analysis, the validity and reliability of the scales will be tested. Then, the differences in green logistics practices according to the demographics of the companies will be examined and suggestions will be made to the companies in the road transport sector. These findings will aid the adoption of green logistics in the road freight transportation industry in Turkey.

KEYWORDS

Logistics, Green Logistics, Road transportation

Paper ID:68

LOGISTICS SERVICE PROVIDER SELECTION FOR HEALTHCARE LOGISTICS

Yunus Kaymaz, Burcu Aracıoğlu
Asst. Dr., yunus.kaymaz@iste.edu.tr
Assoc. Dr., burcu.aracioglu@ege.edu.tr

ABSTRACT:

In the rapidly evolving world of healthcare, the efficient and reliable management of logistics plays a pivotal role in ensuring the seamless delivery of critical medical supplies, pharmaceuticals, and equipment. As the healthcare industry faces the increasing demand for timely and safe transportation, choosing the right logistics service provider becomes paramount. The process of logistics service provider selection for healthcare logistics involves a multifaceted approach that encompasses strict quality standards, adherence to regulatory requirements, and the ability to navigate complex and sensitive logistical challenges. This paper investigates the critical considerations and criteria involved in the selection of a logistics service provider specifically for the healthcare sector. In this study, a hospital in Izmir, were chosen as a case company and thorough a literature review and expert interviews the selection criteria were analyzed and determined in order to select the most appropriate service provider for the case company.

KEYWORDS
Healthcare Logistics, Multi-Criteria Decision Method, Service Provider Selection
RELATED TOPICS
Healthcare Logistics, Service Provider Selection, 3PL

PAPER ID:69

A LITERATURE REVIEW ON DISASTER AND ARTIFICIAL INTELLIGENCE

Yasin AFŞAR, Arzum BÜYÜKKEKLİK

Niğde Ömer Halisdemir University, yasin@ohu.edu.tr
Niğde Ömer Halisdemir University, abuyukkeklik@ohu.edu.tr

ABSTRACT:

Disasters are defined as natural, human-induced or technological events that interrupt or stop people's work and the natural flow of life, and they are situations that the society cannot get out of with their own efforts due to the losses they cause. Disaster logistics, on the other hand, is the process of planning, implementing and controlling goods, goods and information from the point of production to the point of consumption effectively, efficiently and at low cost in order to meet the wishes and needs of the injured individuals. With the development of digital technologies, pre-disaster forecasting, response, damage assessment, assistance, etc. offers many opportunities. The use of digital technology is of great importance for effective disaster management. Thus, all possible scenarios will be revealed with artificial intelligence without disaster. When the effects caused by disasters are considered, they can be listed as loss of life, injuries and physical, economic, social and psychological losses. In this study, it is aimed to scan the articles in the Web of Science (WoS) database, which are published until the end of June 2023, on the topics of disaster and artificial intelligence, and to reveal the research gaps. The articles obtained by scanning will be examined in detail in terms of their subject, purpose and contributions. With the study, it is expected to contribute to the literature in terms of determining the focus areas and research gaps in disaster and artificial intelligence, and especially emphasizing in which sub-areas new research can be made.

KEYWORDS
Disaster, Artificial Intelligence, Web of Science (WOS)
RELATED TOPICS
Humanitarian logistics, Innovative and smart technologies in logistics.

Paper ID:70

THE EFFECT OF AIR TRANSPORT ON HUMAN WELL-BEING: CROSS COUNTRY STUDY ON THE ROLE OF TRADE COSTS RECONCILING DISASTERS WITH EMERGENCY RESPONSES

Ümit Çelebi

Asst. Prof. Istanbul Medipol University, Faculty of Business and Management Sciences, Department of Aviation Management, umit.celebi@medipol.edu.tr

ABSTRACT:

International Air Transport plays an important role in the economic developments of the countries. International organizations predict that air transport will increase exponentially. As the freight and passenger traffic carried by air increases around the world, the quality of air transport infrastructure gains importance. The development of extensiveness and condition of air transport in turn increases speed and efficiency while reduces costs. This important role played by air transport on the economy in usual times becomes much more critical in emergencies such as natural disasters and epidemics. In such cases when and where other transportation systems are ineffective, air transport remains the only tool in the provision of humanitarian aid and supply of urgent needs and has thus significant effects on the human well-being and sustainability. Therefore, this research aims to answer to what extent air transport affect human well-being and what role trade costs play in this relationship. To fulfil its research objective, this study is based on the analysis of Baron and Kenny mediator method, hierarchical regression and Sobel test of 292 samples of 73 countries with which Turkey trades for the years 2010, 2012, 2014 and 2016. The results of the research show that air transport has a significant impact on human well-being. In this effect, trade costs play a partial mediator role.

KEYWORDS
Air Transport, Human Well-Being, Mediator Analysis, Trade Costs.

RELATED TOPICS
Sustainability in logistics and supply chains, Emergency and crisis logistics, Humanitarian logistics.

Paper ID:76

CHALLENGES AND OPPORTUNITIES IN TRADE LOGISTICS PERFORMANCE: A CLUSTER-BASED ANALYSIS OF 120 COUNTRIES USING K-MEANS

İbrahim Miraç Eligüzel, Eren Özceylan

Industrial Engineering Department, Gaziantep University, Gaziantep 27100, Turkey, miraceliguzel@gmail.com
Industrial Engineering Department, Gaziantep University, Gaziantep 27100, Turkey, erenozceylan@gmail.com

ABSTRACT:

The performance of trade logistics is of paramount importance in facilitating a nation's economic expansion and enhancing its position in the global market. The primary objective of this study is to cluster a total of 120 nations, with the aim of providing decision makers with valuable support. The purpose of this assistance is to facilitate the development of efficient and effective strategies that may effectively address the difficulties and possibilities encountered by countries in their trade logistics performance. This study utilises the Logistics Performance Index (LPI) data from the years 2012, 2016, 2018, and 2023, encompassing 120 countries and 14 distinct features. The Python sklearn module is utilized to implement k-means clustering in order to classify these nations. The aim of this study is to offer significant insights to decision-makers, facilitating the development of cluster-specific strategies that can improve trade logistics performance within distinct groups of countries. The outcomes of this research will support the process of evidence-based decision-making for policymakers and stakeholders. It is possible to formulate cluster-specific solutions in order to effectively tackle the distinct trade logistics issues encountered by different groups of countries. The implementation of these plans may encompass various measures such as investments in infrastructure, legislative reforms, developments in technology, and capacity-building efforts that are customized to address the unique requirements of each cluster. In summary, this research makes a valuable contribution to the domain of trade logistics performance analysis through the application of k-means clustering methodology to classify nations according to their LPI ratings. The study provides significant findings regarding the obstacles and possibilities in several clusters, equipping policymakers with focused approaches to improve the efficiency of trade logistics and promote global trade competitiveness.

KEYWORDS
K-means clustering, Decision support, Sustainability, Logistics Performance Index
RELATED TOPICS
Logistics performance, clustering, decision support.

Paper ID:81

DETERMINING THE RELATIONSHIPS BETWEEN LOGISTICS PERFORMANCE (LPI), DIGITAL ECONOMY AND SOCIETY INDEX (DESI), AND GLOBAL INNOVATION INDEX - A STUDY ON EUROPEAN UNION MEMBERS

Betül Çetiner, Tuğrul Bayat

Afyon Kocatepe University, betul.kocaturk@usr.aku.edu.tr
Afyon Kocatepe University, tbayat@aku.edu.tr

ABSTRACT:

Indices are important indicators used in country comparisons. Countries can clearly see their situation in relation to the relevant index. In this way, policymakers can make better decisions, practitioners can develop more appropriate projects and researchers can better see the gaps where they can work. In addition, revealing the relationships between the sub-variables used in the formation of the index can contribute to the better position of the country. In this direction, the main motivation of the research is to determine and compare the relationship between the logistics performance, Digital Economy and Society levels (DESI), and Global Innovation Indices and the sub-dimensions of these indices of the European Union countries, which have an important place in world trade. Correlation analysis is used to determine the relationships between the indices and the sub-variables in the indices. According to the result of the study, strong and statistically significant relationships were observed between DESI and LPI at 65%, Innovation and LPI at 70.1%, and Innovation and DESI at 81.5%. In addition, it was found that there are highly significant positive relationships between the sub-criteria of DESI, Logistics Performance, and Global Innovation Indices in most locations.

KEYWORDS
European Union Countries, Logistics, LPI, DESI, GII, Correlation Analysis

RELATED TOPICS
Special topics in logistics and supply chains, Innovation and technology management

Paper ID:82

THE PERCEPTION OF SMART CITIES IN THE FRAMEWORK OF URBAN LOGISTICS

Assoc. Prof. Dr. İbrahim AKBEN, Dr. Ayça PEKMEZ BAHÇECİ

Hasan Kalyoncu University, Faculty of Economics, Administrative and Social Sciences, Department of International Trade and Logistics, Gaziantep, Türkiye, ibrahim.akben@hku.edu.tr,
Gaziantep University, Vocational School of Social Sciences, Department of Foreign Trade, Gaziantep, Türkiye, aycabahceci@gantep.edu.tr

ABSTRACT:

The aim of this study is to address the concept of a smart city and evaluate it within the framework of an urban logistics case study. The research examines the effects of smart city components, including smart mobility, smart city security, smart environment, smart living, and the concept of smart individuals, on smart city awareness and the realization of a smart city. To determine awareness regarding the smart city concept in Gaziantep, survey data from a sample of 200 individuals in Gaziantep were analyzed using SPSS and AMOS software packages, and some findings were obtained. Hypotheses were tested using regression, correlation, and structural equation modeling. In regression analysis, it was observed that smart living and smart mobility independent variables explained 27% of the variance in the internal variable of the smart city ($R^2 = .272$; $p \leq 0.01$). The independent variables have a lasting, significant impact on their internal variables within the smart city ($F = 36.757$; $p \leq 0.01$). The smart living independent variable was found to have a more significant impact on the variable within the smart city. The Structural Equation Modeling in the Amos Program includes goodness-of-fit index values. The acceptable fit criteria include $2 \leq \chi 2/sd \leq 3$, $.90 \leq GFI \leq .95$, and $.05 \leq RMSEA \leq .08$. A very good fit was observed in the CMIN/DIF value, and an acceptable fit was observed in the GFI and RMSEA values. It was determined that smart city components significantly contribute to smart city awareness and ultimately to becoming a smart city.

KEYWORDS
City logistics, smart cities, urban logistics, logistics

RELATED TOPICS
Smart and durable city logistics, innovative and smart technologies in logistics.

Paper ID:85

SUSTAINABLE LOGISTICS CERTIFICATE, EUROPEAN GREEN DEAL AND CARBON EMISSION REQUIREMENTS EFFECTS ON TURKISH LOGISTICS SECTOR

Yurdagül Meral

ymeral@medipol.edu.tr

ABSTRACT:

Turkey's export volume of 2022 is approximately 254,1 billion dollars and 118,2 billion dollars of total export is to EU countries. European Union market is a very important market for Turkish exporters and logistics companies. The European Green Deal, announced by the European Union in 2019, aims to increase the greenhouse gas emission reduction for 2030 to at least 55%, and aim to achieve the goal of transform Europe into the world's first climate-neutral continent by 2050 via green deal. Turkey is a candidate member therefore European Union's green deal aim of reducing carbon emission to reduce %55 under 1990 by 2030 will have a great impact on Turkish transportation and logistics sector which has a significant share in greenhouse gas emissions. This paper will discuss what can be done in logistics and transportation sector to reduce the impact of reducing carbon emission by 2030 via literature review. the imported products and the transportation of the said products have to be in complaince with the European standards as well. Expected results are that international logistics which is used for exported goods transportation to European Union must be changed to green logistics. Environment protective, transportation methods must be preferred, like railway transportation and current road transportation must be replaced by new vehicles which are acceptable by European Union standards. Our legislation must be amended as per European Union standards. Logistic companies must aim to get sustainable logistics certificates by investing in environmentally friendly technologies.

KEYWORDS
International Trade, Logicstics, European Union, Green Deal, Carbon Emission

RELATED TOPICS
Green logistics and supply chain management, Transportation law

FULL TEXTS

Paper ID:03

THE ROLE OF AUGMENTED REALITY FOR LOGISTICSACTIVITIES IN SUPPLY CHAINS

Ela Sibel Bayrak Meydanoğlu[1], Margareta Teodorescu[2], Ferhat Sayın[3]

***Abstract** - The wave of digitalization has revolutionized supply chains by integrating new digital technologies, such as augmented reality (AR), into logistics processes. Although AR has significant potential to optimize supply chain activities and reduce costs, its adoption and implementation in logistics operations is still in its early stages. This study examines the applications of AR in supply chains, focusing on the benefits and challenges of its implementation. Three main areas of AR application are identified: warehouse operations, consulting and training of logistics operators, and last mile delivery. AR devices can assist operators in tasks such as order picking, storage, and shipping, leading to improved efficiency and reduced errors. Additionally, AR technology offers benefits like hands-free access to information, increased safety, and reduced training costs. However, several barriers are preventing its widespread adoption, including limited battery life, display adjustments, processor overheating, lack of standard programming environments, privacy concerns, and requirements for operator skills. Understanding these challenges is crucial for logistics practitioners planning toinvest in AR technology. Future research should focus on validating theoretical findings through real-world industrial applications.*

***Keywords** – Augmented Reality (AR), AR applications, barriers, benefits, consulting and training, last miledelivery, logistics, supply chain, warehouse operations*

1. INTRODUCTION

Over the recent years, the wave of digitalization has transformed slow and, primarily, paper-based supply chainsinto highly technology-driven chains [1] by integrating new, emerging digital technologies into supply chain processes and activities. One of the technologies that significantly changed daily operations in supply chains isaugmented reality (AR) [2]. This technology is defined as a technology that can improve the execution of manylogistics processes in supply chains [3]- [4]. Although AR has already been adopted and implemented for some time, its use in manufacturing and logistics operations is still in its infancy compared to other industries such asretail and gaming. However, this technology has the potential to make logistics activities and operations more efficient, optimize logistics processes along the whole supply chain, and significantly reduce logistics costs. Forthis reason, augmented reality is considered to be a very promising technology for supply chains

[1] Ela Sibel Bayrak Meydanoğlu, Turkish-German University, Faculty of Economics and Administrative Sciences, Department of Business Administration, Istanbul, Turkey, meydanoglu@tau.edu.tr
[2] Margareta Teodorescu, Koblenz University of Applied Sciences, Faculty of Business and Management, Koblenz, Germany, teodorescu@hs- koblenz.de
[3] Ferhat Sayın, Turkish-German University, Faculty of Economics and Administrative Sciences, Department of Business Administration,Istanbul, Turkey, ferhat.sayin@tau.edu.tr

[5]. In additionto the opportunities and benefits of using the AR technology for logistics and supply chain activities, being aware of the challenges and barriers in adopting and implementing it at company and industry level is of key importance when planning to invest in this technology. In this context, based on the existing literature, this studyaims to provide logistics practitioners with a theoretical reference on the main applications of AR in logistics, focusing on both the benefits and the challenges of this technology.

The remainder of the study is organized as follows. Firstly, an overview related to augmented reality and its rolein logistics activities in supply chains is provided. This is followed by an explanation of potential AR applications in logistics. After presenting the benefits of and barriers to AR applications in logistics, the study concludes with the findings, implications, limitations of the study and future research areas.

2. AUGMENTED REALITY

Augmented reality is a technology that extends the physical reality by superimposing digital or computer- generated information (image, audio, video, touch, or haptic sensation) on the user's view of the physical environment in real time [6]. Among others, the three most important types of devices currently used in AR, which allow users to see virtual objects superimposed on physical objects, are [7]:

a) head-worn devices (e.g., smart glasses),
b) hand-worn devices (e.g., tablets, smartphones),
c) spatial AR devices (e.g., projectors).

Due to widespread digitalization and automation in logistics and supply chains, the demand towards human- machine interaction has increased significantly. However, apart from fully automated systems, there are still some processes where the level of automation is not high enough and the process performance depends mainly on human decisions, experience, and expertise. Order picking activity is an example of this type of process [8]-[9]. Order picking is the process of collecting goods from spaces, shelves, and containers in a warehouse according to customer or production needs [10]-[8]. By using a picking list defining the position, quantity, and sequence of items to be picked, a logistics operator collects items in a specific order and delivers them to the next location. Picking the wrong item, picking the wrong quantity of items, or missing an item to be picked arethe main errors made by operators [8]. The duration of the picking activity and the percentage of errors are the two major indicators for measuring the order picking efficiency. The former affects the efficiency of supply chains, whereas the latter negatively influences the performance of order fulfilment and has a significant impact on customer service and company image as well [11]. To avoid errors and reduce the duration of picking activities, it is necessary to simplify the tasks performed by logistics operators in warehouses. AR can play an important role in this sense by reducing errors and the time required to conduct picking activities. For example,voice-activated AR applications provide pickers with all the information they need at eye level. This reduces the amount of head movement required for reading and understanding the data on the picking paper, resulting in considerable time saving [8]. Furthermore, AR applications can provide operators with additional informationthat allows them to locate their picking positions quickly [3] and without errors, reducing their effort and fatigue[8].

3. POTENTIAL AR APPLICATIONS FOR LOGISTICS ACTIVITIES IN SUPPLY CHAINS

As with the order picking activity mentioned in the previous section, supply chains can benefit from AR applications in various logistics activities. The potential applications of AR in logistics and supply chains can be categorized into three areas: warehouse operations, consulting and training of logistics operators, and last mile delivery.

a) Warehouse operations

Receiving, storing, picking, and shipping are the four warehouse operations that can be supported and improvedby AR technology.

(1) Reception of goods

Augmented reality can be used to scan the received goods, check the reception of goods, and compare themwith the delivery note, show the unloading dock to the driver, and show the operator the instructions on how to effectively unload a container considering the size, weight, and dimensions of the items [5]-[9]-[4].

(2) Storage

AR devices can display the following information to the operators [5]-[9]:

- newly assigned tasks,
- optimal storage location for incoming items,
- image and details of the item to be stored,
- route to the storage location,
- picker's current status as well as the next step in the process,
- reviewed information on locations requiring replenishment during storage.

(3) Order Picking

AR devices with which operators are equipped can display and inform them about the following informationnecessary for picking tasks [5]-[9]:

- new tasks assigned to the operators,
- image and details of the item to be picked,
- storage location of the item to be picked,
- picking route,
- errors and disruptions,
- information on how to avoid congestion in aisles,
- picker's condition, status, and performance.

In addition, AR devices can show operators where to place each item on the picking cart for sorting duringpicking and highlight the location with the required item [5]-[9].

(4) Shipping:

AR devices can display and inform operators about the following information [5]-[9]:

- the type of packaging to use,
- the best way to place the picked items in a package or parcel,
- the right location/pallet for the shipment,
- the right loading area.

Moreover, AR devices show how to place each order, for example in a truck, according to the type of orderto optimally arrange the shipment [5]-[9].

b) Consulting and training of logistics operators

Training is an important area that can be supported by augmented reality technology [12]. This technology provides real-time visual guidance to logistics operators, enabling field and on-the-job training where necessary throughout the supply chain. By superimposing information on objects that provide specifications for completing tasks and through multimedia content that enables user-machine and user-user interaction, AR can train new operators on-site with a practical, interactive guidance [13]. Remote consultation is also possible withAR technology. For example, a forklift driver can replace the battery of the forklift based on the visualized instructions provided by a remote specialist on the forklift driver's AR smart glasses [2].

c)Last mile delivery

Augmented reality technology can assist drivers by providing updated, real-time traffic data, information on speed limits, optimal routes or rerouting of shipments, and possible vehicle malfunctions visualized through smart glasses worn by the driver or projected on the windscreen. While receiving this information, drivers nevertake their eyes off the road. This can increase driver safety since, unlike traditional navigation systems, the driverdoes not have to pay attention to the road and the vehicle [4]. AR recognition also enables the identification of delivery locations and customers to whom products will be delivered [2]-[1].

4. BENEFITS OF USING AR TECHNOLOGY & BARRIERS TO AR APPLICATIONS FOR LOGISTICS ACTIVITIES IN SUPPLY CHAINS

Augmented reality technology overlays information directly onto physical objects with which operators interact,providing instructions on how to perform complex tasks in real-time. For operators, this technology provides a new way of viewing and accessing information. In this context, it reduces the mental effort required for operators while performing their tasks and improves their attention, leading to a reduction in human errors. Even the mostexperienced operators can suffer from information overload caused by an excessive number of procedures to remember. AR technology can assist them in real-time [4]. Decreasing the error rate reduces the need for reworkand the dependence on printed work instructions [5]-[4]. AR technology can improve operator performance andlimit problems such as high costs, high error rates, low efficiency, long times, and excessive use of printed documents. Consulting and training costs, training times, difficulties in understanding training materials can also be reduced [4].

Augmented reality devices allow information and instructions to be received hands-free. This can increase safetyfor logistics operators and drivers. AR devices can also contribute to safety by providing feedback or informationon safety or by warning operators or drivers of an imminent or immediate danger [5]. AR technology can be used to simulate dangerous tasks or destructive events to prevent any risk to operators. Feeling more protected can increase operators' motivation [4].

In addition to the benefits mentioned above, augmented reality technology also has some barriers that need to be considered when implementing it in logistics processes. These barriers can be listed as follows:

a) The battery of AR devices may not last long enough to be used for a full working day. Carrying extrabatteries is not a case desired by operators [5]-[4].
b) The displays used may not automatically adjust to a change in light [5]-[4].
c) After prolonged use, processors overheat and slow down [5]-[4].
d) Since programming environment is not standardized, practitioners cannot easily develop their own applications and connect AR devices to existing systems [5]-[4].
e) Many wearable AR devices are not designed to be used for a long period of time. Therefore, prolongeduse of these devices may cause several comfort problems, such as headaches due to screen latency, discomfort due to the weight of AR devices, and eye fatigue due to non-central viewing [5]-[4].
f) Built-in cameras and microphones or permissions that allow access to face recognition, location, voicerecognition, and contacts creates privacy issues that may make users unwilling to wear AR devices [14].

The use of AR technology and devices such as smart glasses, AR apps, and spatial projectors does not require high skills and programming specifications. However, knowledge of how to use AR devices is necessary. For example, logistics operators must know that they can use apps, select, and resize elementsand holograms with simple gestures or voice commands. Logistics operators using AR devices must beable to perform multiple tasks at the same time, as the hands-free use of AR devices requires operators to be able to perform more than one task simultaneously. In a nutshell, the ability to use new digital interfaces, to interact with holograms, screens, and touch screens, to perform more than one task at a time, and to use data provided in real-time are required skills for logistics operators who use AR technology [5]-[4].

g) The cost of AR infrastructure and the cost of maintaining this infrastructure is also another barrier [5]- [1].

5. CONCLUSION

This theoretical study investigates the potential benefits and barriers for the adoption of AR technology to support logistics activities in supply chains and provides useful insights, particularly for practitioners, in implementing this technology. It was found out that in addition to its benefits, augmented reality technology currently has some obstacles that prevent supply chains from investing in this technology on a large scale. The study was conducted based on the existing literature. The theoretical findings of this study should be validated in future research by analyzing the industrial applications that are expected to increase soon [1].

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Paper ID:16

DESIGNING AN AUTOMATED GUIDED VEHICLE SYSTEM FOR A FOUNDRY

Sinem Komur[1], Berkay Kaya[2], Haluk Yapıcıoğlu[3]

Abstract *– Transportation of raw materials, semi-finished and finished products to their required locations is one of the most difficult operations to organize in manufacturing systems. Moreover, it is inevitable for material handling systems to keep up with industry 4.0, which supports integrated and intelligent systems. Automatic guided vehicles (AGV) have become one of the most important material handling tools in the transition to integrated systems. In this study, a requirements analysis for AGV systems was carried out for a company operating in the foundry industry and the results obtained were verified with a simulation study. To this end, in-plant transportation needs were analyzed, and transportation routes were designed to support the daily production requirements. Using the simulation model, various scenarios were tested, and the results were compared. As a result, a sustainable and industry 4.0 compatible AGV system was designed using analytical methods and simulation modelling.*

Keywords –automated guided vehicles, internal logistics, material handling, system simulation

1. INTRODUCTION

Material handling (MH) is a crucial aspect of production systems that involves the movement, storage, and control of materials and products. MH can affect the efficiency, quality, cost, and safety of production processes, as well as the customer satisfaction and environmental impact. Therefore, designing and optimizing MH systems is an important research topic in operations research and management science.

However, selecting the most suitable MH system for a given production scenario is not a trivial task. It requires considering multiple factors, such as the type, quantity, and variability of materials and products; the layout, capacity, and flexibility of production facilities; the availability, performance, and compatibility of MH equipment; the objectives, constraints, and preferences of decision makers; and the uncertainty and dynamics of production environments.

[1] Sinem Komur, Eskisehir Technical University, Faculty of Engineering, Department of Industrial Engineering, Eskisehir, Turkey, sinemkomur@ogr.eskisehir.edu.tr
[2] Berkay Kaya, berkaykaya@ogr.eskisehir.edu.tr
[3] Haluk Yapıcıoğlu, hyapicio@eskisehir.edu.tr

One of the most widely used technologies for MH automation is the automated guided vehicle (AGV) system. AGV systems consist of self-propelled vehicles that can transport materials and products within a facility without human intervention. They use sensors, cameras, lasers, and other guidance systems to navigate their routes and avoid obstacles [6-8]. AGV systems have some advantages and disadvantages that depend on the context and the objectives of the operation. Some of these advantages and disadvantages can be listed as follows:

Advantages of AGV systems:

- *Increased safety*: AGV systems can reduce the risk of accidents, injuries, and damages caused by human errors or fatigue. They can also operate in hazardous or extreme conditions that humans cannot tolerate [3] [4].

- *Increased accuracy*: AGV systems can perform tasks with high precision and consistency, minimizing errors and waste. They can also track and trace the materials and products they handle, improving inventory management and quality control [3] [4].

- *Reduced labor costs*: AGV systems can replace human workers for repetitive or low-value tasks, saving on labor expenses such as wages, benefits, training, and supervision. They can also run 24/7, increasing productivity and throughput [3] [4].

Disadvantages of AGV systems:

- *High initial investment*: AGV systems require a large upfront cost to purchase, install, and integrate the vehicles, the infrastructure, and the software. They may also need modifications or upgrades to adapt to changing needs or technologies [2] [3].

- *Maintenance costs*: AGV systems need regular maintenance and repair to ensure their optimal performance and reliability. They may also consume energy, fuel, or batteries that add to the operating costs [2] [3].

- *Decreased flexibility*: AGV systems may not be suitable for non-repetitive or complex tasks that require human judgment, creativity, or adaptation. They may also have difficulties in handling unexpected situations or disruptions that affect their routes or schedules [2] [5].

However, designing an AGV system for a given manufacturing scenario is not a simple task. It requires considering multiple factors, such as the type, quantity, and variability of materials and products; the layout, capacity, and flexibility of manufacturing facilities; the availability, performance, and compatibility of AGV equipment; the objectives, constraints, and preferences of decision makers; and the uncertainty and dynamics of manufacturing environments.

In this paper, we present a numerical analysis combined with a simulation-based approach to address the problem of AGV system design in a casting workshop of a foundry. Our approach starts with static calculations as explained in [1] to guesstimate the required number of AGVs to overcome the material handling requirements of the workshop. Results of these calculations are then used as a starting point for the simulation models designed. Based on an extensive scenario analysis to evaluate different AGV alternatives, the simulation model provided very important managerial insights to the use of AGVs in the casting workshop. We show how our approach can help decision makers to select the most appropriate AGV system that minimizes the total cost and maximizes the throughput of the overall system.

The rest of the paper is organized as follows. Section 2 reviews the relevant literature on AGV system design followed by the problem definition. Section 3 describes quantitative calculations, whereas Section 4 introduces the simulation model and the decision analysis framework used in our approach. Section 5 presents the results of our analysis. Along with the implications and limitations of our approach. Section 6 concludes the paper and suggests some directions for future research.

2. RELEVANT LITERATURE AND PROBLEM DEFINITION

The history of AGVs can be traced back to the 1950s.The evolution of AGVs can be divided into four eras, according to the technological advancements and the market acceptance of the systems [13]:

- The first era (1953-1973): The AGVs were simple track-guided systems with tactile sensors such as bumpers and emergency arrest handles. They were mainly used for towing trailers or pallets along fixed routes.

- The second era (1973-1993): The AGVs became more flexible and intelligent, using radio waves, vision cameras, magnets, or lasers for navigation. They were able to perform more complex tasks such as loading and unloading, sorting, and storing. They also integrated with other automation systems such as conveyor belts, robots, and computers.

- The third era (1993-2013): The AGVs became more modular and scalable, using standardized components and software. They were able to adapt to different environments and requirements, such as changing layouts, products, or processes. They also improved their safety and reliability, using collision avoidance and fault detection mechanisms.

- The fourth era (2013-present): The AGVs are becoming more autonomous and collaborative, using artificial intelligence and machine learning techniques. They are able to learn from their experiences and optimize their performance. They are also able to communicate and cooperate with other AGVs and humans, forming smart networks of mobile robots.

AGVs have become a key component of today's intralogistics, providing efficiency, flexibility, and productivity benefits for various industries and applications. They are expected to continue to evolve and innovate in the future, driven by the demands of the market and the advances of technology.

AGV system design is a very popular research topic. Beginning with the deployment of AGV systems in manufacturing facilities, there has been a very rich literature addressing the problem from different perspectives, using different techniques. However, it is not possible to provide a comprehensive literature survey on AGV systems and their design here, as it is not the purpose of this study. Interested readers might refer to [9-10] and [11]. Broadly speaking, there are static approaches that roughly estimates the required number of AGVs as explained in detail such as in [1] given the AGV path, flow, and distance among departments. Another stream of research focuses more on discrete event system simulation. A recent survey on these studies can be found in [9] and [12]. Discrete event system simulation is especially popular among researchers and practitioners as it allows for comparing different design alternatives and what if scenarios more realistically, due to its flexibility [12].

The company where this study is held is a manufacturer of armature and complementary products. The production process starts at the casting workshop. There are five different types of workstations in the casting workshop. These stations and their duties are as follows:

- *Sand Core Preparation Station*: During armature casting, shaping processes of the sand core molds that will form the cavities in the product are prepared in this workstation.

- *Molten Metal Preparation Station*: In this station, the components of the brass alloy that will form the products are prepared, melted in channel type induction furnaces.

- *Casting station*: The prepared sand cores are placed in casting molds and the brass raw material is casted into the molds by low pressure casting method. The product in the desired form is created at this station.

- *Sandblasting station*: The roughness that occur on the inner surfaces of the armature body at the end of the casting process are removed by sandblasting at this station.

- *Decoupage station*: In the decoupage station, armature bodies and runner channels, which are combined after casting, are separated from the main product by cutting.

Except for the sand core preparation station, the transports in the workshop are made using crates colored according to their capacity and strength, using forklifts and pallet trucks. For instance, the molten metal is transported between the preparation station and the casting station by using gray crates and pallet trucks, and transportation between the sandblasting station and the decoupage station is made by using orange crates and pallet trucks. Green crates are transported between the casting station and the sandblasting station using forklifts. The reason for using forklifts between these stations is that the temperature of the products coming out of the casting station is not suitable for transporting with a pallet truck. Transports also include the transport of empty crates back to the stations.

The overview of the casting workshop and the material transport routes are shown in FIGURE 1 below. In FIGURE 1, the red arrows show the material transport path between the molten metal preparation station and the casting stations, the blue arrows show the material transport path between the casting stations and the blasting station and lastly, the green arrows the material transport path between the blast station and the decoupage stations.

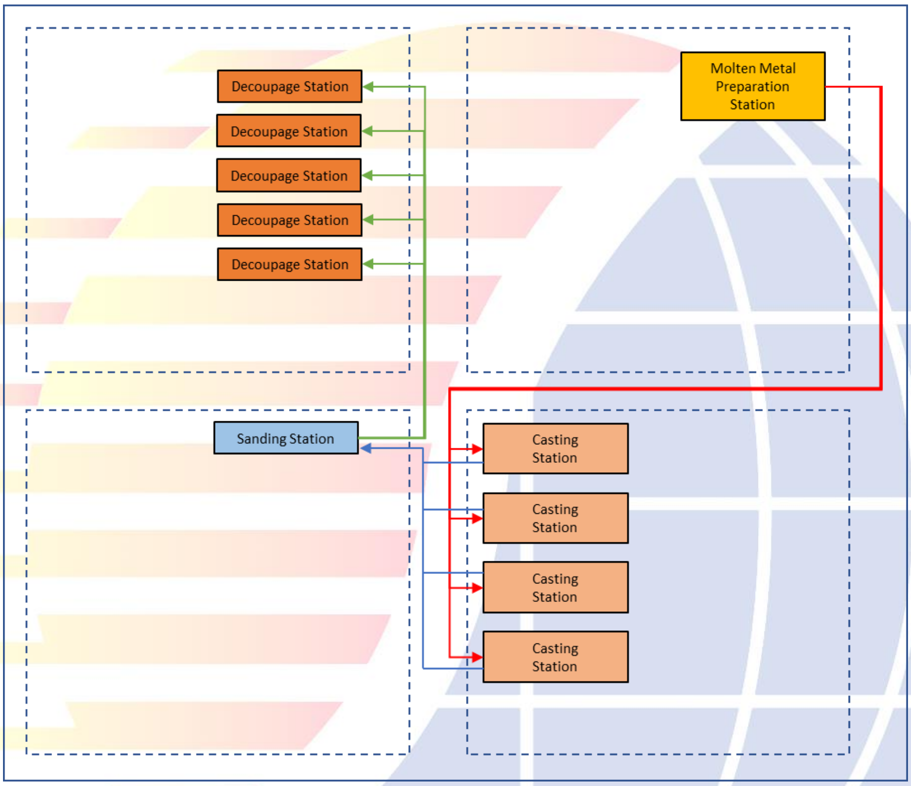


FIGURE 1
Schematic representation of the transportation needs in the foundry. Note that the figure is not drawn to the scale, and locations of workstations are changed to sustain anonymity.

3. DETERMINING AGV REQUIREMENTS: A QUANTITATIVE ANALYSIS

The quantitative analysis of AGV requirements starts with determining the AGV path considering the width of aisles. Although there are several shortcuts and narrow aisles between departments and workstations, AGVs can only use aisles that are wide enough for them to pass through. Consequently, the aisles depicted in FIGURE 1 chosen as the AGV path. Next, for each station pick-up and drop-off points (P/D locations) are determined. While determining the P/D locations, special care is taken in order not to interfere loading operations with the unloading operations. Then, based on the determined AGV path and the P/D locations for each workstation, travel distances between all pairs of P/D locations are calculated.

Once the interdepartmental distances calculated, the next step is to determine the transportation requirements among workstations. For this, daily production requirements and load batches are analyzed. As mentioned previously, the semi-finished goods are transported using crates, and each type of crate has a different maximum payload. As a result, daily transportation requirements between different pairs of workstations may differ from others. For instance, in order to meet the daily production requirements, three crates of semi-finished products need to be transported from the molten metal preparation station to a casting station, whereas from a casting station to the sanding station the daily transportation requirement is six crates. These figures are tabulated in TABLE 1 below:

TABLE 1
Interdepartmental Flow Requirements (Trips/day)

From/To	Molten Metal	Casting 1	Casting 2	Casting 3	Casting 4	Casting 5	Sanding Drop-off	Sanding Pick-up	Decoupage 1	Decoupage 2	Decoupage 3	Decoupage 4	Decoupage 5	Total
Molten Metal		3	3	3	3	3								15
Casting 1	3						6							9
Casting 2	3						6							9
Casting 3	3						6							9
Casting 4	3						6							9
Casting 5	3						6							9
Sanding Drop-off		6	6	6	6	6								30
Sanding Pick-up									10	10	10	10	9	49
Decoupage 1								10						10
Decoupage 2								10						10
Decoupage 3								10						10
Decoupage 4								10						10
Decoupage 5								9						9
Total	15	9	9	9	9	9	30	49	10	10	10	10	9	188

As can be verified from TABLE 1, all transportation requirements follow a symmetrical pattern. All crates start their travel from their respective workstations full of semi-finished goods. For instance, molten metal is transported to one of the casting workstations. Once the crate reaches a casting workstation, it waits there until the crate is emptied. Once the crate empty, it returns to the molten metal workstation. Thus, although the crate returning from the casting workstation to the molten metal workstation is empty, there is still a need for transporting the crate. This situation is generalizable to all transportation requirements in the system. Thus, all the transportation activities within the system are treated as 'loaded travel'. Using daily transportation requirements together with the interdepartmental distance data, total travel requirements for an AGV during a single shift is calculated and results are summarized in TABLE 2 below:

TABLE 2
Daily loaded travel (m/day)

From/To	Molten Metal	Casting 1	Casting 2	Casting 3	Casting 4	Casting 5	Sanding Drop-off	Sanding Pick-up	Decoupage 1	Decoupage 2	Decoupage 3	Decoupage 4	Decoupage 5	Total
Molten Metal		78	59	56	87	143								423
Casting 1	78						539							617
Casting 2	59						483							542
Casting 3	56						427							483
Casting 4	87						364							451
Casting 5	143						267							410
Sanding Drop-off		539	483	427	364	267								2080
Sanding Pick-up									614	557	470	314	238	2193
Decoupage 1								877						877
Decoupage 2								796						796
Decoupage 3								470						470
Decoupage 4								335						335
Decoupage 5								238						238
Total	423	617	542	483	451	410	2080	2716	614	557	470	314	238	9915

From the analysis above, the total distance that needs to be traversed by AGV is roughly 10 kms per shift. Assuming an average AGV speed of 0,4 m/s the total loaded travel time required by the AGV system is calculated as 6,89 hours. Each loading and unloading operation last 36 seconds considering acceleration and deceleration after pick-up and before drop-off respectively. For the total load and unload of 188 times, the time required for loading and unloading is calculated as 1,88 hours. Consequently, the total required AGV time per shift is $6{,}89 + 1{,}88 = 8{,}77$ hours. The company uses 7,5-hour shifts, as a result, the minimum number of AGVs required is computed as $\lceil 8{,}77/7{,}5 \rceil = 2$.

4. SIMULATION STUDIES AND SCENARIO ANALYSIS

In the Quantitative Analysis section, we already established the fact that in order to meet the daily transportation requirements, at least two AGVs are required. Although quantitative analysis provides a fast and reliable analysis of required number of AGVs, it fails to provide information on several other key performance indicators such as blocking effects and average waiting time. To overcome this, we also developed a simulation model of the AGV system and experimented with four different scenarios. These scenarios are (1) a transportation system with one AGV, (2) a transportation system with one AGV, and a forklift, (3) a transportation system with two AGVs, and, (4) a transportation system with three AGVs. Scenario 1 is designed mainly to observe the effects of inadequate transportation capacity on the waiting times for transportation. Scenario 2 is the optimal transportation policy, as suggested by the results of the quantitative analysis. Scenario 3 is designed to answer the questions of the factory managers, on using different type of transportation means simultaneously. And lastly, scenario 4 is designed to investigate the effects of an additional AGV on blocking.

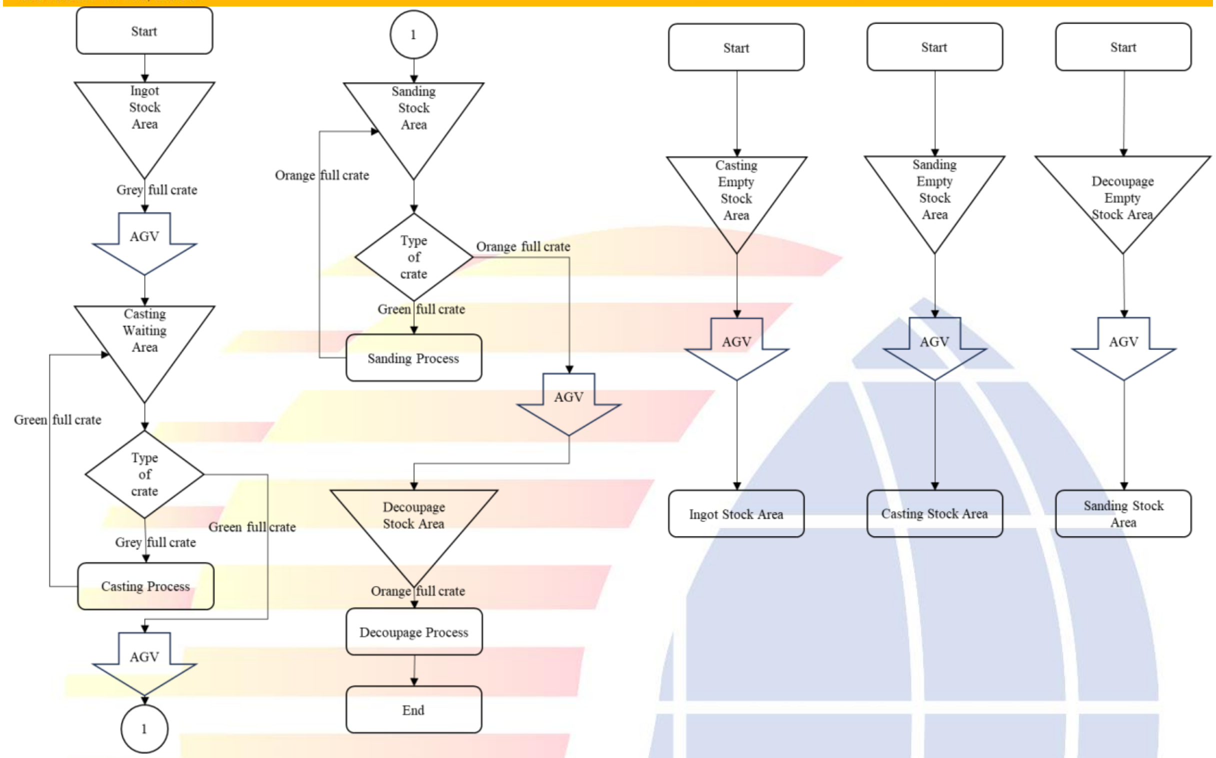


FIGURE 2
Flowchart for loaded travel (left) and unloaded travel (right three)

We start designing the simulation model of AGV system by designing the flow charts depicting the decision rules for crate transportation. These flowcharts are shown in FIGURE 2. To illustrate, consider the leftmost flow in FIGURE 2. A gray full crate is transported from ingot stock area to casting waiting area via an AGV. From casting waiting area, gray crates are transported to casting process, and after the process, semi-finished products are accumulated in green crates. Once a green crate is full, it is transported to sanding stock area using an AGV. In sanding stock area green full crates are sent to sanding process, and at the end of the process semi-finished products that are collected in orange crates are sent to decoupage stock area in orange crates. The remaining three flowcharts defines the empty crate transportation flows for grey, green, and orange crates respectively.

Due to the variety of products produced by the enterprise, part processing times at workstations may differ for different parts and part families. During the data collection phase, it was decided to determine the average machining times on a station basis in order to define the machining times in the simulation environment. Since the subject of the study is material handling systems and the focus is on transport of crates in a timely manner, the product processing times at the stations were determined and conveyed by the company in the form of the average number of crates coming out of stations per shift. The average number of crates coming out of the stations were converted into parts processing times for every workstation. Then, these processing times are used to create transportation orders from each workstation so that the time between transportation orders are equal. For instance, if a workstation creates 10 transportation orders per shift, then the time between two orders is $60 \times 7{,}5 \div 10 = 45$ minutes.

During the quantitative analysis, the durations acceleration and deceleration required after pick-up and before drop-off assumed to be negligible. However, for the simulation studies these durations are also defined along with loading and unloading times to reap the full potential of simulation environment. This also aids in creating a more realistic model of the actual transportation requirements.

Once the decision rules for the transportation of full crates and empty crates along with the other relevant parameters are determined, simulation model of the overall system is designed using FlexSim 3D Simulation Modeling and Analysis Software. The main motivation behind this choice is that the distributors of the software provided permission for us to use unrestricted version of the software for the student project over the duration of the project. A screen shot of the 3D representation of the simulation model is provided in FIGURE 3 In addition to the unrestricted access to the software, we benefited extensively from the features of the software. For instance, the process flow function available in the FlexSim software were used to define the material transport within the simulation.

The operation of AGVs in the simulation model is based on certain logical frameworks. Material handling operations that require an AGV was determined in the 3D modeling of the production environment. In cases where an AGV transport is required, the control points connected to the queues send signals to the AGV control system, and the AGV control system keeps a list of the transports assigned to it. Together with the decision-making rules, AGV transport requirements are decided according to corresponding logical cycle.

In output analysis, which is one of the most important parts of simulation modeling, it is important to have data specific to crate types. To this end, for each type of crate (e.g., green, gray and orange) both empty and full, a different entity is defined, and performance statistics are collected separately for later use in the output analysis. Specifically, workstation status (e.g., idle – busy), AGV status, (e.g., loaded travel, unloaded travel, loading/unloading, blocked, and waiting), number of transports performed by AGVs, average waiting time in queue, and breakdown of transports with respect to the type of crates were recorded and analyzed. Results are provided in the next section.

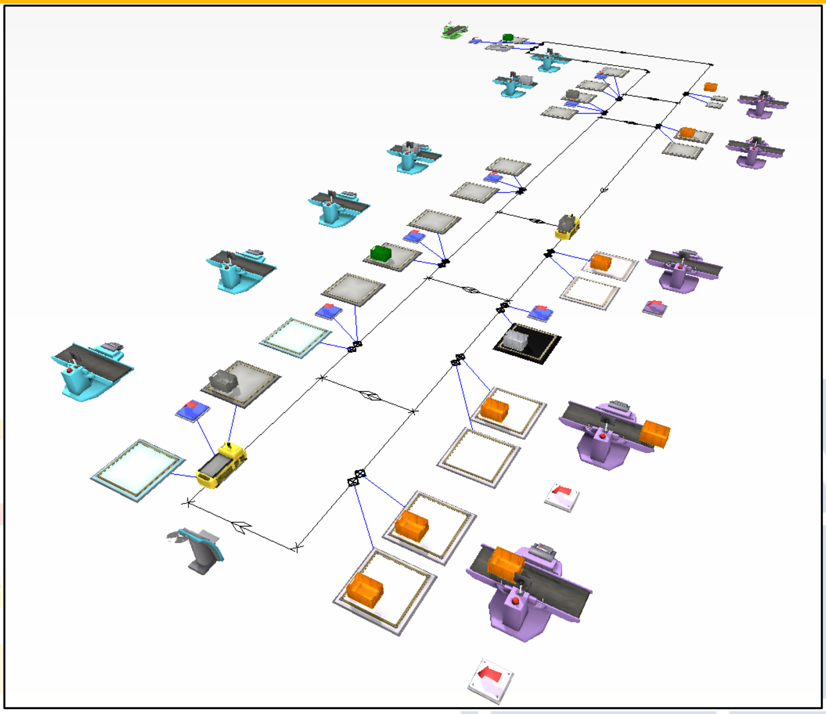


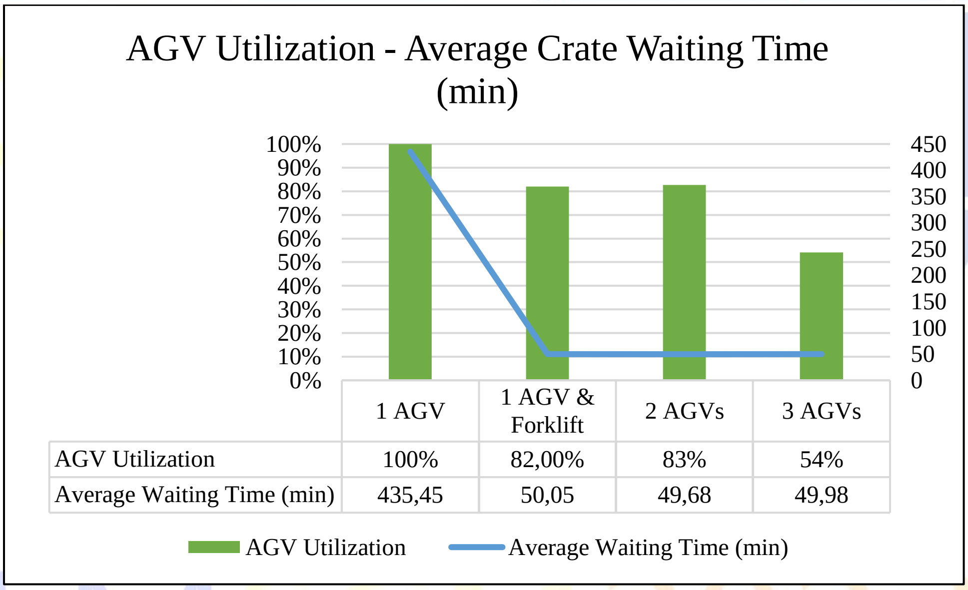
FIGURE 3
Overview of the simulation model

5. RESULTS AND DISCUSSION

In order to provide cross-validation of the results obtained in the quantitative calculation method in line with the determined system configurations and decision rules, and to present the system proposal by comparing alternative models, output analysis was performed based on scenarios that are differing in number of AGVs as explained in the previous section. As a result of the quantitative calculation, it has been revealed that the transportation requirements can be met optimally with a transportation system with 2 AGVs. While doing simulation modeling, it was also evaluated whether 1 AGV is sufficient for the system and whether 3 AGVs yields better results. Also, if the need for an increased transportation requirements arises due to increased production rates in the future, we also wanted to investigate the effect of introduction of third AGV into the system, especially the change in blocking. In addition, since the project was a preliminary study, and the company may want to purchase a single AGV for the material handling system at the beginning, the number of workstations where 1 AGV works was reduced to 3 workstations based on the analysis, and forklift transports were simulated for the remaining transports needs. The scenarios determined in the previous section were used in the analysis. The simulation models were run for a duration of 1 month with a 1-day warm-up period.

At the beginning of the project, the key performance criteria were determined together with the company as AGV utilization and average waiting time in the stock area. AGV utilization is defined as the sum of the AGV's loaded transport, unloaded transport, and loading and unloading times. Outputs on key performance measures of different scenarios are shown in FIGURE 4.

In the system operated with 1 AGV, it is observed that the AGV utilization is 100%. Although the AGV utilization is at the maximum level, 1 AGV cannot keep up with the transportation requirements of the system, as can be verified from the high waiting times for crates. Even when the AGV can meet all the transportation requirements in the system, the desired level of AGV utilization should be less than 100% in order to allow for operations such as charging and/or maintenance. Looking at the system in which 3 AGVs operate, it is observed that although the waiting time in the stock area has decreased, the AGV utilization is very low. This is mainly since 3 AGVs block each other and the job waiting times (e.g., idle times) of the AGVs are high. This is an undesirable situation similar to 100% utilization of an AGV. It basically means that AGVs are not being used efficiently. On the other hand, in scenarios with 1 AGV & forklift and 2 AGVs, both AGV occupancy and waiting times in the stock area are at desired levels as verified by the plant managers.



	1 AGV	1 AGV & Forklift	2 AGVs	3 AGVs
AGV Utilization	100%	82,00%	83%	54%
Average Waiting Time (min)	435,45	50,05	49,68	49,98

FIGURE 4
AGV Utilization and Average waiting times under various scenarios

In an AGV system, the blocking effect is a result of the interdependence of the AGVs in the network. Each of the AGVs moves through the environment while performing a specific task. However, the blocking effect occurs when they need to use the same zone of the path or when the target point of one AGV is occupied by another AGV. In this case, the movements of other AGVs are blocked or delayed due to the blocking effect. The blocking effect can reduce the efficiency of AGV systems and cause productivity losses. It is observed that the increase in the number of AGVs in the system increases the blocking effect as seen in FIGURE 5. The 17% blocking effect of the system with 3 AGVs leads to an undesirable situation for the reasons mentioned. AGVs can delay the tasks they need to do when blocking is in effect.

In FIGURE 5, the operating status of the AGVs in systems with different number of AGVs is shown comparatively. When the chart is examined, it is seen that there is a decrease in the loaded and unloaded transportation times per vehicle due to the increase in the number of vehicles (AGV and forklift) in the system, and these decreases cause an increase in the waiting time of the AGV. It is known that the ratio of AGV waiting time to the total working time of more than 10-20% affects the system efficiency negatively. Considering that the AGV stops because of the obstacles it will encounter on the way during the charging and/or maintenance process and operation. It is seen in FIGURE 5 that the system with 3 AGVs is an example of this situation.

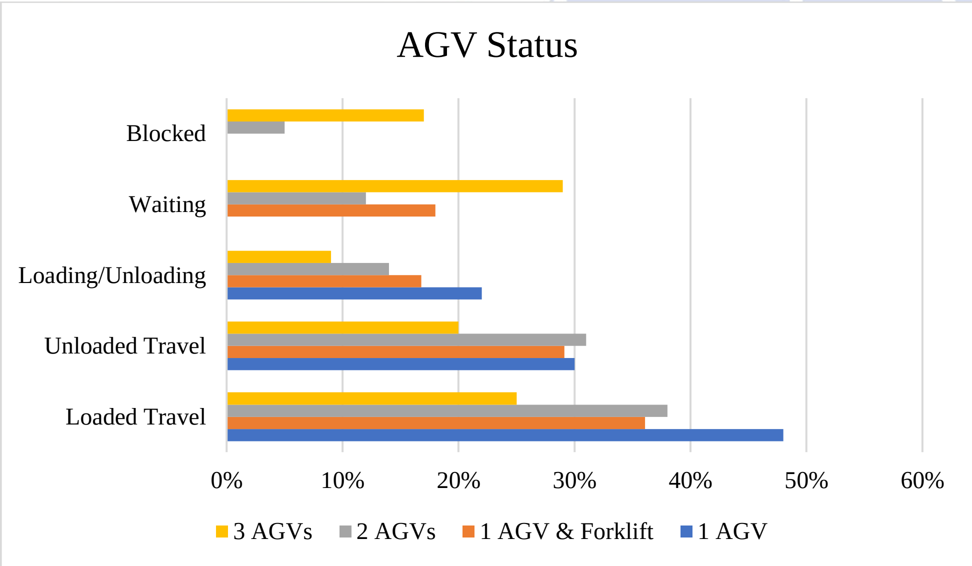


FIGURE 5
AGV Status under various scenarios

As a result of the evaluation, the high AGV waiting times due to the process occupancy of (since the production rates are not fast enough to keep AGVs completely busy) in the system with 3 AGVs and the blocking effect reduces the overall transportation system efficiency. It has been observed that simply adding an additional AGV to the AGV system that has already two AGVs simply increases the idle times and blocked times of the AGVs. Considering the investment cost due to the increase in the number of AGVs, the system with 3 AGVs does not seem to be a good alternative for the current daily production rates.

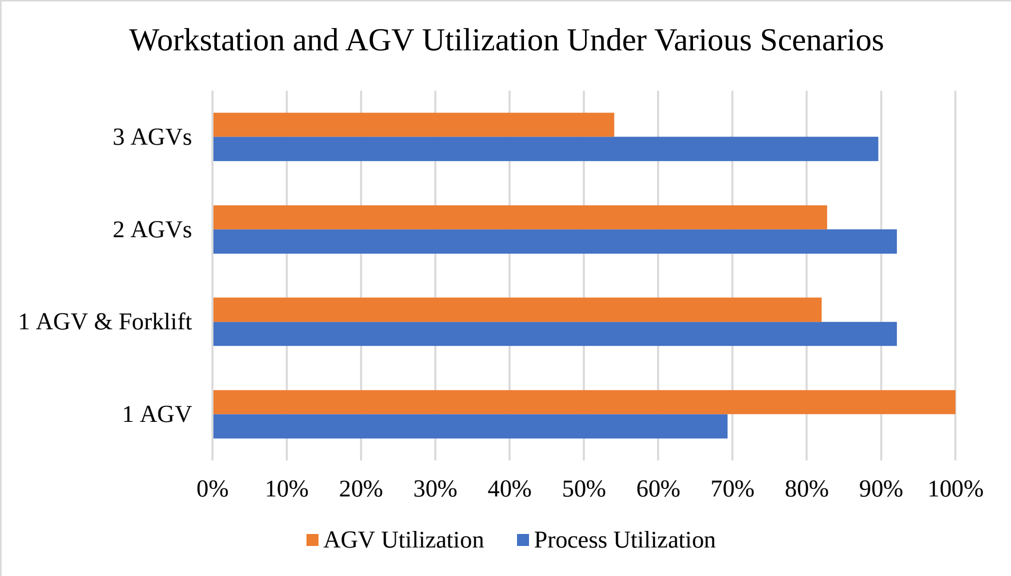


FIGURE 6
Workstation and AGV utilization under various scenarios

In the system with 1 AGV, it is seen that the AGV works without any waiting time as depicted in FIGURE 4. At this point, it is important to know how the production rates are affected by the limited transportation capability. To this end, we provide a comparison of production system utilization under four different transportation policies in FIGURE 6. As clearly seen from FIGURE 6, it is not possible to reach the desired production rates with single AGV. In the remaining three scenarios, daily production levels can be supported. However, the total utilization of the transportation system reduces if there are 3 AGVs in the system. When the crate waiting times are examined together with the production system utilization, it is concluded that the high waiting times adversely affects the material flow within the production system and causes inefficiencies. For this reason, it is seen that the system with 1 AGV cannot meet the current needs and cannot be considered as a viable alternative for the system.

In the current analysis, the transportation system with 2 AGVs and 1 AGV and a forklift have similar performance in terms of reaching the number of crate transports as calculated in the quantitative analysis, AGV waiting time, waiting time of the crates in the queue, and the utilization rate of the processes in the workstations. These two systems with similar results stand out as attractive alternatives for the transportation needs of the plant. At this point, the company must choose between switching to fully autonomous systems by bearing the cost of two AGVs and using AGV and a forklift together. It is recommended to implement a material handling system with 2 AGVs in accordance with the aim of the transition to create a sustainable material handling system in line with industry 4.0.

6. CONCLUSIONS

In this study, an analysis of an AGV system for a foundry is presented. Using a quantitative analysis, it is determined that at least two AGVs are required to meet the transportation needs of the overall production system. This result is verified by the simulation study. Also, with the help of the simulation model designed, it is established that a transportation system with only one AGV cannot meet the transportation requirements of the production system. When the number of AGVs is increased to three, total idle time and the blocking effect becomes a very serious problem. For these reasons, it is recommended that a transportation system consisting of two AGVs provides an ideal solution compatible with transition efforts to Industry 4.0. In case the company does not wish to bear the high initial investment cost of two AGVs, then they might employ a gradual transition to a fully automatized transportation system by employing a single AGV and a forklift to begin with. However, this decision needs to be made also considering the cost of upgrading from one AGV to two AGVs.

ACKNOWLEDGMENT

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Paper ID:20

THE IMPORTANCE OF ROUTE OPTIMIZATION FOR AIR TRANSPORT EFFICIENCY IN DISASTER SITUATIONS

Kemal SARILGAN[1], Vildan DURMAZ[2], A.Zafer ACAR[3]

***Abstract* — In the event of a disaster, trained rescue teams should be dispatched to the disaster area as quickly as possible. In general, in disasters, it is essential that the victims are rescued from the situation they are in so quickly. Turkey has a very high rate of exposure to natural disasters. According to the historical data, it has been exposed to all kinds of disasters and will continue to experience major disasters in the future. For this reason, the first response to the disasters to be experienced should be done in a planned and rapid manner. In this study, the current disaster response plan implemented in Turkey, the current state of our country has been described by examining the last major earthquake disasters of February 6, 2023. Following the description, the situation of the available air transport vehicles for a quick response was revealed and suggestions were made about what solutions could be brought. As a result of the study, it is aimed to minimize the losses to be experienced by including the air transportation, which is not included in the current disaster response plan of our country, but provides the opportunity to respond quickly by overcoming the transportation problems that may occur as a result of the damages caused by the major earthquakes.*

***Keywords* — air transportation, disaster, disaster logistics and management, earthquake*

1. INTRODUCTION

Just like in the past, our country will continue to be affected by natural disasters in the present and future. Most recently, the earthquakes in Kahramanmaraş on February 6, 2023, affected 11 provinces and claimed the lives of 45,089 citizens [2]. The first 72 hours of a disaster are often referred to as the "golden hours," during which disaster response teams need to be rapidly dispatched to the disaster area using the fastest means possible, and rescue operations need to commence as soon as possible.

[1] Kemal SARILGAN, Anadolu Üniversitesi, Sosyal Bilimler Enstitüsü, Havacılık Yönetimi Anabilim Dalı, Yüksek Lisans Öğrencisi
[2] Doç.Dr.Vildan DURMAZ, Eskişehir Teknik Üniversitesi, Havacılık ve Uzay Bilimleri Fakültesi
[3] Prof.Dr.A.Zafer ACAR, İstanbul Bilgi Üniversitesi, Uygulamalı Bilimler Fakültesi

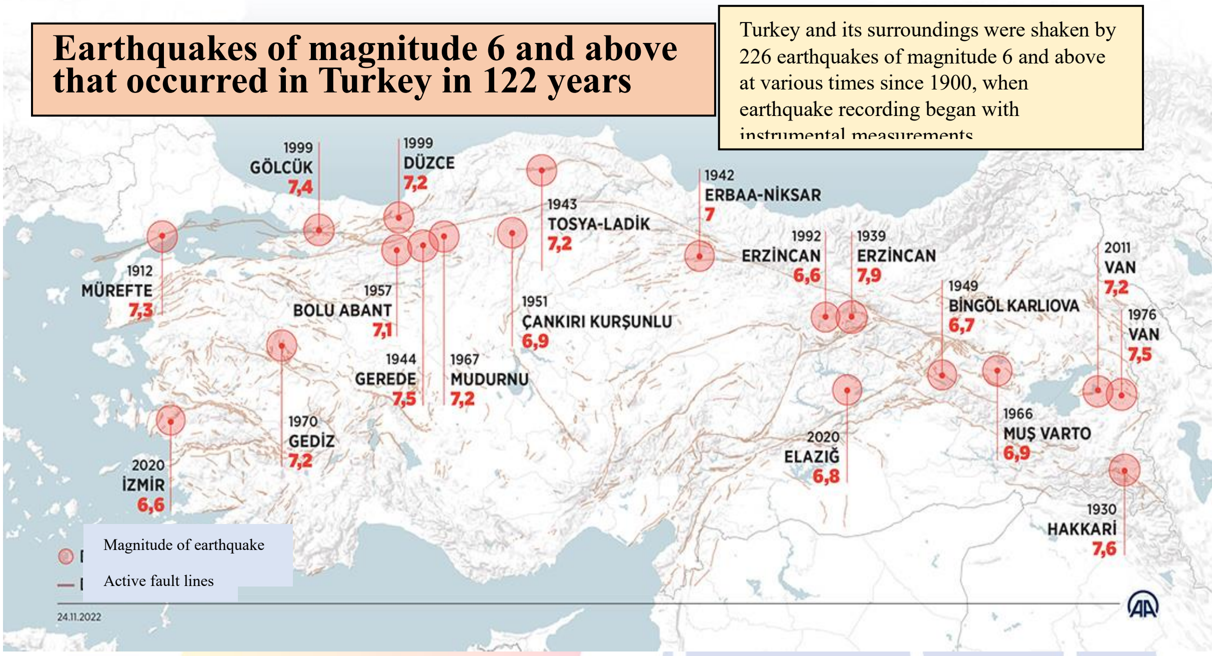

Image 1: Major Earthquakes Occurred in Turkey in the Last 122 Years [15]

As a result of major earthquakes, essential transportation infrastructure can be damaged, leading to disruptions in the movement of disaster victims and their families to and from the affected areas. These blockages and structural damages can cause hindrances in the deployment of disaster response teams via land routes, and the teams might not reach the area in a timely manner. Unfortunately, due to these delays, loss of life can occur, which is something none of us want to see happen.

This study aims to minimize loss of life by proposing effective solutions through the disaster management stages of planning, damage reduction, preparedness, and intervention. This will be achieved by creating necessary route planning for the rapid deployment of disaster response teams to the disaster area using air transportation. The goal is to ensure that disaster response teams reach the affected area quickly and efficiently, ultimately reducing the impact of casualties.

Disaster management

According to the United Nations, a disaster is any natural, technological, or human-induced event that causes physical, economic, and social losses, disrupts normal life, affects communities, and cannot be effectively managed with local resources, thereby halting or interrupting regular activities [3].

When considering disasters as phenomena that can occur regularly within the course of society's existence and can have socio-economic and psychological impacts, it becomes evident that being prepared for such events is paramount for communities. Therefore, being organized and structured in their readiness efforts is a fundamental challenge that societies need to address [5].

Disasters are generally categorized into three types: natural disasters, technological disasters, and human-made disasters. Natural disasters include events like earthquakes, floods, and landslides. Technological disasters involve incidents such as nuclear explosions, industrial accidents, and chemical leaks. On the other hand, human-made disasters encompass actions like violence, displacement, and terrorist attacks [6].

Earthquakes are elastic wave movements caused by the sudden release of accumulated energy in faults, which are fractures within the Earth's crust. This displacement occurs due to the sudden release of accumulated energy, resulting in the rapid release of energy in the form of seismic waves [7].

The factors influencing the magnitude of a disaster can be listed as follows [8]:

- The physical size/intensity of the event,
- The distance of the event from populated areas,
- Level of economic development,
- Rate of population growth,
- Unplanned, unregulated, and rapid urbanization and industrialization in vulnerable areas,
- Degradation of green spaces and forests,
- Lack of education,
- Effectiveness of government and non-governmental organizations in disaster preparedness.

Approaching disaster events with the notion of fate and inevitability is quite incorrect. It is believed that through coordination among various institutions and organizations such as the private sector, government administration, civil society organizations, political parties, universities, and more, both the physical and social damages that occur can be reduced. This emphasizes the need for collaboration to mitigate the impact of disasters [4].

Due to the lack of knowledge and technology to prevent disasters, humankind can only engage in disaster management activities aimed at reducing the impact of disasters. Disaster management involves coordinating, directing, and implementing relevant actions at every level of a disaster event in order to minimize the resulting damages. It entails the appropriate utilization of resources towards this goal, with the objective of reducing the harm caused by disasters [9].

Disaster management involves the organized management of resources with the aim of preventing disasters whenever possible and reducing the damages when prevention is not feasible. This includes coordinating, directing, and implementing relevant activities at all levels of a disaster event within society, encompassing all institutions and organizations. The goal is to align resources in a manner that is appropriate for these purposes [9].

We can liken disaster management to the management of crises and risks. If risks are not managed well, crises occur. Managing crises is more challenging than managing risks. Crises can leave a deeper impact on affected individuals than disasters themselves. Therefore, effective disaster management not only helps keep inevitable dangers at a manageable level but also contributes to minimizing damage by well-managing risks, allowing us to navigate through them with less harm.

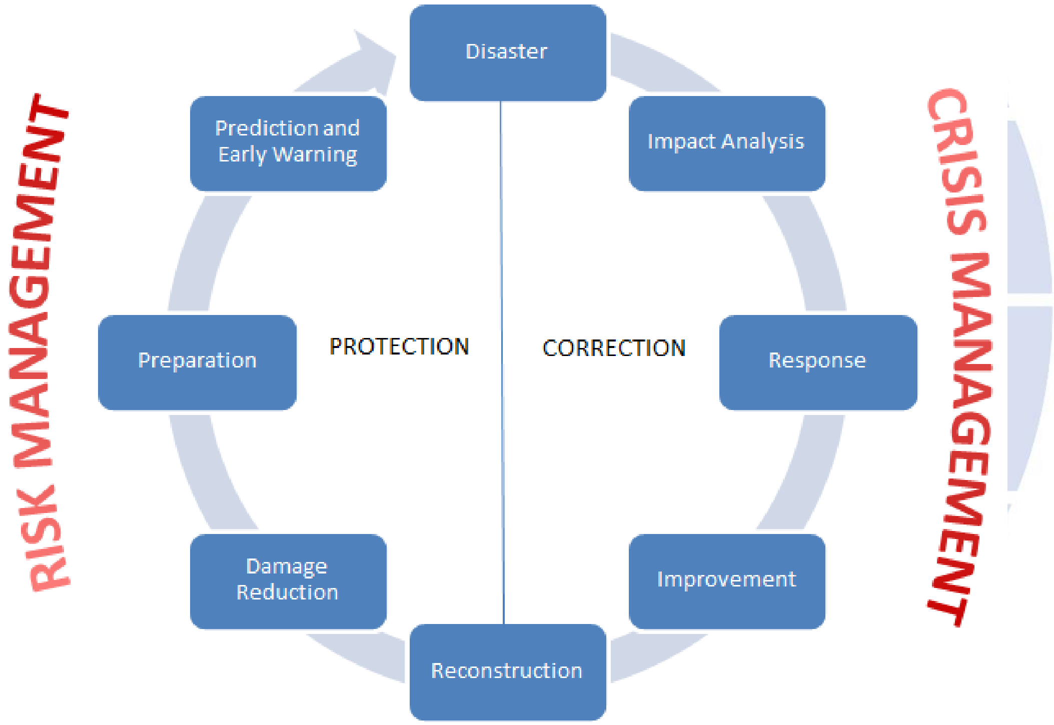

Figure 1: Modern Disaster Management System and its Phases [3]

Disaster management operates within a connected cycle. It involves continuously learning from each disaster, ensuring preparedness levels are consistently higher than the response to the previous event. We are always living in the "D-1" day, constantly preparing for the "D" day when a new disaster strikes. Therefore, to ensure continuous improvement, we must keep our preparations up to date and maintain a dynamic structure.

The planned approach aims to provide effective solutions for the stages of "damage reduction, preparedness, and response." The objective is to propose efficient solutions through the planning process, focusing on the effective deployment of disaster response teams to the disaster area using air transportation.

Turkey is among the world's most risky regions, especially prone to various human or natural disasters such as earthquakes, landslides, fires, and avalanches. According to the Global Risk Index, Turkey ranks 45th out of 191 countries, placing it in the "high risk" category. Earthquakes are a primary concern [10].

In a geography with such high risks, it's crucial not to rely solely on reactive approaches when seeking solutions to disasters. Instead, lessons from past occurrences should be learned, and proactive and predictive planning should be conducted. Scientific decision-making techniques should be employed in this planning process to ensure the most effective outcomes.

Indeed, making scientifically informed decisions requires accurate and sufficient information. Therefore, information regarding our country's disaster management and air transportation will be presented. This information is crucial for making well-informed decisions in these fields.

Air cargo transportation

When there's a need to swiftly send goods over long distances, air cargo transportation provides the shortest possible transit time. Air transportation is ideal for carrying small but high-value items to distant locations, where the delivery time takes precedence over costs. In cases where the quality of customer service takes precedence over costs, air cargo transportation is preferred [11].

In today's world, air transportation is used for both cargo and passenger transport. The part that involves transporting cargo is referred to as "air cargo." The airlines that engage in air cargo transportation are as follows:

- Integrated carriers providing door-to-door service,
- Combined carriers providing both passenger and cargo services,
- They are classified as cargo airlines that exclusively provide cargo services.

There are a total of 12 registered airline operators in Turkey. Among them, 4 hold certificates for both scheduled and non-scheduled flights, allowing them to exclusively engage in cargo transportation (Air Anka Hava Yolları A.Ş., ACT Hava Yolları A.Ş., ULS Hava Yolları Kargo Taşımacılık A.Ş., MNG Havayolları ve Taşımacılık A.Ş.). Other airline operators hold certificates for both scheduled and non-scheduled flights, allowing them to carry both passengers and cargo (combined carriers) [12]. It's important to note that Turkish Cargo, a subsidiary under Turkish Airlines (THY), is specifically established for cargo operations in air transportation. Benefitting from the strength of our national flag carrier THY, Turkish Cargo holds a dominant position in our country's air cargo market.

	Company	Aircraft type	Nu.	Loading limits (height)
1	Air Anka Hava Yolları A.Ş.	A330 – F	3	240 cm.

2	ACT Hava Yolları A.Ş.	B747 – 400	5	300 cm.
3	ULS Hava Yolları Kargo Taşımacılık A.Ş.	A310 – F	3	240 cm.
4	MNG Havayolları ve Taşımacılık A.Ş.	A300 - 600	6	240 cm.
		A330 - F	3	240 cm.
5	Türk Hava Yolları A.Ş. (Turkish Cargo)	A330 – F	10	240 cm.
		B777 – F	8	300 cm.
		B747 – 400F	1	300 cm.
		A310 – 300F	2	240 cm.
		TOTAL	**41**	

Table 1: Air Cargo Operators in Turkey [12]

Image 2: Boeing 747-400F Cargo Aircraft Aircraft

Image 3: A400M Atlas Military Cargo

In disaster situations, it might be necessary to intervene using all available resources of the country, not just civilian airlines. Therefore, it's important to provide information about the Turkish Armed Forces' (Türk Silahlı Kuvvetleri) inventory of air vehicles, including cargo aircraft. (In our study, information about the cargo capacity of these air vehicles is being provided as it will be used for the deployment of intervention teams' vehicles during potential disaster response phases.)

	Headquarters	**Aircraft type**	**Nu.**	**Loading limits (height)**
1	Turkish Air Force	Airbus A400M Atlas	10	385 cm.
		Lockheed C-130	17	274 cm.
		CASA CN 235	41	274 cm.
2	Turkish Naval Forces	CASA CN 235	7	274 cm.

3	Turkish Land Forces	CH -47 Chinook	11	10.886 kg.
		TOTAL	**86**	

Table 2: Cargo Aircraft in the Turkish Armed Forces Inventory [17]

Military cargo aircraft, thanks to their flight capabilities, play a significant role in providing disaster logistics support in terms of air transportation. In the aviation field, General Purpose Helicopters provide services such as ambulance services, search and rescue, and damage assessment [13].

Disaster management in Turkey and AFAD

The Disaster and Emergency Management Presidency (AFAD) was established with the Law No. 5902 on May 29, 2009. Until the establishment of AFAD, a generally reactive approach was taken towards disasters. The earthquakes in the Marmara region in 1999 prompted Turkey to reevaluate its approach to disasters, especially in terms of coordination, and it began to exhibit a proactive approach.

The Disaster and Emergency Management Presidency (AFAD) is an institution that has been established as a versatile, multi-stakeholder, outcome-focused, flexible, and dynamic organization, aiming to plan, direct, support, coordinate, and effectively implement the necessary activities among all institutions and organizations in the country for the prevention of disasters and the reduction of their damages, the intervention in disasters, and the rapid completion of post-disaster recovery efforts while ensuring the rational use of resources in this field. It is based on interdisciplinary work, emphasizing collaboration, and operates as a focal point for the efficient utilization of resources [1].

In disasters and emergencies, the sole authorized organization is AFAD. Looking at AFAD's structure, it is hierarchically positioned under the Ministry of Interior as a presidency. Its hierarchical structure continues with AFAD provincial directorates, which are affiliated with governors in the provinces. Additionally, there are "Search and Rescue Unit Directorates" operating specifically under provincial directorates in 11 provinces. These regions are as follows:

- Adana,
- Afyonkarahisar,
- Ankara,
- Bursa,
- Diyarbakır,
- Erzurum,
- İstanbul,
- İzmir,
- Sakarya,
- Samsun,

- Van [1].

Search and rescue teams and equipment generally include:

- CBRN (Chemical, Biological, Radiological, Nuclear) specialists,
- Divers
- Search and rescue dogs,
- Mobile CBRN decontamination centers,
- CBRN intervention vehicles,
- Transportation vehicles,
- Mobile earthquake simulation centers,
- Communication and image transmission vehicles,
- Mobile disaster coordination centers,
- Compact operation vehicles,
- Heavy-duty search and rescue vehicles,
- Medium-duty search and rescue vehicles,
- Light-duty search and rescue vehicles,
- 8x8 amphibious search and rescue vehicles [1].

Based on the experiences gained from the disasters in our country, the Turkey Disaster Response Plan (TAMP) was developed in 2014 with the aim of ensuring effective intervention in disasters.

Regarding who will carry out the interventions, intervention levels have been determined. These levels are as follows:

- Level 1: Situations where intervention is possible with local resources,
- Level 2: Situations where intervention from 1st group support provinces is needed,
- Level 3: Situations where intervention is required from 1st and 2nd group support provinces, along with national support,
- Level 4: Situations where international support is needed, involving the first three levels of support provinces.

If deemed necessary, AFAD can collaborate with relevant ministries, civil society organizations, and the General Staff Headquarters depending on the magnitude of the disaster event.

	CITY	1. GROUP SUPPORTING CITIES	2. GROUP SUPPORTING CITIES
1.	Adana	Mersin, Osmaniye, Kahramanmaraş, Gaziantep, Kilis, Hatay, Niğde	Kayseri, Konya, Malatya
2.	Adıyaman	Erzincan, Bingöl, Malatya, Elazığ, Kahramanmaraş, Gaziantep, Şanlıurfa, Diyarbakır	Tunceli, Kilis, Kayseri

3.	Gaziantep	Mersin, Osmaniye, Kahramanmaraş, Kilis, Hatay, Adıyaman, Şanlıurfa	Kayseri, Malatya, Adana
4.	Diyarbakır	Şanlıurfa, Mardin, Siirt, Şırnak, Batman, Adıyaman, Malatya, Elazığ, Bingöl, Muş	Bitlis, Erzurum, Tunceli
5.	Kahramanmaraş	Mersin, Adana, Osmaniye, Gaziantep, Kilis, Hatay, Adıyaman, Sivas, Malatya, Kayseri	Şanlıurfa, Niğde, Diyarbakır
6.	Hatay	Adana, Osmaniye, Kahramanmaraş, Gaziantep, Kilis	Şanlıurfa, Kayseri, Mersin
7.	Malatya	Erzincan, Tunceli, Elazığ, Adıyaman, Diyarbakır, Kahramanmaraş, Sivas	Gaziantep, Kayseri, Bingöl
8.	Kilis	Adana, Osmaniye, Kahramanmaraş, Gaziantep, Hatay	Şanlıurfa, Malatya, Mersin
9.	Şanlıurfa	Diyarbakır, Mardin, Siirt, Şırnak, Batman, Gaziantep, Adıyaman	Elazığ, Kahramanmaraş, Malatya
10.	Osmaniye	Mersin, Adana, Kahramanmaraş, Gaziantep, Kilis, Hatay	Kayseri, Adıyaman, Şanlıurfa

Table 3: First and Second Level Supporting Cities According to TAMP [1]

The determination of the first and second-degree supporting cities in the TAMP plan was based on the criterion of proximity to the affected area. However, it should be noted that during an earthquake, regardless of their distance from the epicenter, cities close to the epicenter may also experience extensive destruction depending on the magnitude of the earthquake. Taking Hatay as an example, all the first-degree support cities designated for intervention have been affected by the earthquake. Therefore, there is a need for alternative intervention team deployment planning.

According to TAMP, the main responsible entity for transportation activities is the Ministry of Transport and Infrastructure. Regarding aviation transportation, it is accurate to state that SHGM (General Directorate of Civil Aviation) and DHMİ (State Airports Authority) are involved. However, responsibility does not solely rest with the government. The entire country has responsibilities during the disaster management phase. It is inevitable that the government's power and center of gravity are present in the disaster-stricken area. Therefore, the government can also consider planning, taking into account private businesses' assets during the intervention in the event of a disaster.

Air traffic can be temporarily closed or redirection can be facilitated by providing information about the airports where airborne planes need to land, in order to ensure effective intervention during a crisis.

2. METHODS

The study is a qualitative field research conducted within the borders of Turkey, with an application-oriented approach for the future. Additionally, structured interviews were carried out with a group consisting of civilian air cargo operators, military cargo loading personnel, AFAD intervention team members, post-earthquake airport personnel, and aviation experts.

The data were obtained from open sources and structured interviews. Furthermore, the results that will emerge upon completion of the research will contribute to generating data for disaster management planning.

The study includes the following tasks:

- Determining the number and technical specifications of all cargo aircraft (civilian and military) within the borders of the Republic of Turkey.
- Identifying the quantity and dimensions of intervention vehicles in AFAD's inventory.
- Evaluating the possibility of loading AFAD's vehicles onto cargo aircraft.
- Mapping the locations of AFAD's Search and Rescue Regional Directorates.
- Identifying the airports where all cargo aircraft (civilian and military) within the borders of the Republic of Turkey can perform operations.
- Identifying air cargo terminals capable of serving cargo aircraft (different procedures and equipment may be required for loading and unloading each aircraft).
- Determining potential airports for AFAD's intervention vehicles based on their number and suitable airport locations.
- Identifying the two most vulnerable provinces in terms of both unstable structures and high population density on the active fault line map of Turkey.
- Optimizing the routes of intervention teams based on possible earthquake scenarios.

The scope of the research encompasses the borders of Turkey, and its sample is formed by the two potential earthquake regions.

3. FINDINGS

Literature review, conducted examinations, and interviews have resulted in the following findings:

The intervention vehicles dispatched to the earthquake-stricken areas via roadways have faced delays in reaching their designated locations due to the disruption of transportation infrastructure, harsh weather conditions, obstruction of roads by uncoordinated relief vehicles, and the presence of affected individuals. Additionally, the AFAD vehicles' routes were altered as disaster victims attempted to intervene in their own buildings upon sighting AFAD vehicles, resulting in their inability to reach the assigned areas on time.

AFAD's TAMP was designed with the principle of selecting neighboring provinces that would support each other in the event of any disaster. However, in the case of a major earthquake, the impact spread across a vast geographical area, and even the designated supporting provinces were unable to handle their own problems. Due to their own challenges resulting from the event, these provinces were incapable of extending immediate assistance to other affected provinces during the initial phase of intervention.

It has been observed that state authorities have not made any requests to private air cargo companies for intervention vehicles or humanitarian aid shipments. Civil aviation companies have voluntarily extended their assistance based on goodwill.
It has been observed that the possibility of things not going as planned has been overlooked in the planning process. The absence of contingency plans (Plan B) covering the efficient use of transportation vehicles has been noted.

4. CONCLUSIONS AND DISCUSSION

Due to the fact that major earthquakes can affect extensive geographical areas, local search and rescue teams could find themselves overwhelmed, even unable to help themselves. Therefore, in the planning process, distant provinces that are not affected by the earthquake should also be included to ensure effective response.

It is being evaluated that the vehicles in AFAD's inventory can be loaded onto both civilian and military cargo planes and transported to nearby airports in the earthquake-affected areas.
It has been concluded that if intervention teams coming from distant locations were loaded onto air cargo planes, the total loading and unloading time would take a maximum of 3 hours. This would allow them to reach their duty locations more quickly.

As a result of the findings, it is evaluated that including air transportation vehicles in the national disaster response plans would contribute to reducing the loss of lives in case of disasters.
It is considered that AFAD's future procurement of intervention vehicles should be planned based on the loading threshold values of the most commonly available air cargo vehicles in the market, in order to be more effective.

The planning was done based on the available resources, and it is considered that future studies on similar topics should take into account the aircraft types that will be newly procured and removed from the inventory, which would have an impact on the planning process.

In the next phase of the study, two important earthquake scenarios will be examined to determine route optimization. In these scenarios, the vehicles of the teams that will intervene in the probable earthquake zone closest to the optimal airport for loading will be loaded onto the aircraft, and the possible course of action will be established.

Airports that will not be affected by earthquakes in the future should be investigated and studies should be carried out to dispatch first responders to the disaster area through these airports.

In order to respond to disasters more quickly, future studies need to make integrated response plans not only for air transportation but also for all modes of transportation.

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GREEN LOGISTICS PARK CENTER LOCATION PROBLEM: ISTANBUL APPLICATION

Eren KAMBER[1,2], Murat BASKAK[2]
[1]Department of Industrial Engineering, Alanya Alaaddin Keykubat University, Antalya, Turkey, eren.kamber@alanya.edu.tr
[2]Department of Industrial Engineering, Istanbul Technical University, Besiktas, Istanbul, Turkey, baskakm@itu.edu.tr

Abstract *– European Union aim to achieve climate neutrality by 2050 with the Green Deal. In this direction, it is planned to make radical changes in logistics, construction, energy, production and many sectors. In this study, it is aimed to establish a green logistics park center in Turkey, taking into account the changes that will occur in the European Union and Turkish logistics sector within the scope of the Green Deal. First of all, the problem of determining green logistics park center location has been chosen as the primary goal of the study. In order to solve the problem, it is necessary to determine the criteria for the green logistics park center location problem firstly. The criteria will be determined by literature review. Afterwards, the relevant criteria will be prioritized by the evaluations of decision makers with intuitionistic fuzzy numbers. In addition, an application for green logistics park location selection will be handled with a hybrid multi criteria decision making (MCDM) model including intuitionistic fuzzy sets and TOPSIS method.*

Keywords *– Intuitionistic fuzzy sets, green deal, green logistics, green logistics park center, multi criteria decision making*

1. INTRODUCTION

Logistics is seen as the management of the transportation of goods, people, information and other resources in the processes from the raw material supply of the products to the point of consumption [1]. Starting from the definition of logistics, all stakeholders in the supply chain should be considered during the establishment of a logistics center. In this direction, it is aimed to choose the logistics center location.

Today, when environmental factors are considered, green logistics studies come to the fore in logistics activities. In order to emphasize the importance of green logistics, it is planned to establish a green logistics center within the borders of Turkey in compliance with the Green Deal (2019) within the scope of the study.

In summary, the Green Deal aims to reduce greenhouse gas emissions by at least 50%, 55% if possible, by 2030 compared to 1990 levels, and to zero it by 2050. In this direction, it is planned to make radical changes in logistics, construction, energy, production and many sectors [2].

When green logistics activities are considered in the context of the Green Deal it is decided that the planned green logistics park center will be within the borders of Istanbul province in Turkey.

There are many reasons why the study was limited to the province of Istanbul. When the logistics park center location selection studies in the literature are examined, it is seen that factors such as the proximity to the market, proximity to multi modal transportation, proximity to suppliers, economic potential have been taken into account in the selection of green logistics center location. When all these factors are examined, it is seen that focusing to Istanbul province for green logistics park center location in the process of harmonization with the European Union Green Deal is of great importance for the logistics sector.

The primary focus is determining and prioritizing of criteria and alternatives for green logistics park location selection problem as a scope of this study. In addition, main contributions of this paper is that we apply an hybrid multi criteria decision making model containing intuitionistic fuzzy sets and TOPSIS method for green logistics park location selection problem. Besides, location selection of green logistics parks is an important issue in order to encourage green logistics in the context of the Green Deal.

Within the scope of the study, it is aimed to determine the criteria and choose the best alternative for the green logistics park location selection problem. In this direction, a literature review was carried out as described in section 2, and the importance levels of the criteria determined after this review were determined according to the evaluations of the decision makers. The determined criteria are discussed in detail in the green logistics center location problem. In addition, a literature review has been carried out for the concept of green logistics, and what the concept of green logistics means today is emphasized. Application for green logistics park location slection problem with IFS-TOPSIS method is handled with section 3. Finally, the findings obtained as a result of the study are summarized and the evaluations of the criteria are interpreted in section 4.

2. LITERATURE REVIEW

2.1 Green Logistics

The concept of "green" entered the literature in the 1970s, when there were economic developments, social relations began to develop, and the relations between the environment and natural resources were recognized and defined. The general expression of these demands is primarily found in the Declaration of the United Nations Conference on Human and Environment, adopted in Stockholm, Sweden on June 16, 1972 [3]. The beginning of the 1990s is considered to be the beginning of the development of the concept of 'green logistics'. This period appears as a period in which social awareness and responsibility for the problems related to global warming and environmental pollution increase [4]. Green logistics is driven by regulatory factors followed by the 1997 Kyoto Protocol and subsequently the Copenhagen Protocol, focusing on the sustainability of businesses and the environment [5].

Many different definitions have been made for green logistics in the literature. Green logistics is defined as a set of supply chain management practices and strategies that focus on material handling, waste management, packaging and transportation, reducing the ecological and energy footprints of distribution of goods [6]. Green logistics is concerned with the sustainable production and distribution of products, taking into account environmental and social factors [7].

In other words, green logistics is the integration of environmental objectives into traditional logistics operations. Overall performance in green logistics reflects a company's ability to protect the environment by conserving natural resources and reducing waste through efficient product flow and storage. The use of alternative fuels in transportation, optimization of transportation routes in order to shorten the time, changing the mode of transportation from road to rail or using recyclable packaging materials can be given as examples of green logistics activities [8]. Green logistics management is to integrate environmental aspects into logistics management to take the environment into account in every decision-making process across logistics networks [9].

2.2 Determination of Green Logistics Park Center Location Selection Criteria

As a result of the literature review including the topics of "green logistics park center location selection" and "logistics park center location selection", the criteria that are important for the green logistics park center location selection problem have been determined within the scope of the literature and are shown in Table 1 with the relevant criteria explanations.

When the relevant criteria in Table 1 are evaluated, the criteria titled land and construction cost, disaster risk and environmental factors are defined as cost-oriented, while the other criteria are defined as benefit-oriented.

The criteria determined in the context of the study were evaluated by four senior executives of logistics service provider companies operating in Turkey and three academicians who are experts in the field of logistics, in order to fill the gap in the independent development of applications. A total of seven expert opinions were taken and the weighting of the criteria was carried out.

Various logistics centers have recently been established in major cities for rapid distribution of products. However, this situation brings up many important issues such as traffic congestion, air pollution and high energy consumption. To effectively deal with these problems, it is recommended to combine multiple logistics centers into one green logistics park [31]. Prioritizing topics such as air pollution and high energy consumption is vital for green logisctics park implementations. That is why criterion of environmental factors is included in the green logistics park location selection problem.

TABLE 1

The criteria selected for the Green logistics park location selection problem as a result of the literature review

	Criteria	Definition
K1	Land and construction cost [10, 11, 12, 13, 14, 15]	Cost according to geographical location (real estate value, land slope, height, etc.)
K2	Land expansion potential [16, 17, 18, 19, 20, 21]	Ability to increase land size to meet increasing demands
K3	Proximity to the market [16, 22, 17, 18, 23, 14, 24]	Proximity to customers and target market
K4	Proximity to suppliers [12, 18, 21]	Proximity to manufacturers and suppliers of spare parts, services and raw materials
K5	Connectivity to multimodal transport [20, 21]	Proximity or level of connectivity to highways, airlines, railways and ports
K6	General infrastructure suitability [22, 12, 25, 26, 20]	Electricity, internet, natural gas, water, waste etc. infrastructure quality
K7	Compliance with central and local regulations [18, 21]	Level of restrictions imposed by municipal governments, such as restricted delivery hours, special delivery zones, in line with sustainable freight transport
K8	Disaster risk [12, 15, 27]	Potential natural and unnatural disaster risk
K9	Economic potential [10, 26, 28, 14]	Economic potential of the location, trade volume, Gross Domestic Product
K10	Population density [10, 29, 30]	Population density of the location
K11	Environmental factors [22, 10, 14, 18]	Air pollution, water pollution, soil pollution, noise and vibration levels

After determining criteria, weights consisting of intuitionistic fuzzy criterion pairs were determined by the decision makers for each criterion. Intuitionistic fuzzy number linguistic expressions developed by Alkan and Kahraman [32] to determine the weights of the criteria are shown in Table 2.

TABLE 2
Intuitionistic fuzzy linguistic terms used for criterion weights

Linguistic Terms	IFS	
	m	n
Absolutely High Importance (AHI)	0.90	0.10
Very High Importance (VHI)	0.80	0.15
High Importance (HI)	0.70	0.25
Above Average Value (AAV)	0.60	0.35
Average Value (AV)	0.50	0.45
Under Average Value (UAV)	0.40	0.55
Low Importance (LI)	0.30	0.65
Very Low Importance (VLI)	0.20	0.75
Absolutely Low Importance (ALI)	0.10	0.90

Intuitionistic fuzzy numbers were developed by Atanassov in 1986 and presented as a new version of the fuzzy set defined with membership and non-membership functions by expanding the scope of membership function. If m_I and n_I are defined as membership and non-membership degrees of the intuisionistic fuzzy set (IFS), respectively, then $m_I : X \rightarrow [0,1]$ and $n_I : X \rightarrow [0,1]$ and their sum should not exceed 1 [33]. Also, hesitancy degree (Π) is found as $\Pi_I = 1 - m_I - n_I$.

The scores of the decision makers (DMs) for evaluating the criteria according to linguistic expressions are shown in Table 3. Criteria are defined as K1, K2, K3, …, K11 respectively in this study.

TABLE 3
Evaluation of criteria by decision makers with intuitionistic fuzzy numbers

DMs/ Criteria	DM1	DM2	DM3	DM4	DM5	DM6	DM7	Criteria type
K1	AAV	AAV	AAV	HI	HI	VHI	AAV	Cost
K2	HI	HI	VHI	AAV	AAV	HI	VHI	Benefit
K3	VHI	HI	HI	VHI	AHI	VHI	VHI	Benefit
K4	AV	AAV	AAV	HI	AV	AAV	HI	Benefit
K5	HI	VHI	AAV	VHI	HI	AAV	HI	Benefit
K6	AAV	HI	AHI	AAV	VHI	HI	VHI	Benefit
K7	HI	VHI	VHI	AAV	AHI	AAV	HI	Benefit
K8	HI	HI	HI	AAV	AV	AV	VHI	Cost
K9	HI	HI	HI	AAV	HI	AHI	HI	Benefit
K10	LI	VHI	VHI	AV	LI	AAV	AAV	Benefit
K11	HI	AHI	AHI	HI	HI	AHI	AHI	Cost

The linguistic expressions in Table 3, which were prepared with the evaluations of the decision makers, were transformed into an individual criterion weight matrix consisting of intuitionistic fuzzy numbers by using the intuitionistic fuzzy linguistic expressions in Table 2. Then, with Equation (1) developed by Atanassov [33], individual evaluations of decision makers were transformed into clustered intuitionistic fuzzy criterion weight matrix as shown in Table 4.

$$< \mu(C_i), \nu(C_i) > = < \frac{\sum_{j=1}^{ki} m_{i,j}}{k_i}, \frac{\sum_{j=1}^{ki} n_{i,j}}{k_i} > \quad (1)$$

Let be a set of intuitionistic fuzzy pairs $\{<m_{i,1},n_{i,1}>,<m_{i,2},n_{i,2}>,\ldots\}$ in Equation 1. In this case, the intuitionistic fuzzy number calculation for the element C_i will be done with the corresponding formula. The value of k_i in the formula is the number of decision makers [34].

TABLE 4
Clustered intuitionistic fuzzy criterion weight matrix

Criteria	IFS criterion weight	Criteria type
K1	0.657, 0.292	Cost
K2	0.7, 0.25	Benefit
K3	0.785, 0.171	Benefit
K4	0.6, 0.35	Benefit
K5	0.7, 0.25	Benefit
K6	0.728, 0.228	Benefit
K7	0.728, 0.228	Benefit
K8	0.642, 0.307	Cost
K9	0.714, 0.242	Benefit
K10	0.557, 0.392	Benefit
K11	0.814, 0.164	Cost

3. APPLICATION

After defining criteria for green logistics park selection problem, the importance of establishing green logistics park within the borders of the country is emphasized within the scope of the study. By this way, it has been concluded that the green logistics park centers planned to be established within the borders of the country will primarily be more appropriate within the borders of Istanbul city.

Evaluating the districts of Istanbul city, Çatalca, Arnavutköy, Eyüp, Tuzla, Beykoz districts were determined as alternatives represented by O1, O2, O3, O4 and O5 respectively. It is aimed to select the priority district for the logistics park to be established by evaluating these districts within the scope of the green logistics center location selection criteria determined in the study. In total, 11 criteria (C1, C2, …, C11) will be handled to evaluate alternatives given in Table 1.

To choose the best alternative for green logistics park selection problem, intiutinistic fuzzy TOPSIS (IFS-TOPSIS) will be handled which was improved by Boran et al. [35]. Steps of the IFS-TOPSIS method will be shown with application of green logistics park location selection problem as follows.

Step 1: Decision matrix is created including decision makers' evaluations of five alternatives (Çatalca, Arnavutköy, Eyüp, Tuzla, Beykoz districts) determined as O_i={O1, O2, ….., O5} i=1,2, …, 5, and eleven criteria determined as K_j ={K1, K2, …, K11} with intuitionistic fuzzy numbers. For determining the alternatives by the decision makers, the scale in Table 5 which developed for intuitionistic fuzzy sets by Alkan and Kahraman [32] will be used.

TABLE 5
Intuitionistic fuzzy linguistic terms used for alternative selection

Linguistic Terms	IFS	
	m	n
Certainly High Value (CHIV)	.9	.1

Very High Value (VHIV)	.8	.15
High Value (HIV)	.7	.25
Above Average Value (AAVV)	.6	.35
Average Value (AVV)	.5	.45
Under Average Value (UAVV)	.4	.55
Low Value (LOV)	.3	.65
Very Low Value (VLOV)	.2	.75
Certainly Low Value (CLOV)	.1	.9

Step 2: Aggregated intuitionistic decision matrix is created in this phase. Evaluations of decision makers are combined in aggregated intuitionistic decision matrix by using Equation 1 as seen in Table 6.

TABLE 6
Aggregated intuitionistic fuzzy decision matrix

	O1	O2	O3	O4	O5
K1	0.671, 0.278	0.685, 0.264	0.557, 0.392	0.6, 0.35	0.614, 0.335
K2	0.757, 0.2	0.8, 0.164	0.5, 0.45	0.643, 0.307	0.528, 0.421
K3	0.6, 0.35	0.671, 0.278	0.728, 0.228	0.714, 0.235	0.728, 0.228
K4	0.657, 0.292	0.542, 0.407	0.628, 0.321	0.743, 0.207	0.642, 0.307
K5	0.685, 0.264	0.714, 0.235	0.614, 0.335	0.728, 0.228	0.542, 0.407
K6	0.728, 0.228	0.685, 0.264	0.742, 0.214	0.771, 0.185	0.743, 0.214
K7	0.742, 0.214	0.714, 0.242	0.6, 0.35	0.714, 0.235	0.6, 0.35
K8	0.628, 0.321	0.557, 0.392	0.614, 0.335	0.657, 0.292	0.557, 0.392
K9	0.671, 0.278	0.714, 0.242	0.642, 0.307	0.771, 0.185	0.585, 0.364
K10	0.6, 0.35	0.585, 0.364	0.757, 0.2	0.743, 0.214	0.642, 0.307
K11	0.685, 0.264	0.642, 0.307	0.7, 0.264	0.743, 0.207	0.671, 0.278

Step 3: Weights of criteria are calculated. In this step, clustered intuitionistic fuzzy criterion weight matrix found in Table 4 will be used as a criterion weights.
Step 4: Weighted intuitionistic fuzzy decision matrix is calculated by multiplying intuitionistic fuzzy decision matrix with aggregated intuitionistic fuzzy criterion weight matrix as shown in Equation 2 improved by Atanassov [32]. Let A= (m_A, n_B) and B= (m_A, n_B) are defined as an IFS in this equation as follows.

$$A \otimes B = (m_A m_B,\ n_A + n_B - n_A n_B) \quad (2)$$

Finally, weighted intuitionistic fuzzy decision matrix is determined in Table 7.

TABLE 7

Weighted intuitionistic fuzzy decision matrix

	O1	O2	O3	O4	O5
K1	0.441, 0.489	0.451, 0.479	0.366, 0.571	0.394, 0.541	0.403, 0.53
K2	0.53, 0.4	0.56, 0.373	0.35, 0.587	0.45, 0.48	0.37, 0.566
K3	0.471, 0.461	0.527, 0.402	0.572, 0.361	0.561, 0.366	0.572, 0.361
K4	0.394, 0.54	0.325, 0.614	0.377, 0.558	0.445, 0.484	0.385, 0.549
K5	0.48, 0.448	0.5, 0.426	0.43, 0.501	0.51, 0.421	0.38, 0.555
K6	0.531, 0.404	0.499, 0.432	0.541, 0.393	0.562, 0.371	0.541, 0.393
K7	0.541, 0.393	0.52, 0.415	0.437, 0.498	0.52, 0.41	0.437, 0.498
K8	0.404, 0.529	0.358, 0.579	0.394, 0.539	0.422, 0.51	0.358, 0.579
K9	0.479, 0.453	0.51, 0.426	0.459, 0.475	0.551, 0.383	0.418, 0.518
K10	0.334, 0.605	0.326, 0.614	0.421, 0.514	0.413, 0.522	0.358, 0.579
K11	0.558, 0.385	0.523, 0.421	0.57, 0.385	0.604, 0.337	0.546, 0.397

Step 5: Positive ideal solutions ($A^* = (m_{A*}, n_{A*})$) and negative ideal solutions ($A^- = (m_B^-, n_B^-)$) are calculated by using Equations 3, 4, 5 and 6 respectively [35] and shown in Table 8. J_1 represents criterion is benefit-oriented, and J_2 represents the cases of the criterion being cost-oriented in these equations.

$$m_{A*} = \{(maksm_A | j \in J_1), (minm_A | j \in J_2) \quad (3)$$

$$n_{A*} = \{(minn_A | j \in J_1), (maksn_A | j \in J_2) \quad (4)$$

$$m_{A-} = \{(minm_A | j \in J_1), (maksm_A | j \in J_2) \quad (5)$$

$$n_{A-} = \{(maksn_A | j \in J_1), (minn_A | j \in J_2) \quad (6)$$

TABLE 8
Positive and negative ideal solutions

	Positive Ideal Solutions	Negative Ideal Solutions	Criterion Type
K1	0.366, 0.571	0.451, 0.479	Cost
K2	0.56, 0.373	0.35, 0.587	Benefit
K3	0.572, 0.361	0.471, 0.461	Benefit
K4	0.445, 0.484	0.325, 0.614	Benefit
K5	0.51, 0.421	0.38, 0.555	Benefit
K6	0.562, 0.371	0.499, 0.432	Benefit
K7	0.541, 0.393	0.437, 0.498	Benefit
K8	0.358, 0.579	0.422, 0.51	Cost
K9	0.551, 0.383	0.418, 0.518	Benefit
K10	0.421, 0.514	0.326, 0.614	Benefit

K11	0.523, 0.421	0.604, 0.337	Cost

Step 6: After determining positive and negative ideal solutions, positive separation measures (S^*) and negative separation measures (S^-) are calculated by using normalized Euclidean distance [36] in Equation (7) and Equation (8). Calculations for seperation measures are shown in Table 9.

$$S^* = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}(m_A - \mathrm{m}_{A*})^2 + (n_A - \mathrm{n}_{A*})^2 + (\Pi_A - \Pi_{A*})^2} \quad (7)$$

$$S^- = \sqrt{\frac{1}{2n}\sum_{i=1}^{n}(m_A - \mathrm{m}_{A-})^2 + (n_A - \mathrm{n}_{A-})^2 + (\Pi_A - \Pi_{A-})^2} \quad (8)$$

Step 7: Relative closeness coefficients (C_i) are calculated by using Equation (9). Also, calculations for Relative closeness coefficients are shown in Table 8.

$$C_i = \frac{S^*}{S^-} \quad (9)$$

TABLE 9
Separation measures and the relative closeness coefficients

Alternatives	S^*	S^-	C_i
O1	0.059	0.078	0.571
O2	0.061	0.090	0.597
O3	0.085	0.059	0.411
O4	0.047	0.091	0.660
O5	0.092	0.050	0.351

Step 8: Finally, alternatives are ranked according to relative closeness coefficients. The higher alternative with relative closeness coefficient is choosen as best alternative. As a result, O4 (Tuzla district) is determined as best alternative. Alternatives are ranked as O4, O2, O1, O3 and O5 respectively in IFS-TOPSIS method.

4. CONCLUSION AND RESULTS

When the European Union Green Deal is evaluated in the context of the Turkish logistics sector, the importance of establishing green logistics centers within the borders of the country is emphasized within the scope of the study. In this direction, work has been started and it has been concluded that it would be more appropriate to consider the green logistics park centers, which are planned to be established within the borders of the country, primarily within the borders of Istanbul province.

Within the scope of the study, primarily focused on determining the criteria for the problem of green logistics center location selection. In accordance with the strategy of ensuring the transition to environmentally friendly technologies and encouraging transitions to multi-modal transportation applications in logistics with the Green Deal, it is aimed to establish green logistics park centers in the study. Environmental factors and connectivity to multimodal transport were also included in the criteria in the decision making model. Thus, it was aimed to harmonize with the Green Deal when choosing suitable locations for the green logistics park.

As a result, the decision makers evaluated the criteria determined for the green logistics park center location selection problem in the scope of the study as in Table 4. As a result of the evaluation, the environmental factors criterion, which includes factors such as air pollution, water pollution, soil pollution, noise and vibration levels, has been the most important criterion in the study, considering the carbon emission zero target of the Green Deal. Afterwards, the criterion of proximity to the market was determined as the second important criterion by the decision makers. Compliance with the Green Deal is very important for Turkey, which exports most of its exports to European Union countries. Because, with the Green Deal, the European Union countries did not set specific targets for themselves. At the same time, stakeholder countries that have economic and social relations with the European Union, including Turkey, are expected to achieve certain green targets. When considered in this direction, proximity to the market (within the scope of the study to the European Union) emerges as an important criterion.

Afterwards, general infrastructure suitability and compliance with central and local regulations were determined as the third most important criterion by decision makers at equal importance level. Compliance with infrastructural and sustainable freight transportation and logistics processes will continue uninterruptedly, thus preventing structural problems. The measure of economic potential for the green logistics park center selection problem is the criterion decided at the fourth level of importance. Land expansion potential and connectivity to multimodal transport are equally important and share the fifth place. Afterwards, land and construction cost, disaster risk, proximity to supply sources and population density criteria, respectively, were less important than the preferences of the decision makers in the study. When the preferences of the decision makers regarding the criteria are examined, it is seen that they decide by thinking in the context of the Green Deal and green logistics. Therefore, decision makers choose environmental factors and proximity to the market as the most important criteria.

IFS-TOPSIS method is handled for green logistics park location selection problem. Alternatives are ranked as O4, O2, O1, O3 and O5 respectively hereby with the application of the study. According to the results, Tuzla district, which was determined as the most suitable alternative for the green logistics park location, has many advantages in terms of logistics. The proximity of Tuzla district to multi-modal transportation networks will play an important role in minimizing transportation distances and times with the green logistics park planned to be established. Thus, the carbon footprint in transportation will be reduced with the realization of the project. One of the main goals of the Green Deal is to reduce the carbon footprint. In this regard, another importance of the green logistics center location selection study emerges in terms of the Green Agreement.

In future studies, different decision making models and comparative analysis will be developed in line with the alternatives to be determined by using the criteria selected by the literature review for the location selection of the green logistics park center. By choosing the appropriate fuzzy multi criteria decision making model, it will be aimed to determine the most suitable alternative for the green logistics center. In this direction, Çatalca, Arnavutköy, Eyüp, Tuzla and Beykoz districts were determined as options for future studies in Istanbul city borders. It is aimed to select the priority district for the logistics center to be established by evaluating these districts within the scope of the green logistics park center location selection criteria.

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INVESTIGATING THE USERS OF SHARED MICROMOBILITY SERVICES: A SYSTEMATIC REVIEW

Ahmet Tuğrul Tuğer

İstanbul Bilgi Üniversitesi, Uygulamalı Bilimler Fakültesi, Lojistik Yönetimi Bölümü, Istanbul, TURKEY, tugrul.tuger@bilgi.edu.tr

Abstract – *Micromobility is gradually acknowledged as a bright mode of urban transport, especially for its capability to diminish private car usage for short trips in highly populated cities. As a new and hot topic, the research on shared micromobility appears fragmented taken into account regulations, safety, route optimization, user behaviors, legislation and urban planning related to micromobility services. This paper strives to consolidate extant knowledge with a user lens on shared micromobility research by following four research questions based on externalities, individual factors that exist and open the way for new solutions in the topic.*

Keywords – *Micromobility, Shared micromobility, Shared bikes, Shared e-scooters*

1. INTRODUCTION

Shared mobility refers to the vehicles that are shared among individuals over time or together among multiple travelers and it is estimated to produce up to $1 trillion in consumer spending with the support of information technologies solutions such as such as electronic docking stations, smart cards, mobile phones and mobile apps [1],[7]. As a subset of shared mobility, shared micromobility represents the short trips undertaken by collective usage of micro or light vehicles of transportation such as bicycle, scooter, skateboard, hoverboard [2]-[4]. Micromobility has various legal definitions that change according to the maximum speed, weight of the vehicles, the related continent or country; meanwhile, one classification can be universally adopted: human powered micromobility (bikes, scooters) vs. electric micromobility (e-bikes, e-scooters). As an efficient, advanced solution with mini-vehicles, shared micromobility reduces the idle capacity of urban transport by providing short distance trips for first and last mile urban transport without private vehicle [5]. For example, shared e-scooters are frequently preferred within or close to city centers and they are accepted as a tool for endorsing intermodality in city transport as they create links with public transportation where they can cover gaps in the network [6]. Moreover, bicycle sharing services can reduce energy consumption and carbon emission and thus environmental pollution at macro level, and supports health improvement, economic spending reduction, and mental relaxing at individual level [8], [9].

Lately, a new generation of shared micromobility systems has emerged, with two supplementary developments: dockless locking systems that let a higher accessibility of vehicles with flexible locations, and the support of electric engines that increases the speed and decreases physical constraints for users [10]. This fourth generation is signified by the expansion of a new electric vehicle, the e-scooter despite the new e-bikes that were simultaneously introduced with e-scooter and offered similar characteristics [11]. Differently from previous docking bike sharing systems, this new generation of micromobility has been endorsed mostly by the private companies without the involvement of public authorities [11]. With the rise of e-scooters, shared e-micromobility services have become an important topic for academicians, public authorities and companies in different cities to discuss the advantages and disadvantages on the way to build a better service ecosystem [12],[13].

With the increasing adoption rate of micro-mobility services, comprehensive attention needs to be devoted to interpret the factors influencing different shared micro-mobility services. Scientific evidence on who uses shared micro-mobility services strongly varies by mode, city and other components. In the extant literature, there are worries about the safety of micro vehicles, eventual environmental and financial benefit impacts of intermodality provided among shared micromobility and other transport modes [12]. Actual studies have focused on profiling users [14],[15],[16]; evaluating preferences [17]; [18], sociopsychological factors [19], geography, land use and policy [9], life cycle analysis [20], travel behavior [22]. Therefore, this study's objective is to execute a review of extant literature, firstly to understand actual rider/user patterns, secondly on the internally and externally related factors that influence the shared micromobility service usage, thirdly on the impact of sustainability ad finally on the empowering factors for shared micromobility.

Accordingly, based on a systematic review, this study aims to address the following research questions in the rapidly evolving context of micromobility:

Q1: What are critical external factors of shared micro-mobility services?
Q2: What are internal or user related factors in shared micro-mobility services?
Q3: What are the challenges of shared micro-mobility?
Q4: What are the new enablers of shared micro-mobility?

Several related topics are out of the scope of this study, specifically, the technical details about the riders' safety with e-scooters, land use and transport infrastructure, legal issues. The focus of the study is to understand the users' profiles in different context in order to reveal common points and to provide insights for future research and practical implications.

This paper will be structured as follows. Firstly, based on the actual studies, the components of shared micro-mobility as a service would be reviewed. The shared micro-mobility would be clearly explained with its applications, tools and externalities. Secondly, with the reevaluation of external and user related factors, the enablers of shared micro-mobility would be discussed. Thirdly, consumers' expectations, perceptions and behaviors of shared micro-mobility would be examined. Followingly, the challenges and innovations of micro-mobility would be discussed. Finally, a discussion of different perspectives on shared micro-mobility would be offered to provide insights for future studies and applications.

2. METHODOLOGY

To generate an up-to-date overview of current research on shared micromobility, a systematic literature review (SLR) is carried out in human powered and electric micromobility services. The literature review method structured is the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) Statement [22]. Data for the SLR was extracted and gathered from Scopus, one of the most wide-ranging sources of indexed academic publications and to reduce possible data homogenization with multiple database search, Scopus has been the single source for data extraction. To search database, a set of keywords have been identified to include the interactions among the actors of service encounter in pre-core service encounter, core service encounter and post-service encounter: "shared micromobility, micromobility, micro-mobility, shared micro-mobility, shared micro-mobility, users, customers, consumers". A query combining these keywords (adopting the Boolean operator "OR") in the title, abstract and keywords is executed. The SLR includes the studies until 1st of August 2023. After excluding proceedings, book chapters, books, and materials not published in English, the search provided 452 articles. To ensure that all papers can be evaluated with less subjective views, the principles of inclusion and exclusion are followed in this study. As part of second level inclusion and exclusion, subject areas are limited to Decision Sciences, Engineering, Business, Management & Accounting, Psychology, Environmental Science, Energy, Economics, Econometrics and Finance, Psychology, Interdisciplinary and Social Sciences. Finally, following Reference [23]'s suggestion, 12 academic journals with an A or A star rank in the Australian Business Deans Council (ABDC) list are considered. The final inclusion and exclusion provided 48 articles.

3. FINDINGS

Critical external factors of shared micromobility services

The user or rider behaviors in shared micromobility services cannot be thought independently from external and contextual factors that support or impede their intention, acceptance, and engagement to use the related services. There are different external factors in shared micromobility service depending on different features of micro-vehicles (e-bikes, e-scooters, etc.). Reference [10] underlines three major external factors that impact bikesharing usage: infrastructure (parks, bike lanes), geography (land use) and user demographics such as age, income. In a case study to understand the reasons to shut down bikesharing systems (Pronto) in Seattle, the researchers found out that insufficient system scale, station density, geographic exposure, comfort of usage, and pricing policy were critical in the system's difficulties as system policy makers were not aware of these principles [24]. The same research points out that the dockless bikesharing systems in Seattle, supported with these critical factors, enhanced bike ridership [24]. Meanwhile, dockless shared micromobility cannot be always accepted as a sustainable transport solution since they would add more carbon gas emissions to the whole urban transportation system. Therefore, to reach an optimum level in different scenarios (cities, regions) dockless or free-floating e-scooters must be organized cautiously, with acceptable procedures according to regional or urban features, considering current mobility systems and their energy consumption [20]. As a user related macro environmental factor, e-scooter and other electric micro vehicles need space within the urban transportation to easily park, drive and leave the vehicle [25]. The urban planners, policy makers, regulators and service providers should collaborate to build a sustainable service ecosystem to provide a space allocation for micro vehicles of shared transport. In a study about shared e-scooters usage in Washinton D.C. in 2019, street segments near hotels and other tourist locations, transit points are shown to dominate the shared e-scooter trips [31]

Internal or user related factors in shared micromobility services
Considering the focus on city-based research to understand the characteristics of shared-micromobility services, the demographics, preferences, acceptance, adoption, travel behavior, loyalty of users can change on national and regional base. For example, research with data gathered from Oslo, Norway suggest that bike-sharing users appear to be younger, men, single, concerned about climate change and living in city centers with easy access to public transport; whereas, shared e-scooter users tend to be younger, men, less educated and live in city center [7]. In a comparative study between owners and renters of e-scooters in Vienna, it has been found that e-scooter users tend to be younger, male, highly educated and residents of Vienna, there are significant variances in usage between owners of e-scooters and users of sharing systems [15]. Moreover, while in both groups, e-scooter trips frequently substitute walking and public transport as a mode, e-scooter owners similarly display a substantial mode-shift from private car usage [15].

In another study aiming to analyze and compare the determinants of dockless shared scooters (DSS) and stations-based bike share usage (SBBSU) in Washington D.C., it has been found that time-based use differences between the three user groups, but DSS riders' behavior seemed very parallel to SBBSU non-members [27] Moreover, with the ease of ending the trip with DSS, weather did not appear as an obstacle for DSS users compared with SBBSU members [27]. In another study in USA, including five cities, e-scooter sharing systems ridership has been found to be higher in universities and urban centers compared to other areas and built environment was a critical factor for ridership [28]. In a study made to understand the attributes of the stable e-scooter users in Thessaloniki, Greece, it has been revealed that shared e-scooters frequently substituted walking and public transport tours; so, the positive impact of e-scooters on the environment is questioned [29]. Similarly, the results showed that individuals traveling with bicycle or motorcycle were not at all fascinated by e-scooters [29]. Moreover, females seem to be less keen on using e-scooters compared to males, while people living downtown are more regular users compared with those living in longer distances from the city center [29].

In a comparative study between carsharing young service users and young e-scooter users in Munich, trip time, trip cost, weather conditions (rain), scooter accident and safety risk, and gender have been shown as significant factors on the choice between shared scooter usage and carsharing [33]. In another study evaluating the user patterns in three different (station-based, dockless, hybrid) bike sharing systems within three cities, it has been revealed that the transition from station-based systems to hybrid systems, mix of dockless and station-based systems, would increase the usage frequency [35].

Additionally, hedonic motivations should be considered as a determinant of shared micromobility [36]. E-scooters are considered as a mobility alternative, and they are mostly viewed as fun object and perceived safety can hinder their usage [36]. Moreover, performance expectancy as part of individual convenience can be critical as well [36]. A research about e-bike users in Poland revealed that shared e-bikes were used as a substitute for public transport or as a link to and/or from public transport points [37]. Same research found that the most significant motives for using bicycle sharing systems were positive impact on health, environmental concerns, financial and time utility [37]. A study in Korea examined how people's disposition to use e-scooter sharing service (ESS) rises in different trip situations and studied how the trip situation impacts ESS use intention changes depending on individual's socio-demographic profile and satisfaction with the substitute transportation modes [38]. The research revealed that the trip purpose, trip type, and trip time influence the intention to use the ESS usage, and that their impact may vary depending on socio-demographic characteristics and satisfaction with actual public transportation alternatives [38]. To understand deeply the rider satisfaction in e-scooter sharing services, a survey run in mobile apps reviews found out that women were more satisfied with the services and displayed more positive emotions than men [40].

Concerning the adoption e-bike sharing schemes, a cross-sectional survey directed at a multi-campus university in Southeast Queensland, Australia, revealed that respondents who were using combination of different transport modes, particularly the people who were already cycling and with shared mobility practices, are more positive about adopting e-bike sharing [42]. Mostly one mode car users incline to be more negative to the e-bike sharing scheme whereas international students also tended to be more positive as well [42]. A study made in Zurich, Switzerland, suggests that shared micro-mobility riders tend to be young, university-educated males with full-time employment living in affluent households without children or cars [43]. Shared e-scooter users are younger, yet more representative of the general population in terms of education, full-time employment, income and gender than bike-sharing users [43]. In another study, shared e-scooter usage, including user gender, helmet use, access to shared e-scooters, ownership of an e-scooter, riding locations, opinions on speed limits, and trip purpose were critical factors in e-scooter shared service consumption [44].

A study including the main motivations of shared e-scooter users in Chicago found that the most critical factors were perceived usefulness and perceived reliability [47]. Moreover, social influence, perceived ease of use, variety seeking, and perceived enjoyment, are revealed to characterize the other critical drivers of using e-scooter in the future [47]. In a study about e-scooter sharing service users in Taiwan, it has been shown that platform and mobility service quality positively related to both perceived values [49].

What are the challenges of shared micromobility?

One of the main challenges is the sustainability as in different cities, the shared e-scooters riders can replace walking and increase their carbon footprint because of the carbon emission rise in urban transportation [29]. Demographic differences in a city may stay as a critical barrier against the adoption of shared micromobility services [14] Moreover, traffic safety concerns and lack of space allocation within the urban transportation remain as hindering factors [14]. Lack of infrastructure can be a discouraging factor even for frequent user of shared micromobility [29]. Moreover, in different cities, females do not look as interested as males to be a frequent rider and this can limit the enlargement of shared micromobility schemes in a city [29]. Public opinion is another challenge for shared micromobility. In different studies, results display that riding e-scooters on walkways, parking improperly on walkways, negatively disturb pedestrians' experience and perception [29]. Scooter parking, scooter safety and parking regulations can be thought as enabler and challenge depending on the decisions and plans of policy makers and service providers as it can impede or facilitate the transfer of users from carsharing to e-scooters [33]. Concerning bicycle sharing system (BSS) usage, Reference [37] suggested that the accessibility of shared bicycles and lack of built environment, infrastructure such as bike paths, individual safety concerns, bad weather conditions, car drivers' potential bad attitude were among the discouraging factors of BSS usage [37]. Similarly, in a study about bike sharing users' satisfaction in Madrid, station occupancy and bicycle availability were dominant motives of rider satisfaction with the sharing systems [48].

In a comparative study to evaluate the impact of e-scooter sharing's introduction on the usage of bike sharing systems in Chicago, it has been shown that short, medium and long-distance trips usage of bike sharing decreased after the introduction of e-scooter sharing schemes [39]. Consequently, if not planned and implemented well, the competition between different shared micromobility systems can be a cannibalizing threat for the whole system. Additionally, another study with a substitution perspective points out that shared e-scooters possibly are competing with taxi, lower cost, social/entertainment trip purpose, and user households with multiple vehicles as substitute transport option [44].

What are the new enablers of shared micromobility?

Transport policy in highly populated cities, or mega cities can encourage the shared micromobility in order to diminish the load of private car usage in urban transport. The infrastructure and the policy can support shared micromobility schemes and increase intermodality between public transport and shared service schemes [13]. The policy and the infrastructure would be a good convincer of possible negative public opinion against these systems [13]. Moreover, despite its well-known significance, the convenience of use for e-scooters and the capability to go somewhere earlier than walking and not driving a car, stays a strong enabler to convince potential users [14]. In different studies, tourism seems to be a significant driver in shared scooter trips; touristic places, hotels, and public transport station enhance the frequency of shared e-scooter ridership [31]. To underline the contribution to sustainability, bikeshare systems can be supported in different contexts. For example, in a study to evaluate the environmental impact of change from private car usage to free floating (dockless) shared e-bikes, it has been shown that there is a significant decrease in fossil fuel consumption, stating the criticality of shared micromobility systems for sustainability [34]. To guarantee that shared e-scooters have positive ecological effects, active transport policies and approaches must be considered and implemented [41]. A study focused at revealing the infrastructures type preferred by e-scooter riders, found that e-scooter riders were ready to travel longer distances to ride in bikeways, multi-use paths, tertiary roads, and one-way roads and e-scooter users also prefered shorter and simpler routes [45]. Moreover, a study concerning the environmental impact of autonomous shared bikes vs. station-based and dockless systems, found that autonomy could decrease the environmental impact per user kilometer traveled of current station-based and dockless bike sharing systems by 33.1 % and 58.0 % [46].

4. CONCLUSION

Shared micromobility services increase convenience and flexibility within the urban transportation systems. The findings in the actual literature on shared micromobility are fragmented due to the differences between cities, vehicles used, demographics, regulations, geography. Meanwhile, some critical factors can increase the efficiency of micromobility systems.

Firstly, governments and policy makers should support micromobility service providers who can enlarge their service system, since system scale, concentration, and geographic exposure are key to reaching high service usage with regulations and incentives [24]. Accordingly, they may sidestep policies that discourage large scale, extensive market entry initiatives in the sector. If a city's infrastructure is not ready to the quick introduction of numerous shared micromobility vehicles, a limited-time test would be a better approach for market and infrastructure test [24, 39]. The sharing system scale can be tested at a limited level in different neighborhood(s) to observe the impact of external factors such as regulations, parking or docking space allocation, etc. Moreover, policy makers and companies must attempt to guarantee that micro-mobility vehicles can be get and dropped in appropriate places for the riders. In the contrary case, the shared services of bikes and scooters may risk to lose their appeal for the actual and potential users. To increase the attractiveness of hybrid solutions as a mix of station-based and dockless usage, the policy makers may adopt new regulations that would facilitate the usage of shared micromobility systems and ensure the cohabitation of these systems with pedestrians, cars, and buses. Transportation planners and managers must consider local objectives and urgencies before designing the micro-mobility system. As Reference [24] underlines, a shared micromobility service system that is organized with adequate scale, concentration, and exposure would be critical to align with potential riders' travel patterns on the way to increase their usage frequency, loyalty. Built environment of shared micromobility is critical with public transport points such as metro stations, bus stops increase the links between public transport and shared micromobility [31]. In this context, more studies are needed to investigate the effects of different urban policies regulating space allocation of micro vehicles to support the intermodality between the public transport and micromobility. There is a need to understand the level where policy makers can be enablers but also prohibitor of shared micromobility systems from actual and potential users' point of view. The market insights should be combined with the perspectives of service providers on the way to regulate the service scheme, traffic safety, congestion, environmental impact of shared micromobility services.

Secondly, the user patterns, demographics, motivations may vary depending on different cities and countries. Meanwhile, trip distance, travel time, perceived ease of use, perceived enjoyment, perceived environmental impact (compared with cars' impact) can be accepted as common individual factors that support shared micromobility service usage. Some critical factors driving e-micromobility usage include pro-environmental and technophile attitudes, particularly amongst early adopter users [26]. Moreover, different micromobility riders such as dockless shared system user or station based bikesharing system user look sensitive to fluctuating gas prices [27]. Another important issue is considering that bicycle or motorcycle users can reject using e-scooters based on their habits [29]. Change of modality between these modes can be limited because of individual preferences. In different countries and cities, dockless shared e-scooter and bike sharing systems seem to increase the frequency of ridership meanwhile in the actual studies, there are two critical questions that should be addressed by researchers as well: multimodality between different urban transport mode, such as walking, public transport, and space allocation for the used micro vehicles in different parts of the sharing scheme. Future research should concentrate on better interpreting the shared micromobility service users' connections with other modes (walking, public transport, car sharing) on the way to provide better insights for policy makers and service providers. These studies may further investigate the impact of individual factors such as perceived ease of use, enjoyment on connections between shared micromobility and other transport modes. The role of shared scooters, e-bikes and bikes should be evaluated from users' perspective.

The users' price sensitivity in different e-micromobility schemes are revealed in different parts of the world and there is a need to evaluate the price sensitivity of users in emerging economies where there is an upsurge in demand; moreover, the comparative studies between users from different economies can be fruitful to discover the impact of cost in users' behaviors on the long term. As Reference [10] suggests, supplementary research is needed to more closely link the preferences of shared micromobility users with differences in travel behavior across different business models and service areas to increase the economies of scale in the system. In different studies, most of the shared service scheme users were male, there is a need to conduct in-depth analysis of female citizens in order to reveal their perceptions, motivations related to shared micromobility. While electric scooter use has weakened throughout COVID pandemic, it possibly will rebound with another shared mobility modes such as electric bicycles and mopeds to reach various target market segments of micromobility [31]. Therefore, considering the demographics of potential shared micromobility users would be important in future research [31]. Similarity between rider patterns of shared e-scooters and shared bikes can also give new research ideas for each domain [32].

Thirdly, sustainability remains as a critical challenge for the expansion of shared e-micromobility services. On one hand, shared e-micromobility can create additional carbon footprint with extra demand in urban transport but on the other hand, changing from private car usage to shared e-micromobility can support the sustainability of the cities. Despite the reduction of carbon emission provided by e-scooters, e-bikes, the limited lifetime of vehicles create another critical environmental challenge for potential users and policy makers. Moreover, due to the increase in the number of micro vehicles, the congestion, the space allocation, additional carbon emission can be critical externalities linked with sustainability. Benefiting from actual findings from different cities, the discovered barriers, and enablers to the usage of shared micromobility services can be tested in other cities and contexts in the future researches to optimize the environmental impact of shared micromobility systems. Shared micromobility systems that would offer feeder services in limited locations can be examined from environmental point of view. In addition to externalities, the increasing number of vehicles and service providers remain as a critical challenge for shared micromobility systems as the geography and space of services are limited. Future research should concentrate on the related market value by studying users' habits, intentions, acceptance of the shared micromobility services.

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TRANSFORMATION PARADIGM IN SUPPLY MENTALITY: THE GREEN SUPPLY CHAIN PHENOMENA

Dilber TETİK[1], Haydar YALÇIN[2]

Abstract– *In recent years the environmental impact of manufacturing has reached a remarkable level due to the increase in manufacturing. This situation has caused pressure on the business community by some organizations, hence business community and their supply chain forced to change to their business model to a new one. Today, the sustainability paradigm has reached a significant activity level and has influenced supply chains. Supply chains have been configured to be green supply chains according to the environmental sensitivity approach framework. It is essential to determine the evolution period of this transformation and future focus arguments. The study aims to scrutinize to green supply chain paradigm by technology mining [techmining] methods that enable the determination of scientific resources with text mining. Biographical data of the scientific research within the basis research grade has been analyzed in the study. Basis evolution dynamics of the field have been determined via approximately 1000 scientific publications. Then, weak signals-oriented timeline analysis has done to determine essential notions and their future alternates. According to the determination of emerging clusters evolutionary development of the field has inferred. Research that will guide the improvement of decision-making policies has intended to clarify future scenarios of the green supply chain paradigm.*

Keywords – Green supply chain, Social network analysis, Sustainability, Technology mining

1. INTRODUCTION

The rapid development and competitive environment in the industrial sector have increased the negative impacts of the industry on the environment. The environmental effects of toxic gas emissions have become significantly evident in recent years. Research indicates that urgent measures need to be taken in this regard. Supply chains are one of the priority areas that need to be addressed due to their environmental emissions. In recent years, environmentally conscious trends have emerged prominently in this field. This new paradigm, where green practices are integrated into supply chain activities, is defined as the green supply chain. Green

[1] Student, Dilber TETİK, Ege University, Business Administration Master Program, Turkey,dilbertetik34@gmail.com, Orcid: 0000-0003-1802-4580

[2] Doç. Dr Haydar YALÇIN, Ege University, Management Information Systems Department, Turkey, haydar.yalcin@ege.edu.tr, Orcid: 0000-0002-5233-2141

supply chain management envisions carrying out all operational processes, including waste management, with an environmentally conscious strategy, starting from product design [12]. The concept of green supply chain aims to reduce the environmental impacts of industrial activities without compromising on performance and quality within an economic benefit framework [12]. The underlying idea of the green supply chain goes beyond environmental sensitivity and strives to build an enhanced business approach that adds value to processes [12]. Green supply chain management encourages businesses to act with the goal of reducing emissions [10]. To establish a sustainability-focused structure within the supply chain, the design and management of the supply chain should be primarily addressed [6]. Determining the foundational carbon policy to be adopted in redesigning the supply chain for the purpose of carbon emission reduction is a crucial step [1]. Therefore, a roadmap must be established to model policies related to carbon emission reduction within the supply chain [1]. By revealing the intellectual structure of the research field, this study examines prominent datasets through data-based methods. Using the Techmining method, numerous scientific research texts were analyzed through text mining, and significant datasets were identified through weak signals. The research aims to provide guidance for strategies to be designed in the green supply chain paradigm by presenting a portrait that enables the identification of concepts that will gain importance in the future.

1.1. Green Supply Chain Management: Conceptual Framework

After the significant transformation in quality and supply chain domains following the 1990s, it has been understood that environmental management strategies need to be comprehensively addressed within a holistic framework, encompassing all operational activities [12]. In the subsequent years, legal regulations and increasing customer pressure have acted as driving forces for framing all processes with this understanding [12]. In 1990, the US Environmental Protection Agency [EPA] introduced an incentive program to reduce sulfur dioxide emissions [6]. The Kyoto Protocol, developed to reduce greenhouse gas emissions, was signed by numerous countries in 2005, gaining general acceptance and paving the way for new initiatives in this field [6]. These developments, which compel businesses to construct highly profitable systems under constrained conditions, have broadened the perspective of the supply chain [13]. Influenced by competitive behaviors and consumer trends, operational processes have been reshaped, and after the economic benefits were discovered, the spread of green practices in supply chain management accelerated [13]. Consequently, the supply chain has transformed into a normative form and evolved into an advanced version, the green supply chain paradigm. In the 21st century, numerous businesses have implemented green supply chain management to reduce energy consumption and costs [13]. The proliferation and diversification of green practices have paved the way for innovation in green supply chain management [10]. Green supply chain management has strengthened its position through innovation efforts and marketing activities in the sustainability perspective in recent years [10]. In the current context, businesses are focused on showcasing their best strategies in the green concept to sustain their existence [10].

The attitude of the business plays a significant motivating role in formulating effective strategies in green supply chain management [4]. When the environmental management approach is effectively managed within the business, a reduction in carbon emissions and a balance in fuel consumption are observed [4]. Furthermore, the adoption and management of the environmental management approach by the business administration also play an influential role [4]. An environmentally sensitive attitude of the business enhances sustainability performance [4]. On the other hand, the attitude of the workforce is a hidden resource for sustainability performance, playing a vital role in sustaining this understanding within the business [9]. To successfully implement green supply chain management, focusing on management strategies, workforce profile, and innovation projects is a prerequisite [9].

Research indicates that sharing strategies and technical knowledge developed to reduce environmental impacts within the supply chain is essential for constructing a successful implementation [11]. Currently, supply chain stakeholders collaborate towards sustainability-focused strategies [11]. In recent years, the reduction of environmental impacts has been recognized as a critical success factor for businesses [11]. Additionally, due to green supply chain management, businesses have both reduced their environmental impacts and increased profitability [3]. Studies demonstrate that green supply chain practices positively affect environmental and economic performance [5]. Furthermore, it is known that innovative strategies and methods within the supply chain enhance employees' skills and learning performance, triggering innovation [2]. All these developments motivate businesses to collaborate in innovative strategies.

Customers shape a business's vision through their demands. The increase in environmentally conscious customer profiles necessitates a reevaluation of business activities. Here, it is crucial for businesses to determine the balance between price and performance [7]. Besides price policies, considering customer sensitivity is important for ensuring customer satisfaction.

Agreements and defined goals related to sustainability in recent years have also been significant sources of motivation for businesses. In 2015, the United Nations identified the need for measures in sustainability and established sustainable development goals [8]. In the same period, the Paris Agreement was formulated for the purpose of reducing environmental impacts [3].

In the recent past, disruptions in the supply chain in Europe led to severe supply issues and caused energy crises [13]. These supply problems resulted in price increases in various areas, significantly altering the current economic situation and living conditions [13]. The importance of uninterrupted supply chain activities was experienced during this period, leading to a renewed understanding of the supply chain's significance. This situation, demonstrating the scope and power of the supply chain, provides insights into the environmental devastation caused by the supply chain and indicates the magnitude of the impact of the regulatory changes on the supply chain. Determining strategies in this field is a crucial step for businesses to establish a strong position in the competitive arena. Decisions guiding investments have the potential to shape the future of businesses, guided by the findings based on data. In this context, studying the developmental dynamics of the field and determining the future trends are key indicators for decision-making mechanisms.

2. METHODOLOGY

2.1. Bibliometric Analysis

Bibliometrics is a field of study within library and information science that focuses on the quantitative analysis of scholarly publications, including books, articles, conference proceedings, and other forms of literature. It involves the use of statistical and mathematical methods to analyze various aspects of publications and their citations. Bibliometrics provides insights into patterns of publication, citation, collaboration, and impact within the academic and scientific communities. Bibliometrics has applications in various fields, including academia, research evaluation, science policy, and information retrieval. Researchers, institutions, and funding agencies use bibliometric data to assess the impact of research, identify emerging trends, and make informed decisions about funding and collaboration.

3. RESULTS

3.1. Authors:

List of researchers along with their h-index, citation statistics, and publication metrics. The h-index is a metric often used to evaluate the impact and productivity of researchers. It's calculated based on the number of a researcher's publications that have received at least the same number of citations as the h-index value.

H-index: The h-index value refers to the citation number of each research that must have a citation of at least the total research number of the researcher. It refers to each publication of the researcher has influence as minimum as total publication number. If the researcher has a high h-index value, it shows that the researcher has a broader impact on the field. Therefore h-index value demonstrates effect level of the researcher according to citation based calculation.

Unit: It expresses organization which researcher has affiliated. This parameter presents an opportunity to determine the region that leads to the field. On the other hand, it is feasible to perceive tendencies in the field by determining research interaction.

Citation sum within h-core: The citation sum within the h-core represents the impact of the researcher based on the h-index measurement. This measurement demonstrates the influence domain of the researcher based on the h-index parameter. It represents the citation number that crossed the h-core threshold.

All citations: All citation number indicates the influence level of the researcher's publications in the field. It refers to the total citation number of the research papers that the researcher has. It enables one to comprehend the level of influence of the researcher and the topic jointly.

All articles: All articles represent the total accumulation of the researcher in the field. It refers to the total publication number of the researcher. This measurement gives benefit in examining the experience of the researcher. On the other hand, it gives an idea about the recognition of the topic.

The list includes prominent researchers in the field of green supply chain management and related areas. The h-index, citation statistics, and publication metrics provide insights into the influence and contribution of these researchers to their respective fields. Researchers with higher h-indices and citation counts often indicate greater impact and recognition in their areas of research.

TABLE 1

Most Productive Researchers

h-index	Unit	Citation sum within h-core	All citations	All articles
37	Sarkis, Joseph	8824	8996	47
18	Govindan, Kannan	3634	3646	21
17	Zhu Qinghua	5188	5188	17
13	Khan Syed Abdul Rehman	1055	1057	14
13	Lai, Kee-hung	5271	5274	15
11	Chiappetta Jabbour, Charbel Jose	1018	1022	12
11	Zhu, Qinghua	2136	2149	15
11	Bai Chunguang	930	930	11
10	Geng, Yong	1498	1501	11
9	Feng, Taiwen	245	275	17
9	Tseng Ming-Lang	1283	1284	10
8	Esposito, Emilio	582	582	8
8	Koh, S. C. Lenny	1116	1116	8
8	Cerchione, Roberto	472	472	8
8	Kant, Ravi	283	297	13
8	Centobelli Piera	472	472	8
8	Jabbour, Charbel Jose Chiappetta	615	615	8
8	Sana, Shib Sankar	251	255	9
7	Khan, Syed Abdul Rehman	310	316	11
7	Wei, Guiwu	374	378	12

3.2. Clusters

Clusters generated through a clustering analysis of scholarly publications related to a specific research topic. Clustering is a technique used in data analysis to group similar items or data points together based on certain characteristics or features. In this context, it appears that the clusters are related to research topics within the field of supply chain management, specifically focusing on green and sustainable practices.

TABLE 2

Specific Research Topics

ClusterID	Size	Silhouette	Label [LLR]	Average Year
0	31	0.906	closed-loop supply chain [564.33, 1.0E-4]	2009
1	26	0.922	green supplier selection [2156.02, 1.0E-4]	2008
2	23	0.923	inter-organizational relationship [521.88, 1.0E-4]	2009
3	19	0.965	green supply chain planning [440.23, 1.0E-4]	2010
4	19	0.996	green supply chain [1815.36, 1.0E-4]	2005
5	18	0.886	construction industry [534.34, 1.0E-4]	2008
6	18	0.875	alkaline battery recycling [460, 1.0E-4]	2009
7	18	0.988	green supply chain management [6672.02, 1.0E-4]	2009
8	15	0.864	evaluating carbon performance [822.15, 1.0E-4]	2010
9	14	0.991	green supply chain [1556.69, 1.0E-4]	2010
10	14	0.958	green supply chain [2120.59, 1.0E-4]	2010
11	10	0.975	linguistic preference [827.19, 1.0E-4]	2010
12	7	1	making approaches [187.11, 1.0E-4]	2004
13	2	1	strategic decision framework [24.83, 1.0E-4]	2003
14	1	0	malaysian manufacturing sector [75.96, 1.0E-4]	2018
15	1	0	using bwm [22.19, 1.0E-4]	2018
16	1	0	considering government subsidies [58.65, 1.0E-4]	2016
17	1	0	market-based common [41.96, 1.0E-4]	2016
18	1	0	role [40.61, 1.0E-4]	2016
19	1	0	mine industry [40.61, 1.0E-4]	2015
20	1	0	green partner selection [42.38, 1.0E-4]	2015
21	1	0	double subsidy [89.12, 1.0E-4]	2020
22	1	0	economic growth [90.84, 1.0E-4]	2016
23	1	0	government [20.72, 1.0E-4]	2017
24	1	0	resilient supply chain management [41.58, 1.0E-4]	2017
25	1	0	green cost sharing [41.23, 1.0E-4]	2018
26	1	0	low-carbon fixed-tour scheduling problem [43.39, 1.0E-4]	2015

27	1	0	digitalization [38.56, 1.0E-4]	2019
28	1	0	opportunity-ability framework [57.34, 1.0E-4]	2017
29	1	0	operational environmental sustainability approaches [40.91, 1.0E-4]	2018
30	1	0	corporate sustainability performance [61.62, 1.0E-4]	2015
31	1	0	formalized corporate network [73.02, 1.0E-4]	2015
32	1	0	green energy-saving product adoption [59.6, 1.0E-4]	2016
33	1	0	low-carbon agricultural economy environment [59.6, 1.0E-4]	2017
34	1	0	generic decision support system [58.14, 1.0E-4]	2015
35	1	0	considering transportation mode selection [77.61, 1.0E-4]	2016
36	1	0	freight transportation co2 emission [41.23, 1.0E-4]	2015
37	1	0	credit insurance [91.43, 1.0E-4]	2017
38	1	0	framework [40.07, 1.0E-4]	2015
39	1	0	integration [41.58, 1.0E-4]	2018
40	1	0	green driver [71.58, 1.0E-4]	2015

ClusterID: Cluster analysis creates varied clusters according to their distinction. Thus, cluster identification numbers are generated according to the conclusion of the cluster analysis. They indicate every cluster separately thus clusters can be monitored according to their identity number. Each cluster contains a divergent topic due to the separation process of the cluster analysis.

Size: Size refers to the volume of the research paper numbers on each cluster. Cluster size enables us to evaluate attention on the subject that the cluster identifies. This criterion is directly proportional to the influence level of the topic in the field. So it is safe to say cluster size indicates the substantiality of the topic.

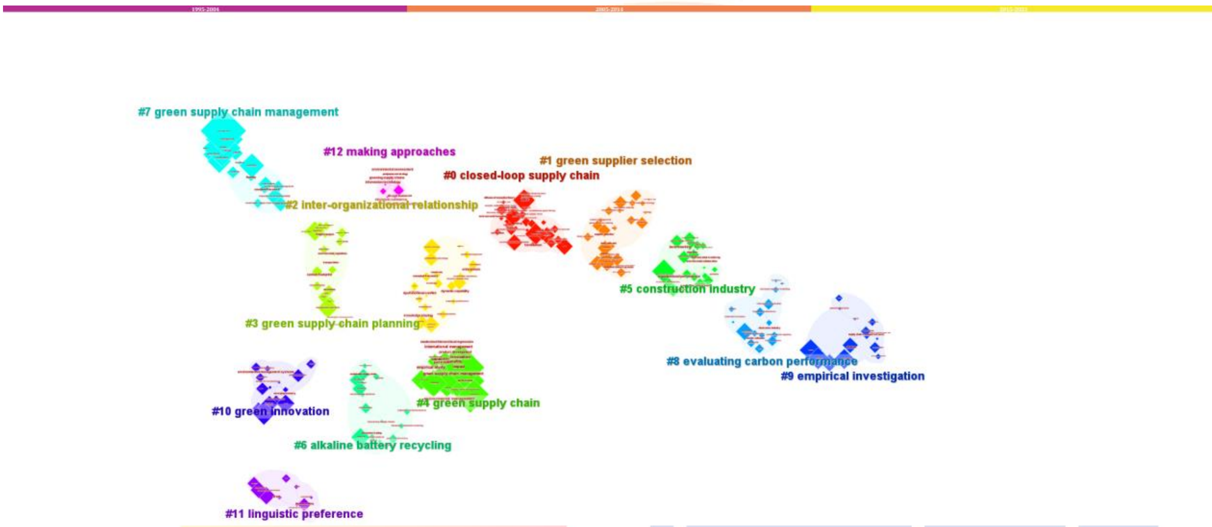
Silhouette: The silhouette is a criterion that represents the separation quality of the clusters. The score of the silhouette measure demonstrates the separation degree of the clusters and if it is high, separation process would be successful. The performance of the separation process affects the effectiveness of the definition of the clusters.

Label [LLR]: The label points out the definition of the topic with a correlation degree. It represents an indicator of the cluster for each topic. It includes binary comments; one is the verbal part, and the other is the numerical part. The verbal part defines a topic, and the numerical part represents the significance degree.

Average Year: Average year represents the publication period of the research papers in the clusters. Hence crucial developments in the field can be determined and reviewed in depth according to it. The average year criterion represents the focussing time interval of the specific subject in the field. Thus it achieves average publication date calculation of the research and presents clues for critical time points.

FIGURE 1

Clusters



From the labels, it's apparent that the clusters are related to various aspects of green supply chain management, sustainable practices, and related topics. Each cluster focuses on different subtopics, such as closed-loop supply chain, green supplier selection, inter-organizational relationships, etc. The average publication year suggests when the research on these topics was prominent.

4. DISCUSSION

According to the analysis results, Sarkis, Govindan, and Zhu are the most notable authors in the field. On the other hand, closed-loop supply chains, green supplier selection, and inter-organizational relationships are the most popular topics. According to cluster analysis, management, planning, innovation, organizational relationships, and various sustainability practices are major clusters. Analysis results indicate that early studies in the field were focused on organizational structure and innovation. In the next period, studies were executed on the strategies of the reformer approaches. Eventually, recent works have examined sustainability practices empirically. It can be mentioned that current studies were focused on attracting sustainability performance and evaluating it. All these findings highlight that sustainability practices have been implemented in the application perspective on the field as distinct from previous ones.

It is worth underlining that sustainability insight will be transformed into an advanced version in the next era. Future research should focus on determining best practices to construct greener supply chain applications.

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DECISION-MAKING ENVIRONMENT FOR HYDROGEN FUEL TECHNOLOGY INTEGRATION OF TURKISH RAILWAY SYSTEMS

Enes Yalçın[1], Mehmet Mete Öztürk[2], Fatma Yaşlı[3]

Abstract - *With increasing environmental concerns, railway systems have started to focus on non-electric solutions to replace existing diesel technologies. Various studies are being carried out in many countries in order to maintain railway system transport in a safe and competitive manner with hydrogen technologies. The hydrogen-supported sustainability of railway systems, which have a significant share in freight and passenger transport, is an important subject of study. On the other hand, Turkey has an important motivation for hydrogen, with the advantages it has in hydrogen production due to the low installation costs of renewable energy-based power plants compared to Europe. This study investigates the criteria for the provision of hydrogen-supported railway transport in Turkey. After a comprehensive literature study and interviews with experts, managerial, financial, technical, social, and market barriers were identified. The study provides an infrastructure for strategic decision-making studies to transition Turkish railway systems to hydrogen technology.*

Keywords –Hydrogen fuel cell, railway systems, strategic decision making, sustainable energy.

1. INTRODUCTION

Today, a significant portion of the energy need in the transportation sector is provided from fossil-based fuels. Although the energy obtained from fossil fuels has a considerable caloric value, it is indisputable that the harm from greenhouse gas emissions has started to attract more attention than the benefit. The focus is now shifting from energy from burning fossil fuels to renewable energy technologies that reduce greenhouse gas emissions. While one of the most promising energy conversion technologies is fuel cell technology, where chemical energy is converted directly into electrical energy with low environmental impact [1], one of the most important fuel sources in the context of renewable energy is hydrogen.

Hydrogen is basically a flammable, odorless, colorless and tasteless gas. It is one of the most promising alternative energy sources for replacing fossil fuels. Although hydrogen is one of the most common elements, naturally occurring hydrogen is generally rare and mostly bound to water and hydrocarbon compounds. Therefore, the production and storage of hydrogen before its utilization is important [2].

[1] Eskişehir Teknik Üniversitesi Raylı Sistemler Mühendisliği, enesyalcin@ogr.eskisehir.edu.tr
[2] Eskişehir Teknik Üniversitesi Raylı Sistemler Mühendisliği mmozturk@eskisehir.edu.tr
[3] Eskişehir Teknik Üniversitesi Raylı Sistemler Mühendisliği fyasli@eskisehir.edu.tr

Based on the increasingly recognized importance of hydrogen all over the world, as stated in the Turkey Hydrogen Technologies Strategy and Roadmap (2023) report, hydrogen has a very valuable production and export potential for our country. The fact that renewable energy-based power plant installation costs in Turkey are lower than in Europe can be considered as one of the most important concrete reasons for this potential. At this point, many important issues such as increasing the share of renewable energy in production and utilization, developing production, storage and utilization technologies, and integrating it into existing natural gas lines emerge in terms of turning the potential into practice [3].

When the literature studies on hydrogen technologies are reviewed, it is seen that in addition to the studies dealing with the technical performance evaluations of this new technology [4], the integration of this technology into existing production systems, which is an important barrier in the utilization of this potential, is also an important field of study [5]. In such studies, where expert judgements are utilized from a multi-criteria decision-making perspective, it is seen that the evaluation criteria are among the most important factors determining the scope of the studies.

In this study, the integration of Turkey's railway systems with hydrogen fuel technology is discussed. The basics of hydrogen fuel technology in railway systems are given and the strategic decision-making environment for the integration of hydrogen fuel cell technology into Turkish railway systems is described. A comprehensive research on the evaluation criteria and sub-criteria, which are the most important elements related to strategic decision making, has been carried out and the problem area related to the decision making environment has been revealed.

2. HYDROGEN FUEL CELL TECHNOLOGY IN RAILWAY SYSTEMS

Humans are on the threshold of a new era characterized by sustainability, advanced technologies and new fuels. Traditional fuels will be replaced by sources that can be produced with almost zero pollution. Hydrogen is seen as the most promising and the most obvious energy source to replace traditional ones [6]. It also plays a significant role in reducing the import of traditional energy sources [7]. It has the highest energy reserve factor and the largest conversion factor to electricity, and its energy efficiency is very high. It produces only water vapor upon combustion, which means that hydrogen has zero carbon emissions [8]. This remarkable property of hydrogen makes it a favorite in the next generation fuel sector.

Since hydrogen is a renewable and clean resource, it is also very suitable for use in fuel cell technology, unlike traditional fuels such as coal, natural gas and oil [7]. A hydrogen fuel cell uses hydrogen and oxygen found in nature to produce water vapor as a waste and direct electrical energy after a chemical reaction. Fuel cells are usually diversified according to the type of electrolyte used. They are classified as phosphoric acid, molten carbonate, alkaline, solid oxide and proton exchange membrane (for the use of methanol or hydrogen).

There are 2 widely used propulsion systems in the railway industry today. One of these two widely used propulsion systems is the cleaner and more expensive electric trains. It is a system in which movement is obtained by operating the electric motors in the railway system vehicle by means of on-board equipment called pantograph on the line with electrical infrastructure and superstructure. Another widely used propulsion system is the traditional internal combustion engine propulsion system. Motion is obtained by starting an internal combustion engine in the railway system vehicle with the energy obtained from traditional fossil fuels (diesel, coal, etc.). Thirdly, diesel-electric systems, which are a combination of these two methods and are less common.

One of the most obvious aims of adapting hydrogen fuel cell technology to railway systems is to avoid the environmental pollution caused by fossil fuel systems and the high investment cost of the electrical infrastructure required for electric propulsion systems. Fuel cell locomotives are thought to help solve urban air quality and foreign energy market dependency issues affecting the railway industry and the transportation sector. For example, in the U.S., dependence on foreign energy is seen as a security issue as about 97% of the energy in the transportation sector is petroleum-based and more than 60% of it is imported. It is known that fuel cell locomotives have the potential to reduce air pollution, increase the energy security of the railway transportation system by using hydrogen, a fuel independent of petroleum, and reduce greenhouse gas emissions [9].

As a result, hydrogen is an environmentally friendly energy carrier that can replace diesel when railway electrification is not economically viable. Many trials and pilot projects around the world have successfully demonstrated the adaptability of hydrogen fuel cell technology to the railway sector in applications ranging from regional passenger trains to trams, trolleybuses to mining locomotives [10]. In this study, the determinants of effective integration of Turkish railway systems into hydrogen fuel technology are discussed. It is aimed to provide a basis for addressing the problem of prioritization of strategic actions emerging on the way of transformation to hydrogen technologies with a multi-criteria decision-making approach.

3. DECISION-MAKING ENVIRONMENT FOR HYDROGEN FUEL CELL TECHNOLOGY INTEGRATION OF TURKISH RAILWAY SYSTEMS

The plan to reduce greenhouse gas emissions to 0 within the scope of combating climate change is on the agenda of decision-making bodies in Turkey. Due to the inadequate supply in the face of developing technology and increasing demand, Turkey is also inclined to invest in hydrogen technologies. In this context, the Ministry of Energy and Natural Resources of the Republic of Turkey has declared hydrogen energy as one of the priority areas in the context of the future of sustainable energy. The report published by the Ministry aims to reduce the cost of hydrogen production to below 2.4 US/kgH by 2035 and below 1.2 US/kgH by 2053 and to increase the installed power capacity of the electrolyzer to 2 GW in 2030, 5 GW in 2035 and 70 GW in

2053. In addition, the technology development process is aimed to be especially domestic, and a strategic road map has been put forward under many headings including hydrogen production, distribution, storage and utilization areas [3].

It can be said that this report, prepared at the ministerial level, does not contain specific recommendations for the adaptation of hydrogen fuel cell technology to railway systems. While the integration of hydrogen fuel cell technology into existing railway lines and rolling stock has relatively easy technical details to overcome, it can be predicted that the production of clean hydrogen will be the biggest obstacle we will face in the integration.

There is a multi-stakeholder decision-making environment in the integration of hydrogen fuel technology, which is a very new technology compared to its traditional alternatives, into the railway systems of our country. This environment arises with various requirements such as setting priorities, creating action options, defining new alternatives, evaluating all alternatives under various criteria together with existing options. Such problems may have conflicting objectives, since the alternative that offers the best under one criterion may offer the opposite under another criterion. Evaluation criteria are also referred to as "objectives" or "attributes" and represent the different dimensions along which the problem is evaluated [11].

In the transition of our country's railway systems to hydrogen fuel cell technology, it is inevitable that many decision-making problems will arise regarding the most effective management of limited infrastructure, know-how, labor, time and money resources. The decision-making problems that arise can be listed as follows, but not limited to those presented.

- Evaluation of the criteria in terms of the advantages they will create for our country,
- Prioritization of potential obstacles to progress towards the criteria in our country,
- Evaluation of the criteria for our country in terms of opportunity costs,
- Prioritization of criteria for actionability in our country in the current situation,
- Identification and evaluation of possible actions in the context of each criterion,
- Identification and prioritization of needs under each criterion,
- Prioritization of criteria in line with partners' interests, etc.

All the problems that need to be overcome in moving the integration process forward need to be analyzed in relevant decision-making environments with multiple experts and the right decision-making methods.

4. EVALUATION CRITERIA IN DECISION MAKING PROCESS

The integration of hydrogen fuel technology, which is a very new technology compared to its traditional alternatives, into the railway systems of our country creates a comprehensive decision-making environment. As a result of the literature research conducted within the scope of the study, it is seen that there are 5 main criteria in the process of integrating hydrogen fuel technology, which is a new technology, into railway systems.

Management Criteria

The integration of hydrogen fuel cell technology into the railway systems enterprises of our country is one of the most appropriate action plans for our country's green energy policies and zero emission targets. List [12] stated in the second half of the 19th century that "the development of national economies requires a system that includes a set of policies based on learning and applying new technologies that will accelerate economic growth and industrialization" is still valid today, at the beginning of the 21st century. Therefore, the concept of a 'national innovation system', which means a system of policies that includes all the pathways a country follows in the process of technological development [13], can be considered as a holistic expression of the managerial support needed in the integration of hydrogen fuel technology into railway systems.

In this integration process, which is planned with long-term strategic goals, there are many details such as obtaining hydrogen through domestic sources or allocating the electrolysis and fuel cell technology to be used, which are costly and require legal supports. Therefore, stakeholders who will be actively involved in the integration of hydrogen fuel cell technology into railway systems need some legal support through relevant policies. All the incentives and supports to be provided to stakeholders on the subject are elements addressed at the administrative level and can be examined more comprehensively under separate sub-headings.

State Aid, Funding and Financial Support: Within the scope of state policies and in line with the targets set by long-term strategies, financial support is provided to stakeholders in order to meet the current or future critical needs of companies or institutions involved in the integration of new technologies, to ensure security of supply and to reduce external dependency. At this point, many sub-objectives emerge, such as realizing the targeted technological transformation or integration, and determining the procedures and principles regarding project-based support for innovative, R&D-intensive and high value-added investments. These objectives, which can be defined as short and long-term policy instruments, can be described as follows [14].

- Regulations to encourage innovation at sectoral and regional level,
- Laws
- Subsidies and other financial incentives,
- Creation of all public infrastructure and superstructure facilities
- Assist in or create other supporting R&D facilities,
- It can take the form of establishing consultancy and technical support units.

In the development and implementation of new technologies, direct or indirect financial support for projects where sector stakeholders are weak and inadequate and cannot afford to work alone is of vital importance.

Local Institutes and Facilities for R&D: Technology policies have a catalytic role to stimulate innovation and high initial costs are recovered in the long term through successful technological learning [15]. R&D efforts should be intensified for the development, localization and nationalization of hydrogen-powered railway systems. The scarcity of R&D institutes and facilities for the adoption and diffusion of new technologies leaves stakeholders in a difficult situation as they cannot provide adequate know-how support. While some stakeholders are already working on the issue, it is vital that there is support for education and research at the national government level to develop and intensify efforts.

Promotion of Technological Development to the Public: One of the most important factors in the development and diffusion of new, non-traditional and uncommon technologies is the transfer and explanation of this technology to the public. Eliminating the lack of public information about the production of advanced technologies and the new products that will be introduced to the market afterwards, caused by the lack of knowledge and experience, is a great necessity for the development of related projects and the market [16]. Hydrogen fuel cell technology, which is one of the new technologies in question and has an important place within the scope of renewable energy, should be introduced and supported to the public in a good and clear way. Introducing a new technology to the public is very important in terms of creating awareness. When the public and the public gain awareness about this new technology, individuals become aware of the effects of these technologies in the context of environmental pollution, energy saving and economic gains. In line with this awareness, citizens' support for these new technologies can influence the shaping of government policies and create opportunities for cooperation.

Support of Governments in Regulation and Legislation: The use of renewable technologies as a primary technology is part of countries' long-term strategic plans. In line with short-term political expectations, governments may be unwilling to act on such investments and support. Just as workshops, papers, television programs and trainings on hydrogen technologies raise awareness among all segments of society [3], governments are expected to be proactive in legislating. With legal supports and obligations, the actions of stakeholders towards hydrogen fuel technology will accelerate. The governments' proactivity in developing rules and regulations for new technologies to utilize renewable energy will reduce the resistance of fossil fuel industries to support these renewable technologies against a possible scenario of declining market shares and will strengthen the integration of the new technology.

Financial Criteria

One of the main pillars on which the diffusion of new technologies such as the hydrogen fuel cell as a primary technology relies is finance. Financial strength plays a crucial role in making hydrogen fuel cell technology a reasonable and viable alternative to other fuel types. Governments and partner organizations specializing in hydrogen and fuel cells are working on developing a hydrogen-based economy to provide centralized production, storage and distribution infrastructure and to supply hydrogen to end users [17]. The financial barriers that hinder the integration and utilization of the hydrogen fuel cell can be eliminated by providing the necessary support, implementing appropriate policies and, most importantly, encouraging governments and the private sector to invest in these technologies. Financial criteria can be addressed under two sub-headings.

Infrastructure Finance: There is a significant need for infrastructure to be used for the development and standardization of hydrogen fuel cell technology for the dissemination and integration of hydrogen fuel cell technology into existing systems, for obtaining, storing and transferring hydrogen, and for R&D studies. Inadequate or inefficient infrastructure is an obstacle to the effective use of the technology. Due to the high costs associated with train prototypes and new infrastructure, funding and appropriations are needed to address the related infrastructure deficiencies and establish associated facilities.

High Initial Investment in Adoption of Renewable Technologies: The future of the hydrogen economy depends on low cost and environmental friendliness. Studies have shown that through thermochemical hydrogen production from nuclear power, it is possible to produce hydrogen from a modular helium reactor for as little as $1.84/kg. The rising cost of feedstock for conventional fossil fuel power plants further reduces the cost of alternative energy sources. Therefore, alternative fuel sources are considered to become the future economic sources of hydrogen [18]. However, obtaining hydrogen by alternative means requires different areas of expertise and costly processes. After establishing the infrastructure for fuel cell technology, which is a new technology that has not yet become widespread, producer stakeholders need very high initial investments for the equipment, technology and personnel requirements to start the processes.

Technical Criteria

One of the important requirements for the use and widespread use of hydrogen fuel cell technology, which is a new technology with sustainable and environmentally friendly policies, is technical elements. There are technical details and requirements in many areas, from the storage, transportation and production of hydrogen to ensuring that the entire system is suitable for the technological equipment to be integrated.

Vehicle Design: The current rolling stock designs are generally designed for electric (catenary and 3rd rail), diesel-electric and diesel-driven energy sources. Integrating fuel cell technology into designs using conventional internal combustion engines and electric motors is quite challenging. Integration of the fuel cell without modifications to the design may cause problems. The fuel cell, hydrogen tank and smaller components to be used may take up more space than other engines and may reduce the passenger capacity of the train or reduce driving performance. In trains that are currently driven by electricity from the catenary system, partial fuel cell use is also possible. On certain parts of the line, the train is propelled by an electric motor driven by an installed catenary system. On parts of the line without catenary, this electric motor is driven by electricity generated by fuel cell technology. These dual-mode designs are not yet widespread and studies on the subject are ongoing. A number of design and integration challenges arise when introducing a large hydrogen fuel cell vehicle. Weight, center of gravity, safety is among the design factors, and roof mounting of a lightweight compressed hydrogen storage system poses design challenges. Shock loads, especially during attachment to railway cars, require component mounting systems capable of absorbing high energy. Furthermore, the system design must address safety and the rules governing the railway transportation industry as well as events such as derailment, side impact from marina traffic, refueling and maintenance [9].

Power Transmission Systems: The technical aspects of the suitability of fuel cell technology to replace existing diesel-powered vehicles are of great importance. The conventional internal combustion engine in the current vehicle design will be replaced by the components of the fuel cell, the electric motor and the storage unit. This relocation and integration process should take into account factors such as weight distribution, energy efficiency balance and safety. The electric energy that will provide the movement of the electric motor to be placed instead of the diesel engine is produced in the fuel cell. Control systems are also required to ensure the healthy and reliable operation of the fuel cell system during the electricity generation process. Electricity distribution system and power transmission elements are needed to transport electrical energy from the fuel cell to the electric motor. Design is also vital to ensure that efficiency does not decrease and safety issues do not arise in the process of meeting this transfer need. There is uncertainty about how the different powertrains will interact and how they should be sized for other railway applications such as shunting trains and mainline locomotives [10]. Given the limited knowledge of train and fuel cell component manufacturers on the standardization and scaling of hybrid powertrain designs [10], there is a significant way to go in terms of technical developments

Fuel Cell Technology: Fuel cells are devices used to generate heat and electrical energy by electrolysis of an external substance. It is a technology with a high potential to replace the traditional internal combustion engines used today. They are differentiated according to the type of electrolyte used. The most widely used fuel cell type is proton exchange membrane (PEM) fuel cells. High power density PEM fuel cells [1], which have the advantages of 90% emission reduction in large pollutants, 60% in electrical energy conversion, and up to 80% in cogeneration systems where electrical and thermal energy are produced together, consist of a proton membrane, anode and cathode electrodes, catalyst, bipolar plates and final outer plates. This structure, which enables the fuel cell to operate, needs technical development to overcome problems such as uptime and cost, and to move to a commercial scale with all its technological dimensions.

On-Board Hydrogen Storage: Developing acceptable cost-effective and safe high-density hydrogen storage technologies is considered a fundamental challenge for hydrogen-powered vehicles [19]. Damage to the hydrogen storage unit during an accident or impact has the potential to cause serious safety issues. For this reason, the location of the hydrogen storage unit in the design is very important. Existing hydrogen storage technologies can be divided into two main groups [19]: 1) As physical storage methods, these are compressed gaseous hydrogen

(CH2), cold compressed hydrogen, liquid/cryogenic hydrogen (LH2) and cryocompressed hydrogen (CcH2). 2) As substance-based (chemical) storage methods, adsorption and absorption. The appropriate storage technology needs to be identified and the technical requirements for the provision of the on-board attachment need to be met.

Social Criteria

According to the mindset of human beings, the new expression is often characterized by uncertainty and sometimes fear. In addition to technical, economic and political studies, the emergence of a new technology also requires studies and planning on a societal level. It is obvious that the widespread diffusion of new technologies will bring many benefits when viewed from a broad perspective and considered in the long term. However, at the same time, it is certain that it will also create some social and humanitarian problems. Therefore, one of the important factors in the integration of hydrogen technology into railway systems is social criteria.

Resistance to Technological Innovation and Change: The use of hydrogen as a fuel is a new initiative in itself. In parallel, in order for hydrogen fuel cell technology to become widespread in transport vehicles, there is an absolute need to introduce the new technology to the public. The public's lack of knowledge about new technologies often makes them advocates of established technologies. Their low level of knowledge about new technology chains causes them to question the reliability of the information they have and leads to debates about decisions taken at the managerial level, about which technologies public funds should be spent on, creating the potential to hinder the development of the subject [20]. Therefore, 'demonstration projects' can be functional in ensuring public awareness [3].

Society's Concern of Being Involved in New Technology Production and Operation Processes: In order to positively influence the approach to new technologies and their adoption by the society, after informing the public about the subject, training the public to use these technologies and to participate as a workforce in the production and operation stages will increase the interest and confidence of the society as a whole in new technologies [21]. The strategy of raising awareness and involving the public in the context of this issue will greatly improve the sustainability of technological development and integration and will benefit the society in adopting and adapting to this technology. Manpower in traditional sectors may perceive the presence of new technologies as a threat due to the fear of becoming unemployed in the face of innovations. Training this labour force and skilled personnel can avoid the fear of unemployment and lack of skilled personnel on a sectoral basis. To address the growing skills gaps in the sectors, current employees and those at risk of losing their jobs should learn new technology and take the opportunity to gain the skills needed for future employment [22].

Market Criteria

Another factor that a new technology will face in the process of becoming widespread in the face of traditional and socially accepted alternatives is the ability to prove itself in the existing market environment and to establish a supply chain. At this point, issues such as ensuring recognition from a marketing perspective, determining customer and demand needs, communication with competitors, pricing and collaborations draw attention.

In industries that produce high-tech products or industries that rely on technology for management and production processes, it is important to appropriately link technologies to markets to increase shareholder value and generate future cash flows. Research and Development (R&D) allocations in such industries are highly dependent on estimates of the potential contribution of R&D projects to future cash flows, which is related to the project's ability to meet current or future customer needs. But resource allocation decisions are difficult given that both markets and technologies are likely to be uncertain. Based on a discussion of technology and market opportunity, the authors develop a conceptual framework for identifying and understanding the barriers managers face in the process of matching technologies with market opportunities. Technology and market barriers include elements such as technology-market linkage, technology accessibility, competitors' technology and market capabilities, and business model possibilities [23].

Customer Demand: In order for a new technological development to be introduced to the market and to find a place, it is essential that it is demanded by the customer, in other words, that a supply-demand balance is established. The customer who will demand the new technology is often concerned about uncertainty about the reliability of the new technological development. This can lead to low demand. To overcome these challenges, technology developers should strive to provide effective marketing strategies, training and solutions that provide value to customers. The rating of how well the technology aligns with customer demand within an existing or potential market opportunity is a barrier in the context of customer demand. In our retrospective literature review, researchers argue that combining market and technology opportunities is a creative process in which product innovators have to experiment with different features, work closely with customers, pursue multiple development paths simultaneously and, at times, make continuous leaps of the imagination [22].

Supplier Availability: Establishing relevant supply chains is crucial for new technology producers and developers in their efforts to realize new technologies and enter the market. The R&D, financial planning and technical infrastructures of new technologies will be as new as the technology itself, and there will be few leading examples in the market. Problems related to the quality and quantity of production that will arise due to the difficulty of finding suppliers with the relevant capabilities are critical to the success of projects. Technology developers should take initiatives to improve the quality of their stakeholders in supply chains to mitigate potential downsides. Supply chain network design or strategic supply chain planning constitutes one of the most critical planning issues in supply chain management. The concept of hydrogen supply chain network design is used for processes involving the distribution, accumulation, transportation and utilization of hydrogen infrastructure. Hydrogen is considered a versatile and clean energy source that can be produced from different feedstocks (natural gas, biomass, water) by different methods (electrolysis, steam methane reforming) [24].

4. CONCLUSION

Innovative energy sources as alternatives to conventional energy sources are gaining an increasing share in energy systems worldwide. Now, more than ever, there is a motivation to reduce carbon emissions from internal combustion engines and fossil fuel energy technologies. In line with this motivation, hydrogen fuel cell technology is a very clean, efficient and innovative technology, making it highly likely to replace traditional fuels. While European countries are known to have buses that run on hydrogen fuel technology, hydrogen refueling infrastructure networks are also growing steadily, and there are studies showing that there is a promising future for hydrogen-based energy production with the development of the needed technologies [10].

As in many strategic action areas, the integration of hydrogen fuel cell technology into Turkey's railway systems involves many decision-making problems. Multiple decision-making problems that arise in many sub-fields such as determining production and storage conditions, creating vehicle designs, shaping infrastructures and establishing supply chains are suitable for multi-criteria decision-making approaches based on the concept of multi-attribute structure and consensus solution by nature.

For the integration of hydrogen fuel cell technology into Turkey's railway systems, it is clear that there is a need for government support and even international cooperation in many issues such as the establishment of infrastructure facilities where the technology will be produced and developed, related know-how support, the needs for qualified personnel, and public information. In this study, the managerial, financial, technical, social and market dimensions that need to be defined in order to address the integration of hydrogen fuel cell technology into Turkey's railway systems as a multi-criteria decision-making problem are presented together with their sub-criteria. For future studies, it is recommended to weight the elements that emerged as criteria in the integration process with the opinions of experts and to make specific evaluations for institutions and stakeholders. The study is a preliminary work for the decision-making environment that emerges in determining strategic action plans for a hydrogen fuel cell technology to the Turkish railway system.

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THE IMPACT OF LEAN OPERATIONS ON FIRME PERFORMANCE

Ahmet ÇETİNDAŞ

Hasan Kalyoncu University, Department of International Trade and Logistics, Gaziantep, Turkiye, ahmet.cetindas@hku.edu.tr

Abstract – *Lean is a term that refers to the elimination of unprofitable activities through the firm. The basic aim of lean production is identified as, eliminating waste in manufacturing and post-manufacturing processes and improving the performance of industrial firms by revealing people's capabilities. Lean operations focus on optimising all production processes by eliminating non-value-added activities in its operations through simplifying, and reducing waste. Businesses apply this strategy to decrease cost and gain performance. Thus, the goal of this study is to explore the effect of lean production on business performance. So, data were collected from 127 manufacturers in the Gaziantep Organized Industry site through questionnaires. In order to disclose the reliability and the construct validity of the scales, exploratory factor analysis (EFA), confirmatory factor analysis (CFA) and reliability analysis were implemented. Regression analysis is then used to determine the impact of lean production on business performance. The results showed that lean production affects business performance (β: 0,24, $<.005$). This confirms that manufacturing firms using lean production methods gain more business performance. Especially in industries where operations can be costly, the lean production method can help to decrease cost.*

Keywords – *Lean Production, Business Performance, Manufacturing Companies*

1. INTRODUCTION

In recent years, small and medium-sized businesses have often been able to improve their performance through the integration of lean production because it has created many prospects for growth and expansion through quality improvements and cost-effectiveness [1], [2]. The idea of lean production originated from the Toyota manufacturing system [3] aims to reduce costs and increase productivity by removing or reducing waste [4]. A manufacturing system might produce waste for a number of different reasons. Examples include overproduction, defects in production, and a lack of consideration for client preferences [5]. Lean production systems are strategic objectives and guiding principles combined with specific techniques and equipment for the complete management of manufacturing processes. Lean production systems are created through the company specific elements such as principles, processes, objectives, methods and tools. Recently, many companies developed their customised lean operation system to their particular requirements [6].

Lean methods and concepts focus on process variability and reducing non-value added operations which are waste [7]. Early research in this area has suggested that a sustained competitive advantage is achievable through creating a lean production system and reaching higher product quality that also reduces lead times [8]. Nowadays, in order to improve performance, lean attempts to place a greater emphasis on providing value to consumers [9]. Continuous operational improvement of the business can result from applying lean production by focusing on decreasing waste [3] and redundant processes and activities in a production system [10], [11].

Therefore, there are three different types of lean production objectives. Firstly, lean production removes waste. Any insignificant action that uses up resources, time, or space while providing no added value to the service or product is considered as waste. Second, lean production decreases lead times. This involves reducing the time it takes to complete an activity which results with cutting waste, and decreasing prices. Third, lean production lowers total costs by consistently producing only what customers require, at the proper time, location, and cost [12].

This study has analysed the effect of lean operations on firm performance. Therefore, a literature review is provided to show the findings of previous studies. Then the normal distribution, reliability and exploratory factor analysis (EFA) of the scales are tested. Furthermore, a regression analysis is conducted with SPSS to test the impact of lean production on firm performance.

2. LITERATURE REVIEW

Many factors influence the integration of lean production practise and principles, including increased consumer expectations, global competitiveness, and demand unstable environment. "Doing more with less" is an easy way to sum up the lean principle. This capital-intensive mass production paradigm, with its massive batch sizes, particular assets, and hidden wastes, is improved by the lean concept, which focuses on eliminating waste and excess from tactical product processes [13].

The literature demonstrates a relationship between lean production and increases in performance [14], [15]. [16], found an impact of lean production on firm performance which is moderated by the use of information technology. [17] proved that lean production increases operational performance through knowledgeable employees. [18] found that lean production affects the green activities of companies which is considered as green performance. Lean production can improve the organisation economically by creating competitive advantages, reducing cost of waste, and decreasing management costs associated with decreasing pollution [19]. [20] argued that lean production applications in developed economies are more extensive than in emerging economies. Some other researchers could not find any relationship between lean operations and firm performance [21], [22].

According to the previous studies there could be a nexus between lean production and firm performance. This objective is the motivation of this study.

3. METHODOLOGY

The purpose of this study is to determine the impact of lean operations on firm performance. The research hypothesis is developed as below:

H: Lean production has a positive impact on firm performance.

Data were collected from 127 manufacturers in the Gaziantep Organized Industry site through questionnaires. The questionnaires were applied to General Manager, General Coordinator or Deputy General Manager. When these could not be reached, employees who had at least one managerial position related to production were surveyed. The scales used in the study were adopted from previous studies. The lean production scale is adopted from [23] and firm performance scale from [24].

EFA, reliability analysis and confirmatory factor analysis (CFA) were applied to reveal the construct validity and reliability of the scales. EFA and reliability analysis results are shown in Table 1.

TABLE 1

Lean Operations Factor Loads and Reliability Analysis

Faktor	Factor Loadings	Alpha	KMO	Tot. Exp. Var. (%)
Lean Production				
LP1: Our company reduces costs through mass production	,491			
LP7: Our company is constantly trying to reduce costs to the customer at all stages.	,799	0,72	0,71	56,31
LP8: Our company is constantly trying to reduce the waste of resources	,851			
Firm Performance				
FP1: Compared to our competitors, we have better return on investment	,788			
FP2: Compared to our competitors, we achieved much better return on sales profit	,881	0.921	0.878	74,95

FP3: We are experiencing much higher sales growth compared to our competitors	,914
FP4: Compared with our competitors, we get much higher profit sales	,868
FP5: We experience higher growth in market share compared to our competitors	,873

As seen in table 1, the factor loads of the lean production scale were found between 0.491 and 0.806. KMO was found to be 0.71 ($p<0.01$). In addition, it was found that the scale explained 56.31% of the variance and the alpha coefficient obtained by the reliability analysis was 0.805. The factor loads of the firm performance scale were found to be between 0.788 and 0.873. KMO was determined as 0.878 ($p<0.01$). In addition, it was found that the scale explained 74.95% of the variance and the alpha coefficient obtained with the reliability analysis was 0.921. This Cronbach's Alpha value is considered statistically significant [25]. AVE, CR and Normal distribution results of the scales are shown in Table 2.

TABLE 2

AVE, CR ve Normal Distribution Results

Variable	N	Mean	St. dev.	AVE	CR	Skewness	Kurtosis
Lean production	127	4,5081	,61531	0,56	0,83	-1,680	-1,168
Firm performance	127	4,0286	,73970	0,74	0,93	-,656	,233

The AVE values of the scales should be above 0.5 and the CR value above 0.7. As a result of the analysis, it was seen that the AVE value of all scales was above 0.5 and the CR>AVE condition was met. In addition, skewness and kurtosis values were found in the range of +2 and -2, so it was understood that the data showed a normal distribution [26]. Additionally, to EFA and reliability analysis, confirmatory factor analysis (CFA) was performed to test the construct validity of the scales. The goodness of fit values reached by the scales are shown in Table 3.

TABLE 3

CFA Goodness of Fit Values

Variable	CMIN	DF	CMIN/DF	GFI	NFI	CFI	TLI	RMSEA
Lean production	4,717	2	2,359	0,982	0,963	0,977	0,932	0,071

Firm performance	5,863	12	1,466	0,981	0,987	0,996	0,989	0,061

As a result of CFA, it was understood that the goodness of fit values of the scales were within acceptable ranges.

The results of the correlation analysis performed to observe the relationship between the variables are shown in Table 4.

TABLE 4

Correlation Analysis

	Mean	Std. Dev.	Lean Operations	Firm Performance
Lean Operations	4,5081	,61531	1	
Firm Performance	4,0286	,73970	,264**	1

**p<0.05

The correlation analysis proved a significant positive relationship between lean production and firm performance (r = ,264).

TABLE 5

Regression Analysis

Independent Variable	β	Standard Error	T	p
Lean Production	,221	,202	3,739	,000

Dependent variable: Firm Performance (p<0.001)

Table 5 shows the model results of the regression analysis. Accordingly lean production affected firm performance (β= 0.221, p<0.001). Accordingly, one unit change in lean production affects firm performance by 0.221.

4. CONCLUSION

The aim of increasing performance through lean operations is a phenomenon between business owners and thus, researchers. Lean production is generally applied to eliminate waste which results as cost decreases. Cost decrease and speed gained through lean production will also provide firm performance.

This study is a primary (survey-based) research where data is collected from 127 manufacturers located in Gaziantep. The objective was to determine the nexus between lean production and firm performance. The results indicate that lean production affects firm performance (β= 0.221, $p<0.001$). This confirms that manufacturing firms using lean production methods gain more business performance. Especially in industries where operations can be costly, the lean production method can help to decrease cost.

Future studies can investigate the nexus between lean production and other performance indicators such as logistics performance, delivery performance or distribution performance. It is advised to manufacturers to apply the lean production strategy in order to gain firm performance.

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BUSINESS MODELS INVOLVING MOBILE CHARGING VEHICLE AND FIXED CHARGING STATION WITH COMMERCIAL AND NON- COMMERCIAL USES

Hakan ERDEŞ[1], Saadettin Erhan KESEN[2]

Abstract – *This study investigates how the efficiency and usage of electric vehicle charging infrastructure can be increased with various business model proposals that are based on sharing economy concept. One of the contributions of the proposed models is the categorization of electric vehicles as Non-Commercial, Commercial and Contracted-Commercial Electric Vehicles. In addition, roles of Commercial Electric Vehicle Fleet Owner Company and charging provider Third Party are defined on the basis of business models. Based on the business model 3, "Mobile Charging Vehicle Routing Problem with Fixed Charging Station (MC- VRP-FCS)" is presented and 0-1 MILP formulations are introduced. While experimental studies are implemented with DC charger and Mobile Charging Vehicle, it is also explained how to implement them with the Battery Swapping Station and Battery Swapping Vehicle. The experimental studies and sensitivity analyses reveals important results on how to benefit from business models.*

Keywords – Electric Vehicles, Mobile Charging Vehicle, DC Charging, Sharing Economy, Battery Swapping

1. INTRODUCTION

Transportation sector and daily transportation processes are well known to have a large share in carbon emissions. The fact that the area is largely dependent on fossil fuels and causes greenhouse gas emissions also forms the basis of carbon emissions. At the point of reducing this pressure on fossil fuels and environmental pollution, the use of Electric Vehicles, which have the potential of replacing traditional internal combustion engine vehicles, has been expanding rapidly [1]. However, there are still significant challenges in front of EVs like charging times and range anxieties [2]. Yet, while only 120,000 EVs were sold worldwide in

[1] Hakan ERDEŞ, Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, Konya Technical University, Selçuklu/Konya, Turkey, herdes@ktun.edu.tr
[2] Saadettin Erhan KESEN, Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, Konya Technical University, Selçuklu/Konya, Turkey, sekesen@ktun.edu.tr

2012, more than that were sold every week in 2021 according to the International Energy Agency (IEA) [3]. Moreover, while around 10% of global automobile sales were made up of EVs in 2021, the total number of EVs increased to approximately 16.5 million. In 2022, 2 million sales were realized in the first quarter, an increase of 75% compared to the same period of 2021 [3].

Carrying on this momentum in EVs also depends on technological developments. On one hand, vehicle users are unwilling to purchase EVs until the coverage of the charging infrastructure is comprehensive enough, on the other hand, charging service providers are skeptical to invest heavily in infrastructure unless significant demand is observed [4]. This situation is called "chicken-egg dilemma" in the literature. At this point, there are some actions that both governments and private companies can take come to the fore. One possible solution would be to provide tax deductions and additional subsidies to the customers by governments and leading companies in order to boost the industry. [5]. For example, Norway aims to ban the sale of all fossil fuel cars by 2025 and imposes high taxes on high-emission cars and low taxes on low-emission cars [6]. In Türkiye, internal combustion engine vehicle users pay special consumption tax between 45% and 160%, whereas this rate is between 3% and 15% for EV users. Locating charging stations properly and utilizing nascent technologies are some other actions that might be taken by private companies. Nevertheless, these actions bring new optimization problems inherently.

Besides the use of EVs by the public, the use of EVs in transportation, cargo distribution, logistics and last mile delivery stands out as a different field of study. The proportion of diesel fuel used in these areas is at an innegligible level. Road transport distribution is also known to consume around 50% of all diesel fuel and accounts for 80% of the global net increase in diesel use since 2000 [8][9].

In addition to aforementioned concerns, initial investment cost for charging infrastructure is a burning question for commercial EVs which mainly emerges because of the uncertainty in the public charging stations [9]. While returning to depot for charging process is called "return-to-base", opting public stations is called "on-route" strategy [10]. Ref. [11] states that vast majority of the studies dealing with the electric vehicle routing problem (EVRP) address the assumption of continuous availability of public stations, which can not be always possible. At this point, contracted charging stations may be required in order for commercial EVs to perform their services to their customers in a timely manner. Dedicating a charging station for just non-commercial or for just commercial EVs might be a way but this time, utilization of the charging stations dramatically drops.

Regarding to these challenges, various business model proposals are presented in this paper. Hereby the main contributions of this paper are given as follows: (i) To the best knowledge of the authors, this study may be one of the first example of its kind in which noncommercial EVs and commercial EVs are discussed in a hybrid fashion and evaluated within the scope of the same problem, (ii) In addition to commercial EVs, the concept of contracted commercial EV is also taken into account, (iii) Through the concept of Sharing Economy, various new business model proposals are presented, aiming to prevent the idle charging resources, considering a total electrification by including all EV vehicle types and aiming to break the chicken-egg dilemma. These models also differ in terms of investing in charging infrastructure and receiving prior service from the charging infrastructure. (iv) Two levels of Mobile Charging Vehicle Routing Problem with Fixed Charging Station (MC- VRP-FCS), namely Level-1 and Level-2 problems are introduced based on model number 3 given in this paper and 0-1 MILP models are introduced for both problems.

The remainder of this paper is organized as follows. Literature review on EVs, EV charging options, Commercial EVs and Sharing Economy are presented in section 2. Section 3 presents the new business model proposals of " Investing in Charging Infrastructure Business Models for EVs with Different Beneficiaries". Problem definitions, assumptions and 0-1 MILP models are given in section 4. More comprehensive experiments on DC Charger and mobile charging vehicle (MCV) are provided in section 5. Finally, Section 6 concludes the paper.

2. LITERATURE REVIEW

2.1. Electric Vehicles and Charging Options

EVs are divided into three as hybrid electric vehicles (HEV), battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV) [12], while BEVs are considered as EVs in this study. On the other hand, charging speed of EV is divided into 3 as level 1 (1.4 kW to 1.9 kW), level 2 (4 kW to 19.2 kW), and level 3 (50 kW to 100 kW) such that an EV can be fully charged in about 30 min. [7]. In addition to fixed charging station (FCS), there are different charging technologies like mobile charging vehicle, battery swapping station (BSS), battery swapping vehicle (BSV) or wireless charging. A mobile charging vehicle has a service battery capacity, goes to location of an EV and provides charging service. Battery swapping, though, refers to those electric vehicles that are not charged via a charging cable, but by swapping the depleted battery with a full battery. One of the most important features of battery swapping is that the batteries can be swapped in a short time and the depleted batteries can be recharged during off-peak hours. Stations where battery swapping is performed are called battery swapping station and vehicles that carry out this process are known as battery swapping vehicles. Ref

[13] studied on location-routing problem in which fixed charging stations are located at the strategic level and mobile charging vehicles are routed with time windows at the tactical level. They also presented a mixed integer linear programming model. [14] presented the location-routing problem in which they simultaneously addressed the determination of the location strategies of battery swapping stations and route planning of EVs and developed a MILP model.

2.2. Commercial Electric Vehicles

Although electric vehicle routing problem is frequently addressed, studies including both commercial EVs and different charging technologies are handful. The problem presented in [15] includes commercial EV and battery swapping vehicles. While commercial EVs meet the demands of the customers, battery swapping vehicles provide full battery to commercial EVs at a predetermined meeting time and location. This provides extra driving range, extra flexibility and lower cost without the need of changing the route of EVs. [9] extends the work with charging stations. In this context, commercial EVs can get charging service from both charging stations and battery swapping vehicles and the study aims to minimize the total distance travelled.

2.3. Business Models and Sharing Economy

Ref. [16], presents four different business models considering the cooperation of various companies serving in different sectors via EVs. These models are mainly based upon the principle that companies invest in the charging infrastructure jointly or that they receive service from a third party/charging service operator. Although the models have advantages on each other, their common point is that they provide service cost reduction and increment for the level of resource usage. Interested readers are referred to [16]. It is noteworthy that the models are based on the logic of the sharing economy. According to the sharing economy concept, in cases where various charging infrastructure resources are not used sufficiently, other users are given access for a certain cost. Ref. [17] introduced "The electric vehicle routing problem with shared charging stations". The problem is that several companies jointly invest in charging stations. A choice is made between potential locations for charging stations and the technologies that these charging stations contain. Routes of EVs are determined for each company as well. The aim is to minimize the fixed opening cost of stations and driver cost. According to the model presented by [18] based on the sharing economy logic, the sharing of private charging stations, which is stated to be idle at a rate of 75%, is discussed. It is based on the logic that people who own an EV charger rent it to other EVs when the device is not used.

3. PROPOSED BUSINESS MODELS

The key point that distinguishes proposed models from others is that charging infrastructures allow access to noncommercial EVs, commercial EVs and contracted commercial EVs simultaneously, which are shown in Table 1. Focal point of the models is commercial EV fleet owner companies (CEVFOCs). CEVFOCs refer to companies that need to provide timely service to their customers and wish to electrify their vehicle fleet. They can both invest in charging infrastucture themselves or have a contract with other CEVFOCs for investing in infrastructure. Another option is to take charging service from Third Parties, which refers to charging service operators. If a CEVFOC is investor or contractor, then it is also priority beneficiary which means it has privileges (receiving service earlier than other EVs or receiving service with reservation etc.) in terms of some conditions. Considering business model 1, while investor is CEVFOC X, contractors are CEVFOC X and Y which means EVs of CEVFOC X and Y have privileges but other noncommercial and commercial EVs can receive service as well. Business model 2 is similar to the model in [17] with a distinction that other commercial and noncommercial EVs can receive service. The party providing charging service is third party in models 3 and 4. The differences between models 3 and 4 are the number of contractors and EV types and the selection between these two models may change according to the regional characteristics. For example, if the region includes lots of logistics and freight companies then the third party may opt to serve only these companies or to also noncommercial EVs. The model 5 is similar to the model in [18]. It includes contract with CEVFOC X and access to other commercial and noncommercial EVs. Meanwhile, a business model might be given with its economic feasibility or with other important elements, but each business model given in this paper could be seen as a strategy that is based on the sharing economy and no comprehensive or detailed information about business models can be provided due to space limitation.

TABLE 1.

Investing in Charging Infrastructure Business Models for EVs with Different Beneficiaries

Model Number	The Party(ies) Investing in Charging Infrastructure	Contracting Parties	Vehicles that Can Benefit from Charging Infrastructure	Priority Beneficiaries of the Charging Infrastructure
1	CEVFOC X	CEVFOC X and Y	CEVFOC X and Y NCEVs and other CEVs	CEVFOC X and Y
2	CEVFOC X and Y	CEVFOC X, Y and Z	CEVFOC X, Y and Z NCEVs and other CEVs	CEVFOC X, Y and Z
3	Third Party	Third Party CEVFOC X	CEVFOC X NCEVs and other CEVs	CEVFOC X
4	Third Party	Third Party CEVFOC X, Y and Z	CEVFOC X, Y and Z NCEVs	CEVFOC X, Y and Z
5	Private Users	Private User CEVFOC X	CEVFOC X NCEVs and other CEVs	CEVFOC X

4. PROBLEM DEFINITIONS AND ASSUMPTIONS

The Mobile Charging Vehicle Routing Problem with Fixed Charging Station (MC-VRP-FCS) is based on business model 3 and is divided into two levels as Level-1 and Level-2. While the Level-1 problem includes noncommercial EVs and commercial EVs, Level-2 problem includes contracted commercial EVs as well. The shared assumptions of both problems are as follow;

- There is a single DC charger and a single mobile charging vehicle connected to charging station. The charging speed given by both DC charger and mobile charging vehicle is linear and there is no obligation to serve all customers in the system. Besides, the demands of charging stations and mobile charging vehicles are separeted, namely there is no decision to make whether the customer take charging service from charging station or from mobile charging vehicle.

- EVs receive charging service from a DC charger with a speed of 100 kWh in charging stations, or from mobile charging vehicle with a charging speed of 100 kWh as well. Charging demand varies between 15-30 min. in charging station and 10-30 min. for mobile charging vehicle.

- The fixed fee is calculated over the service period and it is 1 unit per min for both option.

- The mobile charging vehicle has a fixed service capacity of 85 min. (i.e., it can provide 85 min. of service in total) and is assumed to have sufficient energy to complete each route. The mobile charging vehicle returns to charging station after completing its tour and can recharge its batteries in 10 min.

- The distance between each pair of customers and charging station varies between 5-10 min. The additional assumptions for Level-2 is as follows.

- Some of the commercial EVs in the Level-1 problem belong to the CEVFOC X, and they are processed as contracted commercial EVs in Level-2 problem depending on the contract between CEVFOX X and third party.

- It is obligated to serve the contracted commercial EVs and the fee tariffs applied to these vehicles vary.

Experimental studies include sensitivity analysis on the fee tariffs.

4.1. 0-1 MILP Models for the Problems

In what follows, notations, definitions and the 0-1 MILP formulation of the Level-1 problem is presented.

Notation	Definition
Indices:	
i, j	: (customer, EV)
Sets:	
V_0	: Set of Single Depot
V_{NCM}	: Set of NCEV with request charging service from MCV
V_{CEM}	: Set of CEV with request charging service from MCV
V_{CCM}	: Set of CCEV with request charging service from MCV
V_{NCF}	: Set of NCEV with request charging service from FCS
V_{CEF}	: Set of CEV with request charging service from FCS
V_{CCF}	: Set of CCEV with request charging service from FCS
V_M	: Set of customers request charging service from MCV ($V_{NCM} \cup V_{CEM} \cup V_{CCM}$)
V_F	: Set of customers request charging service from FCS ($V_{NCF} \cup V_{CEF} \cup V_{CCF}$)
$V_{0,M}$	: Set of depot and customers request charging service from MCV ($V_0 \cup V_M$)
V_C	: Set of all customers request charging service ($V_M \cup V_F$)
$V_{0,C}$	: Set of nodes ($V_0 \cup V_C$)
A	: Set of arcs $A_1 \cup A_2$
A_1	: $\{(i,j), \mid i,j \in V_{0,M}, i \neq j\}$ set of arcs for customers requesting charge service from MCV
A_2	: $\{(i,j), \mid i \in V_F, j \in V_0\}$ set of arcs for customers requesting charge service from FCS
	Parameters:
t_{ij}	: Travel time at nodes $i,j \in V_{0,M}$, $i \neq j$
d_j	: Charging demand time of customer $j \in V_C$ (in min.)
r	: The time needed for recharging of MCV (in min.)
Q	: Battery capacity of MCV (in min.)

T	: Planning horizon

Decision Variables:

X_{ij}	: 1 if arc (i,j) is traveled and 0 otherwise for all i,j ∈ $V_{0,M}$, i≠j (Customers of MCV)
	: 1 if customer i takes charging service from FCS and 0 otherwise for all i ∈ V_F, j ∈ V_0 (Customers of FCS)

MC-VRP-FCS is an extension of the capacitated vehicle routing problem (CVRP) [20]. All vehicles have the same capacity [19], all routes start and end at the depot, the total demand of customers does not exceed the vehicle capacity, and the objective function is to minimize the total cost [20].

As stated previously, di is the demand of every i ∈ V0,C and could be also considered as revenue. So, if charging demand of a customer is 15 minutes, then the revenue is 15 units. It should be recalled that according to the assumption of Level-1 the sets VCCM and VCCF = {∅}.

Objective Function

$$max \sum_{i,j\in V_{0,M}} X_{ij}d_j + \sum_{i\in V_F} X_{i0}d_i \quad (1)$$

Subject to

$$\sum_{i\in V_{0,M}} X_{ij} \le 1, \quad \forall j \in V_M \; (2)$$

$$\sum_{j\in V_{0,M}} X_{ij} \le 1, \quad \forall i \in V_M \; (3)$$

$$\sum_{i\in V_{0,M}} X_{ij} = \sum_{i\in V_{0,M}} X_{ji}, \quad \forall j \in V_M \; (4)$$

$$\sum_{i\in V_{0,M}} X_{i0} = \sum_{j\in V_{0,M}} X_{0j} \quad (5)$$

$$u_i - u_j + QX_{ij} \le Q - d_j, \; \forall i,j \in V_M, i \ne j \; (6)$$

$$d_i \le u_i, \; \forall i \in V_M \; (7)$$

$$u_i \le Q, \; \forall i \in V_M \; (8)$$

$$\sum_{i,j\in V_{0,M}} X_{ij}t_{ij} + \sum_{i,j\in V_{0,M}} X_{ij}d_j + r\sum_{i\in V_{0,M}} X_{i0} \le T \quad (9)$$

$$\sum_{i\in V_F} X_{i0}d_i + r\sum_{i\in V_{0,M}} X_{i0} \le T \; (10)$$

$$X_{ij} \in \{0,1\}, \quad \forall i,j \in V_{0,C} \; (11)$$

The objective is to maximize demand met, or equivalently total revenue in (1). Equations (2), (3) and (4) are the constraints for the customers requesting charging service from mobil charging vehicle and they ensure that each customer could be visited by mobil charging vehicle at most once and if there is an arc entering to a node then there is also a leaving arc from that node. Equations (5), (6), (7) and (8) are general constraints which are developed for Vehicle Routing Problem (VRP). Equation (5) ensures that the number of entering of mobile charging vehicle to depot is equal to the number of leaving of mobile charging vehicle from depot. Equation

(6) ensures that the total amount of customer demand on a route do not exceed the vehicle capacity, but also prevents the formation of sub-tours. The Equations (7) and (8) are the constraints that determine the lower and upper limits of the auxiliary decision variables. Equations (9) and (10) are the constraints for time limits. Equation (9) is time constraint for tours of mobile charging vehicle and it ensures that sum of time spent on the way, time spent on the customer nodes, and time spent on the depot for recharging of mobile charging vehicle is at most planning horizon T. Similarly, (10) is the time constraint for charging processes on the depot and it signifies that the sum of time spent on giving charge service to customers and time spent of recharging of mobile charging vehicle is at most again T. Finally, (11) designates the binary decision variable Xij.

All the set of nodes and arcs for Level-1 problem are also valid for Level-2 problem. Equations of (2)-(11) are also valid for Level-2 problem. On the other hand, Level-2 problem includes extra parameters and constraints. First, there is an extra cost rate (ECR) for contracted commercial EVs. For example, if ECR=0.05 then the revenue comes from a customer with a demand of 15 min. is 15.75. There is also a parameter of COMi for i ∈ VC which has a value 1 if customer at node i is a contracted commercial EV and 0 otherwise. So, the objective function of Level-1 problem in (1) is revised for Level-2 problem as in (12). Equation (13) and (14) guarantees that all the demands of contracted commercial EVs from mobile charging vehicle and charging station are met, respectively.

$$max \sum_{i,j \in V_{0,M}} (X_{ij}d_j + X_{ij}d_jCOM_jECR) + \sum_{i \in V_F} (X_{i0}d_i + X_{i0}d_iCOM_iECR) \quad (12)$$

$$\sum_{i \in V_{0,M}} X_{ij} = 1, \quad \forall j \in V_{CCM} \quad (13) \qquad X_{i0} = 1, \quad \forall i \in V_{CCF} \quad (14)$$

5. EXPERIMENTAL RESULTS

In this section, 5 different experiments are presented, varying in terms of number of customers and planning horizon T. Experiment names are given according to "E_Number of Customers_T" order. For each experiment, the problem is solved according to Level-1 assumptions, then half of the commercial EVs are assigned as contracted commerical EVs and the problem solved by respecting Level-2 assumptions. The general-purpose optimization package GAMS with solver CPLEX is used to solve the experiments.

Results belonging to the 5 different experiments and 5 different problem sets for each experiment are presented in Table 2. In addition, Table 2 includes the result of Level-1 Problem and the value of 5% extra revenue accordingly. Column 4 shows the extra cost rate value that the CEVFOC has to pay as an extra followed by a result of Level-2 problem in column 5. As can be observed from Table 2, although the number of customers and T change, extra cost rate value that gives 5% extra revenue is between the range 0.10 and 0.15 with 72% rate.

For instance, considering problem "E_24_180", a CEVFOC that expects to receive the charging service as privileged must pay 16, 18, 17, 16, and 11% more fee respectively. Then the CEVFOC X may decide whether to make an agreement. Considering the privileged service, it is expected that the revenue of the CEVFOC increase inherently due to less potential waiting time at the charging stations. If that revenue is capable of affording the extra cost incurred, then one can say that it is reasonable to have an agreement with third party as in business model 3. Moreover, if such a contract is reasonable for CEVFOC X, Y and Z simultaneously, business model 4 might be adopted.

TABLE 2.

Experimental Results

Title	Result of Level-1 Problem	5% Extra Revenue	ECR Value exceeds 5% Extra Revenue	Result of Level-2 Problem	Title	Result of Level-1 Problem	5% Extra Revenue	ECR Value exceeds 5% Extra Revenue	Result of Level-2 Problem
E_18_180_1	278	291.90	0.24	**293.00**	E_18_240_1	358	375.90	0.15	**377.05**
E_18_180_2	271	284.55	0.14	**284.30**	E_18_240_2	356	373.80	0.15	**374.50**
E_18_180_3	281	295.05	0.11	**296.40**	E_18_240_3	344	361.20	0.15	**361.55**
E_18_180_4	277	290.85	0.22	**291.12**	E_18_240_4	351	368.55	0.15	**369.25**
E_18_180_5	276	289.80	0.10	**292.30**	E_18_240_5	344	361.20	0.13	**361.20**
E_24_180_1	283	297.15	0.16	**298.08**	E_24_240_1	390	409.50	0.14	**411.28**
E_24_180_2	282	296.10	0.18	**296.72**	E_24_240_2	385	404.25	0.14	**405.84**
E_24_180_3	278	291.90	0.17	**292.13**	E_24_240_3	389	408.45	0.12	**408.52**
E_24_180_4	279	292.95	0.16	**293.48**	E_24_240_4	384	403.20	0.19	**404.49**
E_24_180_5	282	296.10	0.11	**297.24**	E_24_240_5	381	400.05	0.14	**400.50**
E_30_240_1	384	403.20	0.11	**404.20**					
E_30_240_2	389	408.45	0.15	**410.75**					
E_30_240_3	390	409.50	0.13	**410.24**					
E_30_240_4	390	409.50	0.11	**409.52**					
E_30_240_5	389	408.45	0.11	**409.95**					

Without major changes in the parameters and assumptions, the charging service provided by DC charging and mobile charging vehicle can be considered as the service provided by the battery swapping station and battery swapping vehicles. For example, the duration of charging with DC charger may be assumed 10 min, and the charging with mobile charging vehicle may be assumed 15 min. DC charging service, therefore, can be treated as battery swapping station and charging service with mobile charging vehicle as battery swapping vehicle. If there are not sufficient batteries to provide this permanency, additional constraints may occur. Figure 1 shows an illustrative example of the problem. Let us consider customers 1-5 are noncommercial

EVs and customers 6-15 are commercial EVs for level-1 problem while customer 11-15 are assigned as contracted commercial EV for level-2 problem. As can be seen, all of the contracted commercial EV (signed with yellow) can get service from fixed charging station or mobile charging vehicle in level-2 problem while only two of them are able get service in level-1 problem.

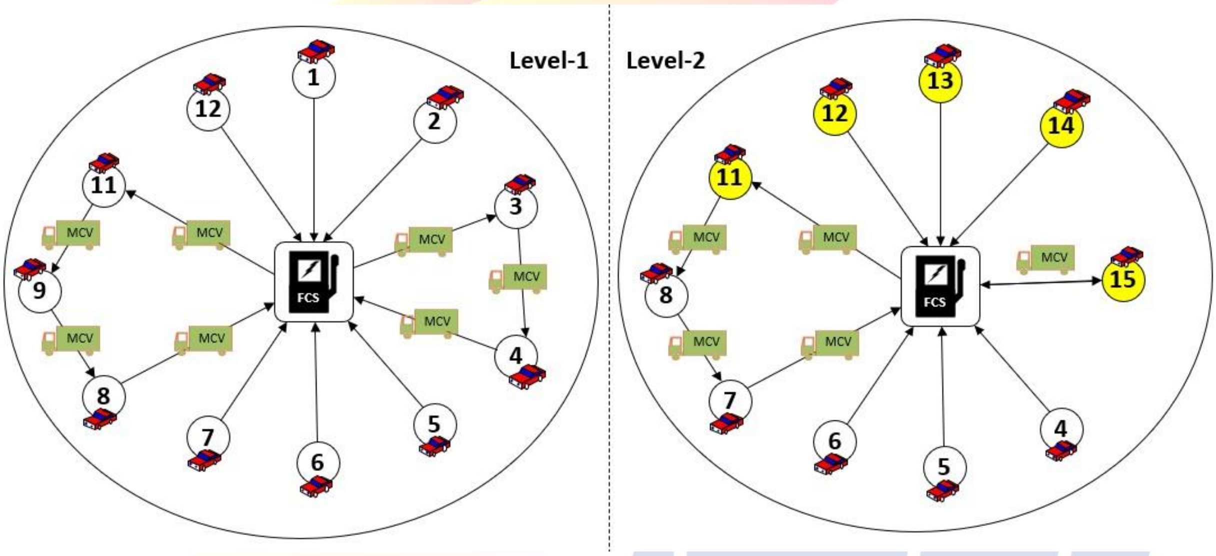

Figure 1. Visualization of Mobile Charging Vehicle Routing Problem with Fixed Charging Station

6. RESULTS AND DISCUSSIONS

In this paper, a novel "Mobile Charging Vehicle Routing Problem with Fixed Charging Station (MC-VRP- FCS)" is presented as 0-1 MILP formulations in two levels. Problems are based on one of the five "Investing in Charging Infrastructure Business Models for EVs with Different Beneficiaries" and these business models are based on sharing economy perspective and different kind of EV charging technologies. Considering other papers and real-world cases, one can reveal that successful and rapid adoption of EV does not rely on only a few factors but many of them. This paper could be perceived as an attempt of couraging some pivotal factors of mass adoption of EVs into consideration. These factors could be listed as follow. (1) Not only fixed or plug- in charging options but also other options are considered, like mobile charging and battery swapping. (2) The assumption of shared charging stations in parallel with sharing economy concept is emphasized. The main question at this point is "how to share charging stations and other charging options" so that the utilization of resources increases and different types of costs decrease. One of the solutions could be evaluating different business models carried out in this paper, so that vehicle or fleet owners are more prone to adopt EV. (3) Not only commercial or noncommercial EVs but also contracted commercial EVs are taken into consideration. The main idea behind this consideration is that paying attention to only noncommercial or commercial EVs may lead to inefficient use of resources.

Considering statistical data, studies in the literature, business models presented in this paper and experimental results, future perspectives can be summarized as follow. (1) First and maybe the most important future perspective could be carrying the business models presented in this paper forward. Developing new mathematical models on other business models would be worth studying. In addition, integrating time windows constraints would make them more realistic. (2) Presenting existing business model with more detail and with their elements would be attractive for offering them as more realistic and applicable. (3) There are other alternative charging methods for EVs such as portable charging stations or wireless charging. Developing hybrid models using these methods could be also compelling. (4) Commercial EVs are considered as EVs of companies in areas of logistic or freight transport but they could be also considered as electric taxis or buses. So, under the logic of sharing economy, new business models could be developed that consider electric taxis and buses and also hybrid of them. (5) Experimental results in this study is limited with 30 customers at most while demands of fixed charging station and mobile charging vehicles are separeted. In future studies, number of customer might be increased for large scale companies, decision might be made between fixed and mobile charging options and heuristic algorithms could be efficiently used if necessary.

As a result, this study is expeced to be a guide for pivotal studies on the adoption of EVs by many individuals and companies and for researchers in this field.

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A BIBLIOMETRIC ANALYSIS OF SUSTAINABLE TECHNOLOGY MANAGEMENT

Harika Akalin, Yunus Eroglu, Türkay Dereli

İskenderun Technical University, Hatay, Turkey, harikakalin@gmail.com,
yunus.eroglu@iste.edu.tr
Hasan Kalyoncu University, Gaziantep, Turkey, turkay.dereli@hku.edu.tr

Abstract – *Nowadays, the term sustainability has become a widely used popular word which can also be defined as a holistic approach that considers economic, social, and ecological dimensions. It is also a crucial issue in the field of technology management. The use of technology in harmony with sustainability goals can play an essential role in solving environmental, economic and social problems and provide guidance for governments, society, and businesses. The literature review shows that there are very few studies that integrate sustainability and technology management. The objective of this study is to analyze the literature on technology management and sustainability using a bibliometric analysis based on the Web of Science database. The study analyzed about 10,000 articles between 2013 and 2023 using VOSviewer software. The study shows the topics, keywords, authors, citations, and their relationships with each other in which research on sustainable technology management is conducted. This study helps to identify a research agenda in this area.*

Keywords – bibliometric analysis, sustainability, sustainable technology management, technology management.

1. INTRODUCTION

Sustainability is an interdisciplinary concept that covers a broad field with multiple dimensions. There are many meanings for the word sustain, but it actually derives from the Latin sustinere (tenere, to hold; sus, up). As defined by the Oxford English Dictionary, the lexical meaning of sustainability is "the capability of being maintained". In 1713, it was the first time the word "Nachhaltigkeit" which is the German term for sustainability was used. It is usual for societies to perceive a concept covering such a large area in different ways. The main reason for the many different definitions of sustainability is due to this broad scope. Sustainability is not static, but dynamic reasons can be summarized as follows:

- Sustainability addresses not only the past but also today and tomorrow.

- Sustainability is self-updating. Sustainability has evolved and changed. The most prominent is the emergence and development of the concept of sustainable development.

- The factor that brings sustainability to the forefront is the inadequacy of resources and the depletion of resources against ever-increasing and diversified needs.

The concept of sustainability has shifted in meaning over the years. Sustainability has been a fundamental conceptual framework for community development since this approach became popular in 1987. The definition of a sustainable community accepted in the global world is known as a "society that meets the needs of today without compromising the ability to meet future generations' needs" [15]. The dimensions of sustainability are defined in "three pillars" as environmental, social, and economic according to equal importance [12]. The Sustainable Development Goals are a set of 17 interlinked goals that are key to achieving a better and more sustainable future for the world. Many global challenges that people have to face such as peace, poverty, climate change, inequality, environmental degradation, and justice are addressed. It continues to play a dominant role as the development paradigm of choice for most policies and program actions carried out by governments, communities, and businesses today. Due to this crucial role, the aim of this study is to analyze the literature on technology management and sustainability.

The rest of the article is structured as follows: a literature review includes information on sustainable technology management (STM) over the last decade. Then, the methodology section provides detailed information on articles, keywords, and journals. The results of the analysis are given in the results section. Lastly, the findings and suggestions for future studies are discussed in the conclusion section.

2. LITERATURE REVIEW

The meaning of sustainability is an emerging concept that promotes significant study and reflection on several issues for instance social equity, public welfare, and economic development at least concerning environmental concerns. That's why difficult to draw sharp boundaries to the definition of sustainability. On the other hand, the literature is examined and the number of studies involving sustainability and technology management is very few. According to the Web of Science (WoS) database, there are only 9 articles in all fields of "sustainable technology management". The information of authors, publication year, method, and data type used in these studies are listed chronologically in Table 1. As can be seen from table, patent information was used as data in most of the existing studies [2, 4-7, 11]. The first study on this subject was about a framework of the technology management field of knowledge as it relates to sustainable development [1]. Reference [14] focus on determining the sustainability indicators at the macro level of the national economy. Reference [2] propose a patent analysis based on statistical analysis for STM. Reference [7] shows a discussion about a hybrid patent analysis method for managing sustainable technologies. There is a comparison of the technologies to determine the evolution of 3D printing technology and technological innovation [11]. Another study is

TABLE 1
"Sustainability technology management" studies from the WoS database

Author (s)	**Year**	**Method**	**Data**
Jun	2019	Bayesian regression; patent analysis; artificial intelligence	Patent data
Kim et al.	2019	Time series and copula models	Patent data
Kim et al.	2018	Text mining, a frequency and co-word analysis	Patent data
Yoon et al.	2018	Technology assessment system (K-TOL)	Liquefied natural gas (LNG) industry case study
Park et al.	2017	Statistical technology analysis, social network analysis	Patent data
Choi et al.	2016	Statistical patent analysis	Patent data
Kim et al.	2016	Data mining techniques	Patent data
Todorović et al.	2011	Objectives matrix model	Concrete data on air quality in Serbia
Brent& Pretorius	2008	Mind map	Journals and papers

about technology assessment model for the sustainable development of liquefied natural gas [16]. Reference [6] proposes a methodology from single patent documents using relevant papers for extracting valid keywords. Lastly, Jun establishes a technology analysis model for STM by using these characteristics of Bayesian statistics [4]. There is clearly a gap in the literature on sustainable technology management. This study aims to analyze the literature on technology management and sustainability using bibliometric analysis and fill this gap.

3. METHODOLOGY

Bibliometric analysis is a method of analyzing all published research on specific topics in databases. The bibliometric method allows us to analyze thousands of studies together, reveal author, word, and citation relationships, and use visual mapping [17]. It is a quantitative research method that provides a general framework and gives information about current trends by analyzing documents related to a research field in detail [9]. Bibliometric analysis has been used in different areas for instance operations research and management science [9], AHP and TOPSIS [18], innovation and sustainability [3], sustainability and risk management [10].

In this study, a bibliometric analysis study was carried out in line with the studies carried out in the field of sustainable technology management in recent years and available in the literature. The data to be analyzed in the bibliometric analysis method in the study were drawn from the WoS. The subject title was chosen as the search type in the WoS database. Searching the database in the form of the subject means that the keywords are searched in the title of the articles, abstract, and keywords. A general search was conducted in the database using the keyword "Sustainable Technology Management" and a total of 9 studies were found. To analyze the subject more comprehensively, an advanced search was made by adding the keyword "sustainable technology management" or "sustainable" and "technology" and "management" together and 24954 studies were found. Since the keywords used are frequently used in the articles, some limitations were added to the study. Studies between 2023 and 2013 were included in the analysis to keep the subject up to date and to determine the trends. As a result of this limitation, 20144 studies were reached. Studies searched in the SSCI, SCI-EXPANDED, and A&HCI citation index were included in the analysis and 13785 studies were reached. Since it was planned to include only articles in the analysis, book chapters, conference papers, and review articles were not evaluated and 10399 studies were reached with this limitation. A total of 10326 article data were included in the study, with the addition of the articles being published in English as the last constraint. In the analysis of the obtained data, maps related to the data were presented by using VOSviewer 1.6.19 software version.

4. RESULTS

The study shows that the number of articles on this topic increased rapidly over the years. According to the WoS database, Figure 1 shows the distribution of research over time. It can be seen that the studies on this topic have increased rapidly over the years. Since 2023 has not yet been completed, it is not included in the figure. Table 2 lists the top five research areas of the articles. It can be seen that the journals deal with the subject mostly in terms of environmental sciences ecology, science technology, and engineering. According to Table 2, 47.60% of the studies on STM were studied by researchers in environmental sciences ecology, 31.13% by science technology researchers, and 25.54% by engineering researchers. Most of the publications were in the journals “Sustainability”, “Journal of Cleaner Production”, “Energies”, “Journal of Environmental Management” and “Science of the Total Environment”, respectively. On the other hand, the most cited journals are “Journal of Cleaner Production”, “Sustainability”, “Technological Forecasting and Social Change”, “Science of the Total Environment” and

"Resources Conservation and Recycling" respectively. Table 3 lists the top ten journals by articles and citations in the study. The most publications on the subject are in the journal Sustainability with a rate of 14.35% and 1482 articles. Journal of Cleaner Production is in second place with a rate of 7.43% and 768 articles. In addition, the Journal of Cleaner Production is the most-cited journal with 29744 citations in this study. Sustainability, the journal with the highest number of publications, became the second most cited journal with 14306 citations. Even though the Journal of Cleaner Production ranks second in Table 3 in terms of the number of publications, it can be seen that it is ranked first in terms of number of citations.

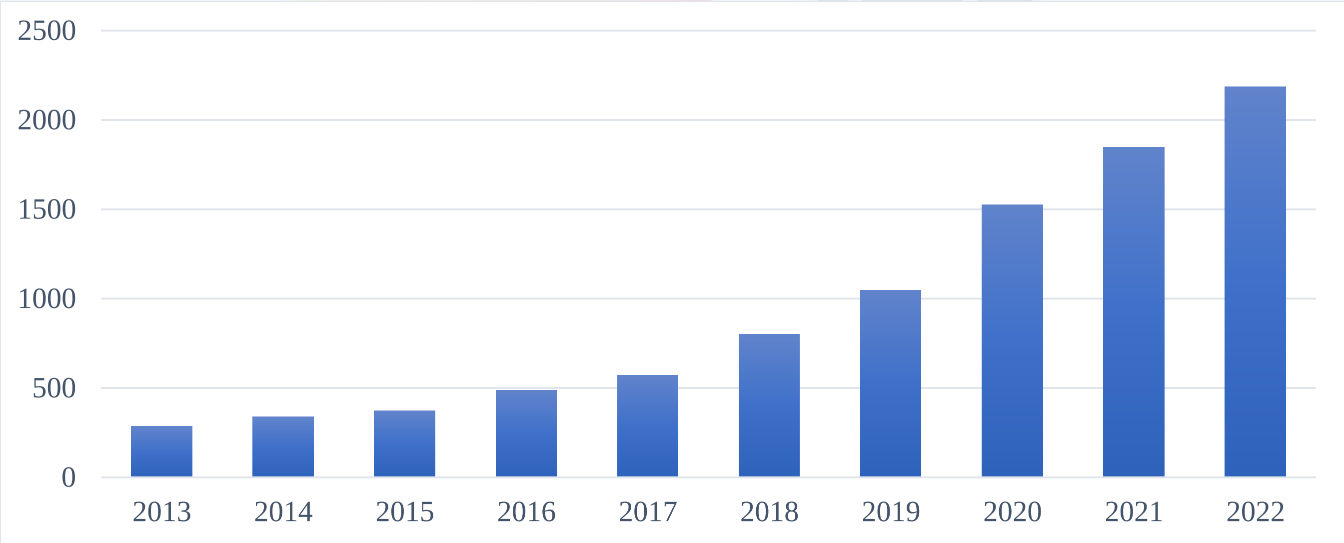

FIGURE 1
Number of publications by years

TABLE 2
Top five research areas of articles in the study

Area	Number of Articles	%
Environmental Sciences Ecology	4960	47.605
Science Technology Other Topics	3244	31.135
Engineering	2661	25.540
Business Economics	972	9.329
Energy Fuels	932	8.945

Figure 2 shows the network analysis of the top high-occurrence keywords. The most frequently used word in the articles was sustainability. Afterward, it can be seen that the most frequently used keywords are "sustainable development, circular economy, renewable energy, management, and climate change". Five main clusters of keywords were detected when conducting a co-occurrence analysis of the articles in this study. The clusters are of similar size. For example, Cluster 1 (in red) has 63 units, and Cluster 2 (in green) has 55 units. The biggest difference between clusters, Cluster 1 and Cluster 2, is only 8 units. Cluster 3 (in blue) has 36 units, Cluster 4 (in yellow) has 35 units and Cluster 5 (in purple) has 32 units, respectively. The main keyword "sustainability" was mentioned 1003 times, with a total link strength of 1407. After that, the second keyword is "sustainable development" with 631 occurrences and total link strength of 761. Both are in the green cluster. In the same cluster "technology" occurs 90 times and the total connection strength is 163. According to the rank of occurrences, the third keyword is "circular economy" with 353 occurrences and a total link strength of 654 located in the yellow cluster. The fourth is "renewable energy" with 180 occurrences and a total link strength of 274 in the purple cluster. Finally, in the red cluster, "climate change" is mentioned 175 times and the total link strength is 235.

TABLE 3

Top ten journals by articles and citations in the study

Rank	**Journals by Article**	**Articles**	**Rank**	**Journals by Citation**	**Citations**
1	Sustainability	1482	1	Journal of Cleaner Production	29744
2	Journal of Cleaner Production	768	2	Sustainability	14306
3	Energies	196	3	Technological Forecasting and Social Change	4743
4	Journal of Environmental Management	153	4	Science of the Total Environment	4525
5	Science of the Total Environment	135	5	Resources Conservation and Recycling	3893
6	Environmental Science and Pollution Research	115	6	IEEE Access	2979
7	Water	106	7	Journal of Environmental Management	2911
8	Resources Conservation and Recycling	101	8	Waste Management	2766

9	Technological Forecasting and Social Change	97	9	Water Research	2664
10	IEEE Access	83	10	Applied Energy	2628

5. CONCLUSIONS

The fact that the studies in the field of sustainability and technology management have increased and gained importance in the literature, makes it necessary to examine the studies on this subject. In this context, we see how important the bibliometric analysis studies in the literature are. The articles on sustainable technology management in the WoS database were reviewed against a set of criteria and subjected to bibliometric analysis in the study. A total of 10326 articles between 2013 and 2023 were analysed using the VOSviewer software version 1.6.19, which was used to create the network map and to visualise the literature. The distribution of studies by research areas is seen to focus on environmental sciences ecology, science technology, and engineering. The journals in which the 10,326 articles analyzed in the study were published are listed. Sustainability is the journal that published the most articles in this field with a higher availability of 1482 articles. The Journal of Cleaner Production is in second place with 768 articles. On the other hand, Journal of Cleaner Production is the most cited journal in this field with 29744 citations. Sustainability, the journal with the highest number of publications, became the second most-cited journal with 14306 citations. Although the Journal of Cleaner Production ranked second in terms of number of publications, it ranked first in terms of number of citations. It is noteworthy that Technological Forecasting and Social Change, which ranks ninth in number of publications, is the third most cited journal with 4743 citations. This shows that these journals are important and influential in this field. The analysis was also evaluated in terms of the number of studies and citations. While the author with the most publications has 1252 citations with 31 studies; the other author, whose number of studies was 16, became the highest-cited author with 2634 citations. The VOSviewer created five clusters for network analysis with the co-occurrence of author keywords. Cluster 1 is the biggest cluster with 63 units. The most frequently used keyword was "Sustainability" with 1003 occurrences and 1407 total link strength located in the green cluster. It was followed by the keyword "sustainable development" with 631 occurrences and a total of 761 link strengths in the same cluster. This shows that the term sustainability is often used together with sustainable development. Also, the keyword "technology" appears 90 times and has a total of 163 total link strengths in the green cluster too.

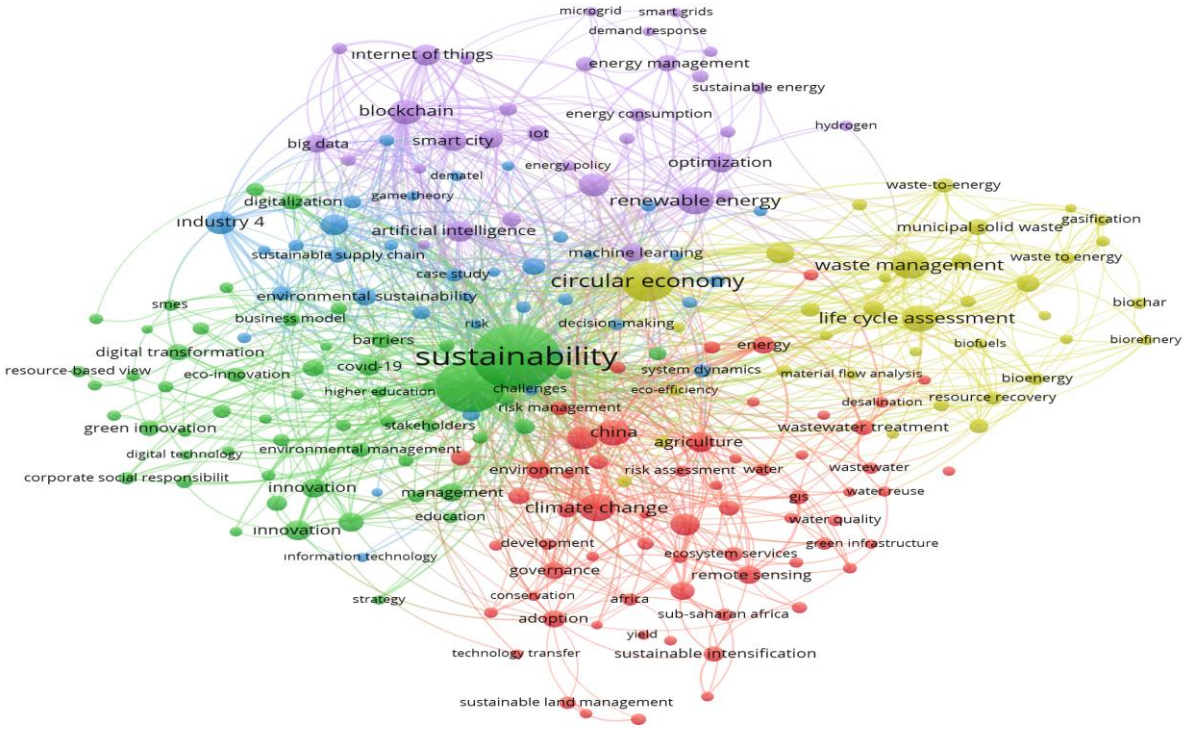

FIGURE 2
Network Analysis with co-occurrence of author keywords.

According to the results of the study, the number of studies in this field will continue to increase in the years to come. The study shows the topics, keywords, authors, and citations where research on sustainable technology management is conducted. This study helps to identify a research agenda in this area. It is expected that the results of the research will guide researchers in future studies on this subject. It is estimated that within the scope of the information in the findings section, it can give an idea to the researchers in the selection of the article topic. The study can be expanded by considering other databases in future research. In future studies, studies can be prepared for different periods by choosing different databases such as Scopus or Springer Link. The type documented in this study is limited to articles. However, conference proceedings, reviews or book chapters can be considered in future studies. Moreover, the collaboration between the authors and institutions may be analyzed in further research.

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SELECTING BEST FIRM ALTERNATIVE IN COLD FOOD SUPPLY CHAIN USING DECOMPOSED FUZZY SET BASED VIKOR METHOD

Özlem Arslan[1], Selçuk Çebi[2]

Abstract *– With the world-shaking impact of the COVID-19 pandemic, the importance of the supply chain has once again come to the fore. The breaks in the supply chain have negatively affected many product costs in the retail sector, especially inflation. During the global crisis, it is necessary to determine the effective factors in the supply chain and the interaction between these factors and to develop measures for the relevant factors. For this reason, decomposed fuzzy set based VIKOR method has been presented in this study. Decomposed fuzzy set is a fuzzy set extension that has just been presented in the literature. The contributions of this study are that the VIKOR method is the first time extended to decomposed fuzzy sets and best firm alternative in the cold food supply chain has been selected using the proposed approach.*

Keywords , Decomposed Fuzzy Sets, MCDM, Supply Chain Management, VIKOR Method

1. INTRODUCTION

When solving some real world problems, there are situations where the available alternatives need to be ranked under certain criteria [1]. Various methodologies have been developed to solve decision-making problems that involve multiple goals, criteria or objectives that may conflict with each other, and these are called multi-criteria decision-making methods. For this reason, some methods are presented under the title of multi-criteria decision making (MCDM) methods. The general structure of MCDM methods is to formulate alternatives, determine the evaluation criteria, calculate the criteria weights and finally rank the alternatives using a ranking method [2]. Thus, a ranking is obtained from the most suitable alternative to the least suitable alternative under the specified criteria. VIsekriterijumska optimizacija i KOmpromisno Resenje (VIKOR) method is also one of the most frequently used MCDM methods [3]. This method helps the decision maker to make a decision by finding the alternative that is closest to the ideal. The VIKOR method can be used in its traditional form or it can be extended with fuzzy in cases

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where there is uncertainty. On the other hand, when the literature is examined, it is seen that it is also used with many fuzzy extensions. In this study, the VIKOR method is extended with Decomposed Fuzzy Set (DFS) for the first time as DF VIKOR and explained with an application. The final outcome intended to be obtained is to choose the most suitable one among five companies operating in the cold food supply chain, taking into account the specified criteria. For this purpose, the DF VIKOR method has been chosen. The main reason for selecting this method is to take into account the inconsistent responses or indecision of decision-makers when collecting their evaluations. In this way, a more valid and reliable approach is utilized when selecting the most suitable cold food chain company alternative. Linguistic evaluations from decision makers are vital for solving the fuzzy MCDM problem. For this reason, it is important to get the most accurate information from decision makers by asking relevant questions. DFS is a new fuzzy set extension that aims to get more and clearer information from decision makers by asking questions from an optimistic and pessimistic perspectives [4]. In existing fuzzy set extensions, decision makers are asked one-way questions to get answers; in DFS, decision-makers are asked two-way questions, both optimistic and pessimistic, and the differences and inconsistencies arising from their perspectives are taken into account. It makes it more cautious and reliable than other fuzzy set extensions. For this reason, the VIKOR method, one of the most used MCDM methods, was extended to DFS, a new fuzzy set extension, and it was aimed to select the best alternatives for companies operating in the cold food supply chain. One of the aims of this study is to explain the steps of DF VIKOR method, which is presented to the literature for the first time, and to illustrate it with an application on the cold food supply chain. Our study structured as follows: A literature review related to topic is given in Section 2. Section 3 explains the proposed methodology and a case study from a cold food supply chain industry is given in Section 4. The conclusion is summarized in Section 5.

2. LITERATURE REVIEW

The cold food chain constitutes an important part of the supply chain and is very important for the transportation of food products that may spoil. During transportation of the products, any deterioration must be prevented by providing adequate cooling/freezing degrees to the food products. Otherwise, spoilage of food products, endangering customer health, and damage to the economy by causing waste are inevitable consequences. When the literature is examined, it is seen that there are many studies on the food supply chain, but the number of studies on the cold food supply chain is insufficient. This situation led us to the field of Cold Food Supply Chain, integrating the well-known VIKOR method with DFS, which is newly introduced to the literature, and helping us find the best cold food company alternative. The VIKOR is a well-known method among MCDM methods and is a useful for ranking alternatives. Considering that real life problems involve uncertainty and imprecise situations, we see that many MCDM methods are integrated with fuzzy. The VIKOR method, like other MCDM methods, is often used with fuzzy for situations with uncertainty and vagueness. Since there are hundreds of studies on the VIKOR method in the literature, the articles examined in this study are limited to last 5 years. In this study, we reviewed the studies in which the VIKOR method has been integrated with fuzzy in the last 5 years and found an increase in the number of studies. The review in the literature was found by searching under the topic "fuzzy VIKOR". That growing trend can be seen in Figure-1. Considering that the year 2023 has not been completed yet, it can be seen that this number may increase this year as well.

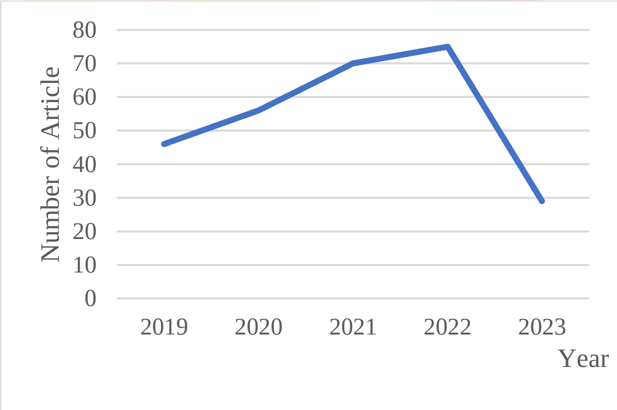

FIGURE 1

Number of Fuzzy VIKOR Method by Years

MCDM methods can be used with traditional fuzzy logic as well as with fuzzy set extensions. This also applies to the VIKOR method. Figure 2 shows the number of studies in which the VIKOR method has been integrated with fuzzy set extensions in the last 5 years. It can be concluded that it is used more frequently with some fuzzy set extensions and less with others. The least study seems to be with the neutrosophic fuzzy set. Deveci et al [5]. used the neutrosphic fuzzy VIKOR method for the selection of a technology that aims to enable users to communicate with each other to be used in the transportation sector. There is quite a lot of work with the Pythagoren fuzzy set. Chen [6]. proposed a new distance index-based VIKOR method in PF environment, demonstrating its applicability in real-world problems such as performance evaluation, quality evaluation. Cui et al [7]. addressed the problem of site selection of electric vehicles and utilized the PF VIKOR method. Gul et al [8]. conducted a risk assessment study in underground mining, which is considered very dangerous for occupational safety, with the PF VIKOR method and applied it on a case. The extention of the VIKOR method with Intuitionistic fuzzy has also been widely seen in the literature. Li et al. [9] used IF VIKOR method for planning landscape resources in rural tourism. Again as a risk assessment, Fu et al [10]. extended FMEA method by utilized the IF VIKOR, and used it in the railway sector. Spherical fuzzy VIKOR is used by Gundogdu and Kahraman [11] for a warehouse location selection problem. For the selection of beef supplier, Meksavang et al [12] utilized picture fuzzy VIKOR method.

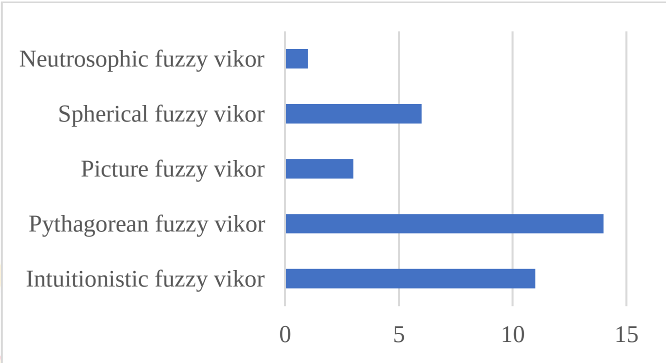

FIGURE 2

Fuzzy Set Extensions of the VIKOR Method in the last 5 years.

As can be seen from these studies in the last 5 years, while different fuzzy set extensions are used with the VIKOR method, there is no study that includes DFS which is newly presented to the literature and VIKOR integration. For this reason, in this study, the VIKOR method has been extended with DFS and explained with an application on the cold food supply chain.

3. METHODOLOGY

3.1. Decomposed Fuzzy Sets

DFS which is an extension of intuitionistic fuzzy sets, was presented to the literature by Cebi et al [4].

Definition 3.1: A decomposed fuzzy sets can be defined follows:

$$\tilde{A} = \left\{\langle x, \left(O\left(\mu^{o}_{\tilde{A}}(x), v^{o}_{\tilde{A}}(x)\right), P\left(\mu^{p}_{\tilde{A}}(x), v^{p}_{\tilde{A}}(x)\right)\right) \mid x \in X\rangle\right\} \quad (1)$$

Definition 3.2: Let $\tilde{\alpha}=\{O(a,b), P(c,d)\}$, $\tilde{\alpha}_1 = \{O(a_1,b_1), P(c_1,d_1)\}$ and $\tilde{\alpha}_2 = \{O(a_2,b_2), P(c_2,d_2)\}$ be DFS. The operators given below:

Addition:

$$\tilde{\alpha}_1 + \tilde{\alpha}_2 = \left\{O\left(\frac{a_1+a_2-2a_1a_2}{1-a_1a_2}, \frac{b_1+b_2-2a_1a_2}{b_1+b_2-b_1b_2}\right), P(c_1+c_2-c_1c_2, d_1d_2)\right\} \quad (2)$$

Multiplication:

$$\tilde{\alpha}_1 x \tilde{\alpha}_2 = \left\{O(\tilde{\alpha}_1\tilde{\alpha}_2, b_1+b_2-b_1b_2), P\left(\frac{c_1c_2}{c_1+c_2-c_1c_2}, \frac{d_1+d_2-2d_1d_2}{1-d_1d_2}\right)\right\} \quad (3)$$

Multiplication by a scalar:

$$\lambda.\tilde{\alpha} = \left\{O\left(\frac{\lambda a}{(\lambda-1)a+1}, \frac{b}{\lambda-(\lambda-1)b}\right), P\left((1-(1-c)^{\lambda}), d^{\lambda}\right)\right\} \text{ for } \lambda > 0. \quad (4)$$

λth power of $\tilde{\alpha}$, λ>0:

$$\tilde{\alpha}^{\lambda} = \left\{O(a^{\lambda}, 1-(1-b)^{\lambda}), P\left(\frac{c}{\lambda-(\lambda-1)c}, \frac{\lambda d}{(\lambda-1)d+1}\right)\right\} \text{ for } \lambda>0. \quad (5)$$

Definition 3.3: Let $a_i = \{O(a_i, b_i), P(c_i, d_i)\}$ be a colletiction of Decomposed Weighted Arithmetic Mean (DWAM) with respect to, $\lambda_i = (\lambda_1, \lambda_2, \ldots. \lambda_n)\lambda_i \in [0,1]$ and $\sum_{i=1}^{n} \lambda_i = 1$,
DWAM $((\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots\ldots \tilde{\alpha}_n) = \lambda_1.\tilde{\alpha}_1 + \lambda_2.\tilde{\alpha}_2 + \cdots + \lambda_n.\tilde{\alpha}_n$

$$=\left\{O\left(\frac{\sum_{i=1}^{n}\lambda_i a_i}{1+\sum_{i=1}^{n}\left(\lambda_i a_i - \frac{a_i}{n}\right)}, \frac{\prod_{i=1}^{n} b_i}{\sum_{i=1}^{n} b_i^{n-1}\lambda_i(1-b_i)+\prod_{i=1}^{n} b_i}\right), P\left(1-\prod_{i=1}^{n}(1-c_i)^{\lambda_i}, \prod_{i=1}^{n} d_i^{\lambda_i}\right)\right\} \quad (6)$$

Definition 3.4: Let $a_i = \{O(a_i, b_i), P(c_i, d_i)\}$be a collection of Decomposed Weighted Geometric Mean (DWGM) with respect to $\lambda_i = (\lambda_1, \lambda_2, \ldots. \lambda_n)$, $\lambda_i \in [0,1]$ and $\sum_{i=1}^{n} \lambda_i = 1$.
DWGM $((\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots\ldots \tilde{\alpha}_n) = \tilde{\alpha}_1^{\lambda_1} x \tilde{\alpha}_2^{\lambda_2} x \ldots. \tilde{\alpha}_n^{\lambda_n}$

$$=\left\{O\left(\prod_{i=1}^{n} a_i^{\lambda_i}, -\prod_{i=1}^{n}(-b_i)^{\lambda_i}\right), P\left(\frac{\prod_{i=1}^{n} c_i}{\sum_{i=1}^{n} c_i^{n-1}\lambda_i(1-c_i)+\prod_{i=1}^{n} c_i}, \frac{\sum_{i=1}^{n}\lambda_i d_i}{1+\sum_{i=1}^{n}\left(\lambda_i d_i - \frac{d_i}{n}\right)}\right)\right\} \quad (7)$$

Definition 3.5: The consistency index (CI) of the decomposed fuzzy number $(\tilde{a} = \{O(a,b), P(c,d)\})$ is defined as:

$$CI = 1 - \sqrt{\frac{(a-d)^2+(b-c)^2+(1-a-b)^2+(1-c-d)^2}{2}} \quad (8)$$

Definition 3.6: The score index (SI) of the decomposed fuzzy number $(\tilde{a} = \{O(a,b), P(c,d)\})$ is defined as:

$$SI(\tilde{a})\begin{cases}\frac{(a+b-c+d)CI(\tilde{a})}{2k}, & SI(\tilde{a}) \geq 0\\ 0, & SI(\tilde{a}) \leq 0\end{cases} \quad (9)$$

k is obtained by applying the formula below:

$$k = (a_{max} + b_{min} - c_{min} + d_{max})xCI^{*}(\tilde{a})/2 \quad (10)$$

Definition 3.7: The distance between two DF number $\tilde{\alpha}_1 = \{O(a_1, b_1), P(c_1, d_1)\}$ and $\tilde{\alpha}_2 = \{O(a_2, b_2), P(c_2, d_2)\}$ can be found as [13]:

$$= \sqrt{\frac{1}{4}[(a_1-a_2)^2 + (b_1-b_2)^2 + (c_1-c_2)^2 + (d_1-d_2)^2]} \quad (11)$$

3.2 Decomposed Fuzzy VIKOR (DF VIKOR)

Step 1: Following the basic logic of DFS, decision makers are asked optimistic and pessimistic questions under each criterion, for each alternative. Considering the scale in Table-1, linguistic evaluations of the decision makers are taken. Convert the linguistic evaluations to corresponding DFNs. Construct the decomposed fuzzy decision matrix. Also determine the criteria weights $w_j (j = 1,2, \dots, J)$.

TABLE 1

Fuzzy Linguistic Scale

Linguistic Terms	μ	ν
Absolutely Low (AL)	0.05	0.9
Very Low (VL)	0.25	0.6
Low (L)	0.4	0.5
Medium (M)	0.5	0.5
High (H)	0.7	0.2
Very High (VH)	0.85	0.05
Absolutely High (AH)	0.9	0.05

Step 2: Aggregate decision makers' assessments (if there is more than one decision maker) using (6) or (7) and calculate the Score Index (SI) by utilizing (9). Suppose the alternatives A_i $(i = 1,2, \dots, l)$, and criteria C_j $(j = 1,2, \dots, J)$. Choose ideal values $h_j^* = max_i h_{ij}$ and $h_j^- = min_i h_{ij}$, that can be defined as the best and worst values of A_i over the benefit criterion C_j. The best and worst values of A_i over the cost criterion are $h_j^* = min_i h_{ij}$ $h_j^- = max_i h_{ij}$.

Step 3: Compute the values of $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$. The distance calculation can be done by utilizing (11).

$$\tilde{S}_i = \sum_{j=1}^{J} w_j \frac{d\left(h_j^*, h_{ij}\right)}{d\left(h_j^*, h_j^-\right)} \quad (12)$$

$$\tilde{R}_i = max_j \left(w_j \frac{d\left(h_j^*, h_{ij}\right)}{d\left(h_j^*, j_j^-\right)} \right) \quad (13)$$

$$\tilde{Q}_i = v \frac{\tilde{S}_i - \tilde{S}^*}{\tilde{S}^- - \tilde{S}^*} + (1 - v) \frac{\tilde{R}_i - \tilde{R}^*}{\tilde{R}^- - \tilde{R}^*}$$
(14)

$\tilde{S}^* = min_i \tilde{S}_i$, $\tilde{S}^- = max_i \tilde{S}_i$, $\tilde{R}^* = min_i \tilde{R}_i$, $\tilde{R}^- = max_i \tilde{R}_i$, v is the maximum overall utility and generally accepted as 0.5.

Step 4: Rank the alternatives according to $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$ values. The solution should satisfy both of the following conditions:

Condition 1: $\tilde{Q}(A^2) - \tilde{Q}(A^1) \geq \frac{1}{l-1}$

Condition 2: A^1 should be ranked best by $\tilde{S}_i$ and $\tilde{R}_i$.
If these two rules are not met at the same time, skip to Step 5.
Step 5: In case of not satisfying the Condition 1, find the maximum value of N according to (15).

$$\tilde{Q}(A^N) - \tilde{Q}(A^1) < \frac{1}{J-1} \tag{15}$$

All alternatives of $A^{(i)}$is solution.
In case of not satisfying the Condition 2, A^1 and A^2 are solution.

4. CASE STUDY

As it is well-known, in the cold food supply chain, the flawless transportation of food products holds particular significance. This is because any issues that may arise during the transportation of these food products can lead to potentially hazardous consequences. Therefore, companies operating within the cold food supply chain must have various qualifications and be carefully selected. As a result of detailed literature review in the field of cold supply chain, a pool consisting of many main and sub-criteria was created. In order for the presented method to be understandable, only 3 main criteria from that pool have been considered. C1: Financial Criteria, C2: Quality Criteria, C3: Social Criteria. What we aim to find is which of the five alternative companies operating in the cold food supply chain is the most preferable, considering the specified Financial, Quality, and Social Criteria.

Step 1: Linguistic evaluations of the decision maker were taken by asking two questions that have the same meaning but were asked differently (optimistic & pessimistic) under each criterion, and they were converted the corresponding DF numbers. Results are summarized in Table 2 and Table 3.

TABLE 2

Decomposed Fuzzy Linguistic Evaluations

	C1		C2		C3	
A1	L	H	M	L	M	L
A2	M	H	M	M	H	L
A3	M	L	H	L	H	M
A4	H	H	VL	H	L	L
A5	VH	L	M	H	M	VL

TABLE 3

Decomposed Fuzzy Decision Matrix

	C1				C2				C3			
A1	0,4	0,5	0,7	0,2	0,5	0,5	0,4	0,5	0,5	0,5	0,4	0,5
A2	0,5	0,5	0,7	0,2	0,5	0,5	0,5	0,5	0,7	0,2	0,4	0,5
A3	0,5	0,5	0,4	0,5	0,7	0,2	0,4	0,5	0,7	0,2	0,5	0,5
A4	0,7	0,2	0,7	0,2	0,25	0,6	0,7	0,2	0,4	0,5	0,4	0,5
A5	0,85	0,05	0,4	0,5	0,5	0,5	0,7	0,2	0,5	0,5	0,25	0,6

Step 2: In order to calculate h_j^* and h_j^- values, score indexes (SI) of DF numbers were calculated by using (9). The results were presented in Table 4.

TABLE 4

(SI) Values of Alternatives

	C1	C2	C3
A1	0,133	0,423	0,423
A2	0,157	0,428	0,332
A3	0,423	0,332	0,283
A4	0,084	0,127	0,367
A5	0,272	0,157	0,451

Step 3: $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$ values were calculated using (12), (13) and (14). Note that the criteria weights were considered equal in this case study. All values found are presented in Table 5.
Step 4: Alternatives were ranked according to the $\tilde{S}_i$, $\tilde{R}_i$ and $\tilde{Q}_i$ values.
Step 5: Compromise solution was derived. $\tilde{Q}_1 < \tilde{Q}_5 < \tilde{Q}_4 < \tilde{Q}_3 < \tilde{Q}_2$, $\tilde{R}_1 < \tilde{R}_5 < \tilde{R}_4 = \tilde{R}_3 < \tilde{R}_2$ and $\tilde{S}_1 < \tilde{S}_5 < \tilde{S}_4 < \tilde{S}_3 < \tilde{S}_2$. $\tilde{Q}_5 - \tilde{Q}_1 = 0.272 > 1/(5-1)$. So, A1 can be accepted as best alternative.

TABLE 5

Summary of All Values Found Using DFS-VIKOR Equations

	C1				C2				C3				$\tilde{S}_i$	$\tilde{R}_i$	$\tilde{Q}_i$
A1	0,4	0,5	0,7	0,2	0,5	0,5	0,4	0,5	0,5	0,5	0,4	0,5	0,575	0,314	0,000
A2	0,5	0,5	0,7	0,2	0,5	0,5	0,5	0,5	0,7	0,2	0,4	0,5	1,307	0,641	1,000
A3	0,5	0,5	0,4	0,5	0,7	0,2	0,4	0,5	0,7	0,2	0,5	0,5	0,835	0,422	0,343
A4	0,7	0,2	0,7	0,2	0,25	0,6	0,7	0,2	0,4	0,5	0,4	0,5	0,756	0,422	0,289
A5	0,85	0,05	0,4	0,5	0,5	0,5	0,7	0,2	0,5	0,5	0,25	0,6	0,754	0,412	0,272
h_j^*	0,5	0,5	0,4	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,25	0,6			
h_j^-	0,7	0,2	0,7	0,2	0,25	0,6	0,7	0,2	0,7	0,2	0,5	0,5			
$d(h_j^*, h_j^-)$	0,278				0,225				0,225						

5. CONCLUSION

MCDM methods are used in order to rank the available alternatives under multiple and conflicting criteria. The VIKOR method is a well-known method among these methods and is frequently encountered in the literature. In the literature, it is seen that the VIKOR method is extended with fuzzy set extensions.

In this paper, the VIKOR method was extended with DFS which was newly introduced to the literature, for the first time. The proposed DF VIKOR method has been applied on the cold food supply chain, which is an important area of supply chain, to provide a better understanding. By applying the DF VIKOR method, the decision makers made evaluations from a positive and negative point of view, therefore a more accurate evaluation was made by getting more information from the decision makers.

The cold food supply chain is an important part of supply chain. Every day, tons of perishable food products are distributed. During this distribution, it is very important to deliver these perishable food products to the customers safety. Because if sufficient coldness is not provided, the products may deteriorate, which adversely affects both the company's reputation and health of the customers.

First of all, a detailed literature review was made and a pool of criteria used in the cold food supply chain was created. Among these criteria, 3 important criteria (C1: Financial Criteria, C2: Quality Criteria, C3: Social Criteria) were selected. Under these criteria, 5 different company alternatives operating on cold food supply chain were evaluated with the DF VIKOR method. As a result of this evaluation, it was concluded that A1 company is the best alternative. By applying the DF VIKOR method in this study, we selected the best alternative from 5 companies operating in the cold food supply chain. The aim of choosing the best alternative could be done with any fuzzy set extension of the VIKOR method, but the aim of the DF VIKOR method is to take into account the uncertainties and inconsistencies that decision makers may give to the questions, thus achieving more effective results. The basic data used in decision-making problems are decision maker evaluations. For this reason, being able to receive decision-maker evaluations in the most accurate way plays an important role in reaching the right result. Therefore, it is to our advantage to use DFS when solving real-world decision-making problems.

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A BRIEF REVIEW ON BUSINESS MODELS WITH DIVERSE ROLES OF STAKEHOLDERS FOR ELECTRIC VEHICLES: A NOVEL BUSINESS MODEL PROPOSAL

Hakan ERDEŞ[1], Saadettin Erhan KESEN[2]

Abstract *– This study reviews business models on Electric Vehicles through diverse perspectives and discusses the future directions for more comprehensive researches. These perspectives are roles of stakeholders, type of electric vehicles, charging technologies, roles of investor for the charging infrastructure and charging strategies. First, the consitituing elements of a business model is presented, then a novel business model proposal to the literature is introduced following the literature review. The novel business model proposal distinguishes from its counterparts in several respects; (i) It contains a contract between a Charging Service Operator and a Commercial Electric Vehicle Fleet Owner Company, (ii) It covers both Noncommercial Electric Vehicles and Commercial Electric Vehicles. In this regard, the contribution of the paper is multifold; (i) Presenting new research perspectives for the full-scale adoption of electric vehicles, (ii) A novel business model proposal which can contribute in electrification in transportation. Limitations of the study are also discussed and the paper is concluded.*

Keywords – Electric Vehicles, Business Model, Charging Technologies, Logistics, Transportation

1. INTRODUCTION

Private transport and transportation industry are known as some of the biggest contributors to greenhouse gas emissions. The fact that these areas are mostly dependent on the internal combustion engine vehicles, it leads up to increament in the carbon emission. In parallel with this, the electrification of the transportation has become a crucial step for mitigating carbon emission, and commercial vehicles were responsible for the 40% of global CO_2 emissions in 2015 and even expected to be doubled from 2015 to 2050 [1]. In return for this, electric vehicles (EVs) led to 80 Mt of greenhouse gas emissions reduction in 2022 [9]. However, there are

[1] Hakan ERDEŞ, Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, Konya Technical University, Selçuklu/Konya, Turkey, herdes@ktun.edu.tr

[2] Saadettin Erhan KESEN, Department of Industrial Engineering, Faculty of Engineering and Natural Sciences, Konya Technical University, Selçuklu/Konya, Turkey, sekesen@ktun.edu.tr

various barriers in the electrification such as charging time and range anxiety [5]. These barriers can be overcome by investing in technological developments, yet in order for companies to invest in technological developments for EVs, the demand and interest must be scaling up. Despite the emergence of the first EVs in the late 1800s, internal combustion engine vehicles overtook EVs due to factors such as inadequacies in battery technology, cheap oil and inadequate electricity grid infrastructure [6] and it lasted more than 100 years for EVs to regain its momentum. Therefore, at the point of increasing interest in electrification, access to charging infrastucture for both noncommercial and commercial use should be easier, with lower cost and a smoother transition and also all types of EVs should be able to access to public charging stations in order to let investors (car makers, charging service operators, logistics companies etc.) can make profit throught the investments [1]. With the increase in EVs sales in the near future, more charging stations will be needed. Yet, utilisation rates may remain low during the phase of increasing charging resources and makes it harder to recover capital costs and earn profit for charging infrastructure developers [8] and may prevent all the aforementioned developments from accelerating further. In parallel to the support of the government to some actions such as the installation of charging stations, producing EV, purchase subsidies and applying tax benefits, the utilisation rates can be increased with various strategies and business models by private companies. These models should be applied in a sustainable way and it should be recalled that as the any other ecosystems, the electric vehicle ecosystem could be sustainable in the long run if the all the stakeholders are able to get a good business value, product or service [13].

The contribution of this paper can be summarized as follow; (i) This paper presents a short review of business model for EVs from various perspectives and propose one which has the potential of providing sustainability, higher utilisation rates and decreasing initial investment cost. (ii) To the best of the authors' knowledge, none of the papers has discussed a business model or a strategy covering noncommercial EVs, commercial EVs and charging service operator (CSO) simultaneously. In this context as a complementary to literature review, a business model proposal as an example is presented to literature. In this context, this paper firstly presents the nine building blocks of business model of Osterwalder and Pigneur (2010) [16] and display the way of generating a business model in Section 2. In Section 3, firstly the review papers which has directed this paper and has the potential of directing similar papers are discussed. Then, rest of the sub-sections of Section 3 presents the business models for electric vehicles in different fields. The reviewed papers are discussied and the limitations of the study is provided in Section 4. A business model proposal is briefly presented in Section 5. Finally, Section 6 concludes the paper and presents the future directions.

2. HOW TO GENERATE A BUSINESS MODEL

Generating a robust business model should be meeting several conditions like, creating value for the customers by providing valuable goods and services with multiple alteratives, providing profits for the parties that are creating values and services. EVs may have advantages in terms of efficiency or operational cost but still suffer from high investment costs [13]. In this respect, kind of strong strategies and robust business models have the potential of sustaining the EV industry and go a step further. Generating such robust business models with its constituting elements could be carried out by the Osterwalder and Pigneur (2010)'s [16] well known method "Business Model Canvas" which consists of nine building blocks. As they state, the challenging issue about creating a business model is that the concept must be simple, relevant, and intuitively understandable, while not oversimplifying the complexities of how enterprises function. They present a concept for generating a business model which is already used by giant firms all around the world. Relevant concept basically includes nine building blocks and their brief explanations are given as follows [16]:

Customer Segments: This block expresses the people or organizations that the enterprise gives service to. Value Propositions: It describes the product or service packages which create value for a customer. Channels: It is the method or way that the company deliver value proposition to the customer. This channel might be a website or a store. Customer Relationships: It might be carried out in a way that asssigning personal assistance or automated services as well. Revenue Stream: That covers the cash that the company get from the customers. It might be selling a product, usage fee, subscription fees, renting or leasing. Key Resources: They are the most pivotal assets that enable a business model to function. These resources let the company offer a value, manage relationships or earn revenue. Key Activities: The most crucial operations to be performed for a working business model; designing, producing, delivering and problem solving etc. Key Partnership: It covers the suppliers and the other partners who are the part of a functioning business model. It also enables a company to optimise the business model or reduce risk. Cost Structure: It is the overall cost incurred while working a business model; maintaining relationships, delivering value, generating revenue etc.

3. LITERATURE REVIEW

The body of literature review is divided into 6 main categories. It is initiated with the relevant literature review papers on EVs and business models. It is followed by the business models for commercial EVs and it includes a paper utilising from Osterwalder and Pigneur (2010)'s [16] method. Models related to different charging techologies are promising ones due to capacity of extending the key resources, customer segments and revenue streams, so it is presented as a separate section. Charging service operators which is placed in section 3.4 have an inevasible role in the EV industry. The question of "who to invest in charging infrastucture" is a burning question and different approaches related to this issues is presented in section 3.5. Charging at depot (return-to-base) or on-route is another dilemma for the commercial uses and discussed in section 3.6.

3.1. Related literature review papers based on EVs and business models

Ref. [11] presents a literature review depending on 136 published papers for the EVRP and its extensions. Ref [11] defines EVRP and discuss the variations of it, also present mathematical formulations and solution approaches. Some of the papers that they reviewed are also discussed in this paper in terms of business model concept in the following sections. As ref. [4] points out, EV is a global phenomenon and it is also a common concern for the entire world, namely governments and industries. That's why, this area contains lots of challenges and opportunities. Hereby, it a necessary to create holistic systems with promising technologies, policies and business models in order to achieve the tranformation for EVs. So, authors present various business models related to EV including charging infrastructure, market models, billing strategies, battery technology, fleet applications, carsharing and also business models from different countries. Ref. [22] reviews the literature on EV business models and focus on key insights considering the business model elements. Its focus is particularly passenger EVs namely noncommercial EVs rather than commercial EVs. Authors especially underline that conventional cars related business models may not be applicape for EVs due to technological limitations like higher initial cost and shorter range. Ref. [1] conducted a study which is mainly focusing on the charging infrastructure of commercial EVs and they present exhaustive review on studies related to commercial EV charging. While authors especially underline the charging of medium and heavy duty vehicles, two pivotal charging strategy are discussed in detail which are return-to-base and on- route strategies.

3.2. Business models for commercial EVs

Ref. [14] remarks that although the focus of the EV industry is primarily personal consumer market, namely noncommercial EVs, commercial EVs offer a enormous chance for the manufacturers. The author underlines that in case of commercial EVs, charging strategy plays a significant role so that, battery size can be optimised, the profit can be maximised and the cost of the vehicles can be minimised. So the importance of the smart charging is emphasized. Then the author presents proposes for charging infrastructure business model depending on the Osterwalder and Pigneur (2010)'s nine major building blocks and the model is centred on product service system in which product and service are integrated. In this context, product represents the commercial EV and service represents the charging service. The details of the business model proposed is as follow; Customer Segment is determined as urban goods distributors. Some of the main Value Propositions are zero-emission trucks and both smart and simple charging management. An online management platform and customer relationship management are shown as the main Channels of the business model. Due to EV leasing is very crucial for business model presented, Customer Relationship plays a more vital role for the durability and may be in a way that individual attention or consultation. While vehicle lease is the fundamental Revenue Stream, consultation and second use of batteries are also take place. Key Resources are presented as charging equipments, online platforms and other related resources for maintenance of the service. Deciding the vehicle type, optimal size, charge planning and the charging maintenance, conditions of leasing service are some Key Activities. Key Partners specified mainly as other potential charging infrastucture investors like EV supply equipment supplier or utility/distribution operator. Two main components of the Cost Structure are installation plus maintenance of charging infrastructure and information platform.

In [19], five different charging strategies are presented. These strategies are based on the mobility applications executed in Germany with aim of increasing the utilisation within the existing technological restrictions. They also develop key performance indicators based on the empirical evidence. They report that the indicators point to the use of EVs in fleets. Ref. [10] includes the companies with EV fleets which are jointly investing in charging infrastucture which means it covers commercial EVs.

Ref. [15] explores how a group of companies with fleet of EVs from different sectors can collaborate and share charging infrastructures to be more environmentally friendly and related four main business models are presented as follow; (i) a company that has a charging infrastructure shares its charging infrastructure with others, (ii) joint investment by companies in charging infrastructure in a common area, (iii) installation of the charging infrastructure jointly by the companies at a point where a common customers exist, (iv) management of charging infrastructure through a charging service operator for related companies.

3.3. Business models based on different charging technologies

Ref. [17] presents the "Electric Vehicle Routing Problem with Time Windows and Synchronized Mobile Battery Swapping (EVRPTW-SMBS)". In this problem, commercial EVs meet the demands of customers and battery swapping vehicles meets the battery demand of commercial EVs, which means they swap the depletted battery with a fully charged battery and it takes place at a predetermined location and time window. Even though the authors do not call this strategy as a business model, the model presented in the paper might be evaluated as a startup business model with its customer segment, value propositions, key activities etc. They simply present an opportunity to commercial EVs to charge their battery without spending extra time and energy. Another study by the same authors, a similar problem is presented and additionaly recharging stations are included [18]. It basically means that there is an extra cost for the cost structure and extra channel but at the same time it might reveal an extra customer segment and value propositions. Ref. [7] presents a business case depending on fast charging stations and it investigates mainly two scenarios in which 5% and 10% of the EV charging demand is met by fast charging respectively. Author also analyses both cases are for 5 and 10 years. Consequently, return of investments are compared. Refs. [19] and [10] which are presented in the previous section also includes multiple charging technologies as AC & DC charging and slow, moderate and fast chargings respectively.

3.4. Business models from the perspective of the charging service operator

Ref. [13] designates their view about the necessity of building up business models for charging service operators. Such that, these business models should let operators be able to recover their costs and also offer EV users reasonable pricess so that they can compete with internal combustion engine vehicles. To this end, the authors present three different scenarios based on different charging alternatives, charging power, charging station ownership and accessibility.

The fourth business model presented by ref. [15] and also included in section 3.2. depends on the logic of reducing the initial cost for companies with a fleet of EVs, having more flexibility of usage and a less commitment. Even though it is presented from the view of companies, it cracks the door for the perspective of charging service operator.

3.5. Investing in charging infrastructure

Ref. [12] offers four modes of developing charging infrastructures for EVs. Modes differ in terms of the side that invests in the infrastucture. These are EV manufacturers with a government subsidy to EV consumers, solely EV manufacturer, government by providing a subsidy to EV consumers and solely government. Authors report that the modes with a government subsidy to EV consumers are more effective and the mode EV manufacturer invests maximises the social welfare. Ref. [10] presents the electric vehicle routing problem with shared charging stations in which more than several companies invest in charging infrastructure jointly. These companies are running a distribution system and have fleet of EVs. In short, it could be infered that the side investing in charging infrastructure is EV fleet owner. By the way, the objective function of the problem is minimising the sum of the fixed building cost of charging stations and drivers costs. The study also includes more than one charging stations technolongy. The first three business models of ref. [15] depends on the investment by the EV fleet owner companies and it could be noted that the abovementioned paper which is ref. [10] is a kind of second business model presented by ref. [15].

3.6. Charging at depot or on-route

Ref [3] investigates commercial EVs for optimal charging problems both with charging stations at depot and with on-route public charging stations. They model the problem as an optimisation problem and provide the solutions. What they consider in the problems is features of public charging stations, waiting times, partial recharging, electricity tariffs and peak demand of the depot charging. They especially study on impacts of commercial EVs charging conditions at depots on charging schedules and at public charging stations as distinct from the relevant literature. They assume that the commercial EVs can get service from public charging stations. Ref. [2] especially studies on heavy EVs and proposes a smart charging system which is able to manage the charging process of heavy EVs, namely the electric trucks, at the commercial facilities. They study on return-to-base strategy for the electric truck, correspondingly the objective at the paper is minimising the peak demand aggregate load.

4. DISCUSSIONS AND THE LIMITATIONS OF THE STUDY

In this section, overall evaluation of the papers and the limitation of the study is addressed. First of all, it should be designated that none of the papers simultaneously discuss a business model which covers noncommercial and commercial EVs which belong to companies in logistics or in goods distribution in the reviewed articles. Even though there are papers that study noncommercial EVs and electric taxis [20], there is no comprehensive investigation and discussion on noncommercial and commercial EVs (logistics, good distribution etc.) simultaneously. So, commercial EV proposal of this paper is limited but could be extended with electric taxis or buses as well.

In the reviews, attention is drawn mainly to the following roles; charging service operator and EVs fleet owner companies. However, the study can be extended with a several other significant stakeholders. One of them is vehicle original equipment manufacturer also referred to automaker and they may have crucial role where there is no profitable business cases in order to bolster the market [14]. So, they can represent the roles of automaker and charging service operator simultaneously. There are additionaly two other roles presented by ref. [13]. One is the electro-mobility service provider which offers charging, routing and other services to EVs and the other one is marketplace operator which is a business-to-business environment where business partners can offer their EV services to be bought which include charging, reservation, routing etc. So, one can easily conclude that roles are not separated from each other with sharp lines.

As can be seen, the optimisation related papers especially indicate the charging technologies utilised ([10], [17], [18] and [3]). However, these are limited to AC charging, DC charging, battery swapping but could be extended to wireless charging, portable charging stations or road charging.

5. A BUSINESS MODEL PROPOSAL AS AN EXAMPLE

The proposed business model is presented through the eyes of the of charging service operator, so it is the investor for the charging infrastucture [15]. CSO provides service to both noncommercial EVs and commercial EVs belong to logistics companies which makes them the Customer Segment. CSO also presents a special service for commercial EVs depending on a contract which enables them to wait at charging stations less in response to an extra fee. Besides providing charging service to noncommercial EVs, special service to commercial EVs is a different kinf of Value Proposition. Even though charging at depot is not a negligible option, it also creates economic and technical contraints [1] and therefore applicable and reasonable on-route strategies are needed. Such that, on-route charging provides freedom of movement for the EV users and users are wishful to pay a bit more fee to get this service [13], which leads to conclusion that commercial EVs fleet owners to be wishful to pay extra fee in order to have freedom of routing, avoid initial investment and meet more customers' demand. On the other hand, Channels are slow and fast charging stations in the fixed charging stations, mobile charging vehicles and battery swapping vehicles. In order to manage the Customer Relationship with both noncommercial and commercial EVs, dedicated personnels could be employed. As is stated, main Revenue Stream is providing charging service plus special service to commercial EVs and it could be extended through different commitments (less waiting etc.). Charging resources and a mobile application in which customers can view the status of charging resources or make payment could be evaluated as Key Resource. In order to provide a service with higher quality and less cost, the CSO should decide amount and the capacity of charging resources, keep their offers updated, vehicle type of mobile chargers if exist and conditions of charging resource. So, these are some Key Activities. In this business model, the main Key Partnership of the CSO is the contracted commercial EV fleet owners. CSO can also have automakers or other CSOs as the partnership. Two main components of the Cost Structure are inherently installation and maintenance of charging infrastructure. The mobile application and mobile chargers are the other cost constituting elements.

6. CONCLUDING REMARKS AND FUTURE DIRECTIONS

In this paper, a novel business model proposal which covers both noncommercial and commercial EVs is presented with its constituting elements depending on Osterwalder and Pigneur (2010)'s [16] well known method "Business Model Canvas". To the best of authors's knowledge, such a business model is studied in literature for the first time. The paper that starts with the nine building blocks of business model continues with the literature review. The literature review covers other literature review papers and various business models in terms different types of EVs, charging technologies, roles of stakeholders, investors and charging strategies. As is beforementioned, the decision of who to invest in charging infrastructure is a significant question mark and it is determined that investor to be charging station operator. Charging station operator may referred to different names in the literature and may have extra roles or value propositions. There are varied charging options provided by CSO and the main charging strategy is charging on-route for the commercial EV fleet owners. The model also includes the noncommercial EVs as the customer segment. It is mainly due to dedicating a charging station to a group of EV or one type of EV may lead to low utilisation rates resulting in a higher initial cost. Because such a strategy leads to more charging resource installation and consequently to low utilsation rates [21]. On the other hand, the reviewed papers and the limitations of the study are also discussed. Considering all the information, reviews, discussions, limitations and the business model proposal, this explorative study can extended in several points;

(i) The business model proposal is presented briefly and no detailed information about technical specifications of EV or charging infrastructure, conditions of contract between the parties etc. is provided. So, it can be extended with a more comprehensive literature review and be elaborated. (ii) As is abovementioned, there are several other role of stakeholders which are not address in this paper like automaker or marketplace operator. However, they have undeniable roles in EV ecosystem. So, they can be integrated into business model by enlarging the literature review. (iii) Not only a contract between CSO and commercial EVs but also between CSO and noncommercial EVs can be taken into account. It might be in a way that providing special service or monthly or annual subscriptions which leads to new revenue streams.

(iv) This paper adopts the on-route charging strategy. However, different services can be designed for large scale companies that can already provide charging services at depot but still need charging on-route for as support force which generates extra value propositions. (v) Electric taxis, electric buses or other types of commercial EVs are not addressed in this paper. So, they can be integrated into this business model or even an indepented business model could be generated for them.

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