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Toros University FEASS Journal of Social Sciences is a peer-reviewed journal published twice a year and indexed by international. The journal covers scientific articles on research in social sciences such as economics, business, finance, accounting, history, political science, international relations, international trade and logistics, and psychology etc. The language of the journal is Turkish and English. In the case of the Word file, the candidate articles sent to ***http://dergipark.gov.tr/iisbf*** *are directed to the referee process after checking plagiarism and the compliance with the writing rules. The articles published in the journal belong to the author of language, science, legal and ethical responsibility. Articles cannot be used without reference.*

İçindekiler/ Context Sayfa/Page

Special Issue on International Symposium of Sustainable Logistics

This is the second special issue of Toros University FEAS Journal of Social Sciences. The articles published in this issue were found eligible for publication by being subject to the blind peer-review process applied within the scope of journal publication rules from the papers presented at 2nd International Symposium on Sustainable Logistics "Circular Economy" held on June, 23-24 2022, hosted by Toros University in 2022. The International Symposium on Sustainable Logistics was held online in cooperation with Toros University Faculty of Economics, Administrative and Social Sciences Department of International Trade and Logistics and Tokyo University of Marine Science and Technology (TUMSAT) and Jean Monnet Centre of Excellence on Sustainability (ERASME), with the support of the Logistics Association (LODER).

2nd International Symposium on Sustainable Logistics "Circular Economy" was held for the second time and attracted attention by researchers and industry representatives from home and abroad. Participants from 5 different countries (Estonia, France, Greece, Japan, and Turkey) attended at this organization. 60 papers were accepted to the symposium and 45 paper was presented in English and 15 papers was presented in Turkish as well.Papers within the scope of the symposium focused on Applied Logistics, Logistics in Business, Environmental Logistics, Agricultural Logistics and Marine Science. In this context, an academic discussion platform has been established.

In this special issue, 12 valuable full papers from among the ones presented at the symposium were to be appropriated for publication as result of the peer review.

4 different valuable keynote speakers delivered presentations at the symposium as well.

- ***Professor Dr., Michael Schneider, RWTH Aachen University-Germany***
  Title: Freight Transportation Using Electric Vehicles.
- ***Professor Dr., Hakan Keskin, İstanbul Aydın University***
  Title: he Role of Logistics for the Sustainable Development of Global Economy
- ***Assoc. Prof. Dr., Arnaud Diemer, Université Clermont Auvergne / Jean Monnet Centre of Excellence on Sustainability***
  Title: How Circular Dynamics redesign our economic system ? Drivers and Challenges
- **Assoc. Prof. Dr., *Ryuichi Shibasaki, The University of Tokyo, Graduate School of Engineering***
  Title: Logistics Analyses Using Maritime Big Data.

We hopefully that this special issue of Toros University FEAS Journal of Social Sciences will be fruitful to the all-academic world.

Toros University FEAS Journal of Social Sciences

Editors

Toros University FEASS Journal of Social Sciences
Special Issue on 2nd International Symposium of Sustainable Logistics "Circular Economy"
Toros Üniversitesi İİSBF Sosyal Bilimler Dergisi 2. Uluslararası Sürdürülebilir Lojistik "Dögüsel Ekonomi" Sempozyumu Özel Sayı

RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

ISSN: 2147-8414

Blockchain Technology and Sustainable Logistics: Integration in the Circular Economy

Blockchain Teknolojisi ve Sürdürülebilir Lojistik: Döngüsel Ekonomi Entegrasyonu

Emel YONTAR[1]

ABSTRACT

Recycling, reuse and reduction, which are among the "3R" actions of the circular economy, have an important place in ensuring resource efficiency. Minimizing the use of resources, ensuring their reuse and obtaining gains by recycling them at high standards can contribute to the sustainability studies of the logistics sector. This study covers associating the circular economy with blockchain technology, taking into account sustainable logistics studies. From the circular economy perspective, the features of blockchain technology that are thought to affect sustainable logistics; carbon emission reduction, logistics cost reduction, ease of communication, hacking, increased performance, data immutability, effective information sharing, transparency, uncertain legal situation, new technology and trust. From this point of view, the place of blockchain technology on the road to circular economy has been examined in the current study.

Keywords: Blockchain technology, Circular Economy, Sustainable Logistics, Logistics, Entropy Method

ÖZ

Döngüsel ekonominin "3R" eylemleri arasında yer alan geri dönüşüm, yeniden kullanım ve azaltma, kaynak verimliliğinin sağlanmasında önemli bir yere sahiptir. Kaynakların kullanımının en aza indirilmesi, yeniden kullanılmasının sağlanması ve yüksek standartlarda geri dönüştürülerek kazanımların elde edilmesi lojistik sektörünün sürdürülebilirlik çalışmalarına katkı sağlayabilir. Bu çalışma, sürdürülebilir lojistik çalışmaları dikkate alınarak döngüsel ekonomiyi blockchain teknolojisi ile ilişkilendirmeyi kapsamaktadır. Döngüsel ekonomi perspektifinden bakıldığında, sürdürülebilir lojistiği etkilediği düşünülen blockchain teknolojisinin özellikleri; karbon emisyonunun azaltılması, lojistik maliyetlerinin azaltılması, iletişim kolaylığı, bilgisayar korsanlığı, artan performans, veri değişmezliği, etkin bilgi paylaşımı, şeffaflık, belirsiz yasal durum, yeni teknoloji ve güven. Bu noktadan hareketle mevcut çalışmada blockchain teknolojisinin döngüsel ekonomiye giden yolda yeri incelenmiştir.

Anahtar Kelimeler: Blockchain teknolojisi, Döngüsel Ekonomi, Sürdürülebilir Lojistik, Lojistik, Entropi Yöntemi

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1. INTRODUCTION

Logistics activity, which is the last link of supply chain management, has become more important when it is associated with sustainability. Logistics activities not only make a significant contribution to economic performance, but also contain elements that must be taken into account in terms of environmental and social aspects. The first is responsible for consuming significant energy resources and generating greenhouse gas emissions. On the other hand, it causes air and noise pollution. Again, with the increase of industrialization, increasing wastes due to the use of resources bring along various problems. The signal of depletion of resources, that resource use is expected to increase threefold globally until 2050 due to the increase in consumption (Jaeger and Upadhyay, 2020), and the circular economy, which is a sustainable model as a result of seeking solutions to the increasing environmental pollution, may be an idea for the sector at this stage.

The circular economy model, which ensures the use of resources as long as possible, energy savings and reduction of waste by keeping the resources in the loop, is based on sustainability and was born against the known linear economy model.

Recycle, reuse and reduce, which are among the “3R” actions of the circular economy, have an important place in ensuring resource efficiency. Reduce, reducing the use of raw materials; Reuse, the most efficient reuse of products and components; Recycle means high quality reuse of raw materials. Minimizing the use of resources, ensuring their reuse and obtaining gains by recycling them at high standards can contribute to the sustainability efforts of the logistics sector. In the circular economy, waste is minimized by properly designing products and industrial processes so that resources and materials are constantly flowing and in use; The wastes and residues that are inevitable to come out are recycled or recovered (EMF, 2014).

On the other hand, technological developments provide various benefits to businesses on the way to sustainability. Blockchain technology, which is one of them and has been frequently heard in studies in recent years, can be the subject of sustainable studies within the scope of circular economy. Blockchain is recognized as a cost-effective technology (using smart contracts) to control communication between multiple participants in a reliable, efficient and decentralized manner (Nesarani et al., 2020). Blockchain technology includes three core technologies: asymmetric encryption algorithms, distributed data storage, and consensus algorithms. This technology can actually be defined as a system that allows the flow of information to be done reliably and without any outside interference.

While blockchain technology benefits the supply chain line in many ways, it is considered to be capable of solving many problems, especially when logistics activities are taken into account. In the literature, studies using blockchain technology within the scope of logistics activities and associating it with sustainability have been examined (Table 1).

Table 1. *Literature reviews contributing to the study*

Authors	Scope	Methodology	Sector
Tektaş and Kırbaç (2020)	A case study is conducted on the use of blockchain technology in logistics and supply chain, and an application study of this case study is carried out in a logistics company using appropriate methodological methods.	Case study	Logistics
Orji et al. (2020)	It proposes a technology-organization-environment (TOE) theoretical framework of critical factors affecting the successful adoption of blockchain technologies in the transportation logistics industry and prioritizes it using ANP.	ANP	Logistics

Tijan et al. (2019)	"It explores the decentralized data storage represented by blockchain technology and the possibility of its development in sustainable logistics and supply chain management."	Case study	Logistics
Sundarakani et al. (2021)	It explores the need for blockchain in the Industry 4.0 environment from the perspective of Big Data in supply chain management.	Case study	Logistics
Andreou et al. (2018)	In this study, a smart contract mechanism over blockchain is presented for advantages in logistics.	Case study	Logistics
Yi (2019)	It offers techniques to leverage blockchain to secure logistics.	Case study	Logistics
Sunmola and Apeji (2020)	It focuses on blockchain technology and explores sustainable supply chain visibility and features of blockchains.	Literature review	General
Upadhyay et al. (2021)	Discusses the current and potential compatibility of blockchain with circular economy.	Case study	General
Rejeb and Rejeb (2020)	It explores the blockchain literature and its relevance to supply chain sustainability.	Literature review	General
Kouhizadeh et al. (2021)	Provides a comprehensive overview of the barriers to adopting blockchain technology to manage sustainable supply chains.	DEMATEL	General
Esmaeilian et al. (2020)	It provides an overview of Blockchain technology and Industry 4.0 to drive supply chains towards sustainability.	Literature review	General
Yadav and Singh (2020)	It allows the use of blockchain technology to be explored and supply chain management to develop efficient sustainable supply chain management.	Fuzzy DEMATEL	General
Tsolakis et al. (2021)	It examines the design of blockchain-based food supply chains that support the Sustainable Development Goals.	Case study	Food
Nandi et al. (2021)	Using blockchain technology and circular economy principle capabilities, it offers a potential solution by addressing localization, agility and digitization (LAD) features.	Case study	General

In the circular economy integration of blockchain technology, which is considered within the scope of sustainability, its compliance with the supply chain line has had a positive effect in many studies. Some of the benefits can be listed as follows;

- Faster and error-free process management
- Accelerating the physical flow of goods thanks to its transparency feature
- Efficient process operations
- Preventing fraud in resource management and tracking
- Increased trust as a result of effective information sharing among supply chain stakeholders
- Avoiding delivery delays
- While doing all this, reducing carbon emissions with optimum planning

In the current study, it is aimed to contribute to the literature by examining the place of blockchain technology on the road to circular economy. Blockchain technology allows the monitoring of all workflows, from the material selection point of the products to the distribution, when logistics activities are taken into account in designing the circular economy. Many parameters such as the material of the product purchased as raw material, whether it uses fossil fuels during production, the amount of carbon emissions exposed in the logistics processes, the amount of product and waste suitable for recycling can be provided with blockchain. These are positive developments that will contribute to the circular economy.

The aim of this study is to evaluate the compatibility of blockchain technology with the circular economy in sustainable logistics activities without being indifferent to technological developments. Considering the circular economy on the road to sustainability, the criteria that are among the features of blockchain technology have been evaluated in this context.

2. METHODOLOGY

In this section, the criteria determined by considering the concept of circular economy and its compatibility with the sustainable logistics sector by considering blockchain technology are tried to be explained. At this stage, Entropy Method, one of the Multi-Criteria Decision Making methods, is used.

2.1. Entropy Method

The entropy method is used to measure the amount of useful information provided by existing data (Wu et al., 2011). In the entropy method, the data in the decision matrix is used to calculate the weights of the criteria in the decision problem. The applicability of the method is made strong because there is no need for any other subjective evaluation. The entropy method consists of 5 steps (Wang and Lee, 2009). Stage 1. Creation of the decision matrix; the decision matrix consisting of xij values (the value of the i. alternative according to the j. evaluation criterion) is included in Equation (1).

$$D = \begin{matrix} A_1 \\ .. \\ A_m \end{matrix} \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix} \tag{1}$$

Stage 2. Normalization of the decision matrix; the values are standardized with the help of Equation (2).

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \tag{2}$$

Stage 3. Finding the entropy values of the criteria; the entropy values (ej) of each evaluation criterion are calculated by the Equation (3).

$$e_{ij} = -k.\sum_{j=1}^{n} p_{ij}.\ln p_{ij} \qquad \text{i=1,2..m j=1,2..n} \tag{3}$$

Stage 4. Finding degrees of differentiation; using the ej values found in the 3rd stage, the dj values are found by Equation (4). A high dj value indicates that the distance or differentiation between alternative scores for the criteria is large.

$$d_j = 1 - e_j \quad \text{j=1,2..,n} \tag{4}$$

Stage 5. Calculation of entropy criterion weights; the weight values of the criteria are calculated with the help of Equation (5).

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} \tag{5}$$

3. RESULTS AND FINDINGS

Considering the “3R” headings of the circular economy, the criteria considered appropriate for the logistics sector and in the literature are brought together. (Table 2).

Table 2. *Definitions of the criteria that are the subject of the study*

Criteria	Authors	Code	Description
Reducing carbon emissions	Green, 2018	BC1	Blockchain technology can promote clean energy trade by improving carbon emissions with optimum transport management.
Reducing logistics costs	Tijan et al., 2019; Chang et al., 2019	BC2	It can significantly reduce logistics costs, additional costs, transportation costs.
Ease of communication	Author*	BC3	It provides accurate and reliable communication between the end-to-end stakeholders of the supply chain process.
Hacking	Min, 2019	BC4	It can prevent hacking, vulnerability disputes by increasing transaction security.
Increased performance	Author*	BC5	It increases the end-to-end speed of the supply chain process and provides performance increase.
Data immutability	Dutta et al., 2020	BC6	Data is immutable due to the need for verification by other nodes and traceability of changes.
Effective information sharing	Litke et al., 2019; Min, 2019	BC7	It can contribute effectively to information sharing among supply chain stakeholders.
Transparency	Wang et al., 2019; Saberi et al., 2019	BC8	It helps to keep track of the status of an item during a transaction
Uncertain legal status	Niranjanamurthy et al., 2018	BC9	The uncertain legal situation can be confusing and prohibitive.
New technology	Hughes et al., 2019; Johansson and Nilsson, 2018	BC10	The fact that it is a new technology may cause it to not be understood yet.
Trust	Saberi et al., 2018; Tijan et al, 2019	BC11	Trust among stakeholders can increase as data becomes more transparent.

* Created by the author.

As explained in Table 2, when the recycle, reuse and reduce activities of the circular economy are considered, the sustainable criteria in these stages are included in 11 studies. These are the blockchain features obtained from the literature by considering every stage of the logistics process (Reducing carbon emissions, Reducing logistics costs, Ease of communication, Hacking, Increased performance, Data immutability, Effective information sharing, Transparency, Uncertain legal status, New technology, Trust). These parameters in advanced technology are of a nature that will benefit the circular economy and explain its compliance with sustainability. Accordingly, a decision matrix is first created (Table 3) and normalized for the evaluation between criteria (Table 4).

Table 3. *Decision matrix of Entropy method*

	BC1	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**	**BC10**	**BC11**
BC1	1.00	7.00	2.00	7.00	0.20	7.00	0.17	6.00	8.00	7.00	0.25
BC2	0.14	1.00	2.00	2.00	0.33	3.00	2.00	5.00	6.00	6.00	3.00
BC3	0.50	0.50	1.00	2.00	0.20	0.25	0.20	0.33	6.00	6.00	0.33
BC4	0.14	0.50	0.50	1.00	0.14	0.17	0.17	0.20	0.50	0.33	0.20
BC5	5.00	3.00	5.00	7.00	1.00	3.00	2.00	4.00	6.00	6.00	2.00
BC6	0.14	0.33	4.00	6.00	0.33	1.00	0.33	3.00	6.00	5.00	0.33

BC7	6.00	0.50	5.00	6.00	0.50	3.00	1.00	6.00	7.00	7.00	3.00
BC8	0.17	0.20	3.00	5.00	0.25	0.33	0.17	1.00	5.00	5.00	1.00
BC9	0.13	0.17	0.17	2.00	0.17	0.17	0.14	0.20	1.00	2.00	0.25
BC10	0.14	0.17	0.17	3.00	0.17	0.20	0.14	0.20	0.50	1.00	0.25
BC11	4.00	0.33	3.00	5.00	0.50	3.00	0.33	1.00	4.00	4.00	1.00

Table 4. *Normalized decision matrix of Entropy method*

	BC1	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**	**BC10**	**BC11**
BC1	0.06	0.51	0.08	0.15	0.05	0.33	0.03	0.22	0.16	0.14	0.02
BC2	0.01	0.07	0.08	0.04	0.09	0.14	0.30	0.19	0.12	0.12	0.26
BC3	0.03	0.04	0.04	0.04	0.05	0.01	0.03	0.01	0.12	0.12	0.03
BC4	0.01	0.04	0.02	0.02	0.04	0.01	0.03	0.01	0.01	0.01	0.02
BC5	0.29	0.22	0.19	0.15	0.26	0.14	0.30	0.15	0.12	0.12	0.17
BC6	0.01	0.02	0.15	0.13	0.09	0.05	0.05	0.11	0.12	0.10	0.03
BC7	0.35	0.04	0.19	0.13	0.13	0.14	0.15	0.22	0.14	0.14	0.26
BC8	0.01	0.01	0.12	0.11	0.07	0.02	0.03	0.04	0.10	0.10	0.09
BC9	0.01	0.01	0.01	0.04	0.04	0.01	0.02	0.01	0.02	0.04	0.02
BC10	0.01	0.01	0.01	0.07	0.04	0.01	0.02	0.01	0.01	0.02	0.02
BC11	0.23	0.02	0.12	0.11	0.13	0.14	0.05	0.04	0.08	0.08	0.09

After the normalized matrix, the entropy values (ej) of the criteria are found (Table 5).

Table 5. *Entropy values for criteria*

	BC1	**BC2**	**BC3**	**BC4**	**BC5**	**BC6**	**BC7**	**BC8**	**BC9**	**BC10**	**BC11**
BC1	-0.16	-0.34	-0.20	-0.29	-0.16	-0.37	-0.09	-0.33	-0.29	-0.28	-0.08
BC2	-0.04	-0.19	-0.20	-0.14	-0.21	-0.28	-0.36	-0.31	-0.25	-0.26	-0.35
BC3	-0.10	-0.12	-0.13	-0.14	-0.16	-0.05	-0.11	-0.05	-0.25	-0.26	-0.10
BC4	-0.04	-0.12	-0.08	-0.08	-0.12	-0.04	-0.09	-0.04	-0.05	-0.03	-0.07
BC5	-0.36	-0.33	-0.32	-0.29	-0.35	-0.28	-0.36	-0.28	-0.25	-0.26	-0.30
BC6	-0.04	-0.09	-0.29	-0.27	-0.21	-0.14	-0.15	-0.24	-0.25	-0.23	-0.10
BC7	-0.37	-0.12	-0.32	-0.27	-0.27	-0.28	-0.28	-0.33	-0.28	-0.28	-0.35
BC8	-0.04	-0.06	-0.25	-0.24	-0.18	-0.07	-0.09	-0.12	-0.23	-0.23	-0.21
BC9	-0.04	-0.05	-0.03	-0.14	-0.14	-0.04	-0.08	-0.04	-0.08	-0.13	-0.08
BC10	-0.04	-0.05	-0.03	-0.18	-0.14	-0.04	-0.08	-0.04	-0.05	-0.08	-0.08
BC11	-0.34	-0.09	-0.25	-0.24	-0.27	-0.28	-0.15	-0.12	-0.20	-0.20	-0.21

Then, the weightings of each criterion are determined (Table 6).

Table 6. *Determination of weights*

	BC1	BC2	BC3	BC4	BC5	BC6	BC7	BC8	BC9	BC10	BC11
ej	0.654	0.658	0.870	0.941	0.917	0.774	0.773	0.799	0.912	0.931	0.811
dj	0.345	0.341	0.129	0.058	0.082	0.225	0.226	0.200	0.087	0.068	0.188
wj	0.177	0.1748	0.0661	0.0301	0.0421	0.1152	0.1159	0.1025	0.0446	0.0351	0.0965

Accordingly, the targeted reduction of carbon emissions in the circular economy is benefited by using blockchain technology from the logistics sector. Looking at the ranking between the criteria (Table 6) (Figure 1), the BC1 coded "Reducing carbon emissions" criterion proves this benefit.

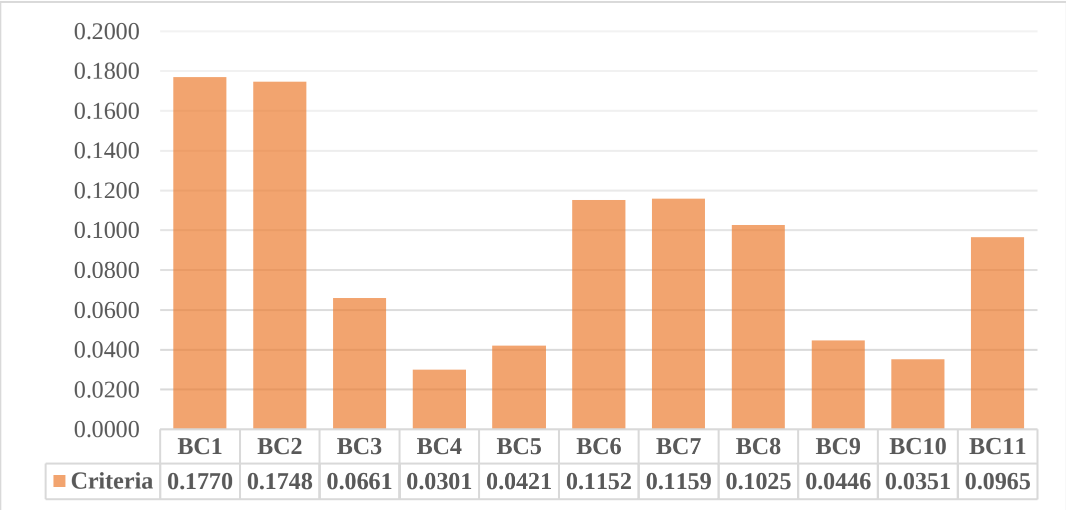

Figure 1. *Ranking of criteria*

In the same way, the circular economy BC2 coded "Reducing logistics costs", which calls for a source different from the linear economy to stay in the heart at the point of contributing to the economy, and when blockchain technology is used, it will help to reduce costs. These criteria are followed by BC7 "Effective information sharing" and BC6 "Data immutability" parameters. With effective information sharing and data immutability, stakeholders in the supply chain line will be able to assume more effective roles. The BC8 "Transparency" criterion that follows will provide a high-level impact on the resource management for the visibility and tracking system and will be able to decide on the evaluations of the resources within the economy. BC11 "Trust" criterion ensures trust between stakeholders. With the BC3 "Ease of communication" criterion, which comes later, it will again facilitate communication between stakeholders and provide the opportunity to produce fast solutions to problems that may arise. The BC9 "Uncertain legal status" criterion is currently considered negative for the cross-country adoption and enforcement of blockchain technology, so it is at the bottom of the list. It is inevitable that BC5 "Increased performance" will contribute to the increase in performance in logistics processes at the point of circular economy. The BC10 "New technology" criterion is that the technology is new and has low awareness among stakeholders, which negatively affects it. The BC4 "Hacking" criterion, which is in the last place, is effective against hacking and damage that may occur to works with blockchain technology.

4. CONCLUSION

The circular economy model, which keeps resources in the loop, ensures the use of resources as long as possible, enables energy savings and reduces waste, is a concept developed against the known linear model. On the other hand, developing technologies that contribute to businesses also support this economic model. Every business aiming at sustainable logistics also contributes to the circular economy model. This model, which makes resource management effective, reduces carbon emissions, and ensures recycling and recovery of waste, is possible with blockchain technology. In this study, the circular economy and blockchain technology integration, which are discussed in the light of these parameters, are shown with criteria.

At this stage, Entropy Method, one of the Multi-Criteria Decision Making methods, was used. As a result of the blockchain technology literature examined within the scope of sustainability, 11 criteria (Reducing carbon emissions, reducing logistics cost, ease of communication, hacking, increased performance, data immutability, effective information sharing, transparency, uncertain legal status, new technology, trust) were decided and evaluated. As a result of the evaluation, the most important criteria were Reducing carbon emissions and reducing logistics cost. It can be said that these criteria will contribute significantly to the "3R" rule of the circular economy.

Considering the sustainable logistics studies for businesses, the importance of blockchain technology, which has been shown to facilitate the transition to the circular economy, has been tried to be conveyed in this study. The importance of blockchain technology will increase gradually when uncertainty disappears in future studies. In this process, in addition to this study, criteria can be developed and solutions can be evaluated with new methods. At the same time, logistics activities of different sectors can be examined in detail and contribute to the literatüre.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Multi-Criteria Decision-Making Technique for Personnel Selection: PSI Sample

Personel Seçimi İçin Çok Kriterli Karar Verme Tekniği Yaklaşımı: PSI Örneği

Ayhan DEMİRCİ[1]

ABSTRACT

Considering that it will not be easy to make an improvement in production factors without any cost, the most critical field for businesses to minimize costs is logistics and supply chain structures. Likewise, the most important production factor that provides competitive advantage for businesses is human resources, also known as intellectual capital. In this context, it is vital to assign the right personnel to the right job. In case of selection and assignment of personnel based on merit, efficient use of business resources will be ensured and the final efficiency of the business will be positively affected, thereby paving the way for competitive advantage. Today, a wide variety of applications and tests are carried out for personnel selection. These methods, most of which are based on intuitive and personal judgments, can sometimes lead to wrong selection. It is obvious that short job interviews and/or job trial periods will not be enough to get to know the individual with his/her personality. In this context, the importance of multi-criteria decision-making techniques, which are frequently used in choosing the most suitable one among different personnel alternatives, is mentioned in the study. Multi-criteria decision-making techniques are an important aid for decision makers in personnel selection, as in many different areas. Although a significant part of the methods still require intuitive approaches such as expert opinion, the PSI method used in the study allows for the impartial evaluation of the alternatives and to reach conclusions on the numerical values they have, with the application stages in a completely rational way. In the study, a personnel selection decision to be made under the influence of many criteria with different importance levels is solved with the PSI method, which is one of the multi-criteria decision-making techniques and has been frequently used in different fields recently, and the results are shared. In this context, one of them is cost-oriented (C1-Negative Personality Traits) and the others are benefit-oriented (C2-Foreign Language Grade, C3-Year of Experience, C4-Team Work Skill, C5-Empathy Ability, C6-Problem Solving Ability and C7-Appearance) considering a total of 7 criteria, the most suitable one among 6 candidates was determined.

Keywords: Multi-Criteria Decision-Making Techniques, Personnel Selection, PSI.

ÖZ

Belirli bir maliyete katlanmaksızın üretim faktörlerinde bir iyileştirme yapılmasının çok da kolay olmayacağı düşünülürse, işletmeler için maliyet minimizasyonu yapılabilecek en kritik faaliyet alanı lojistik ve tedarik zinciri yapılanmalarıdır. Aynı şekilde işletmeler için rekabet avantajı sağlayan en önemli üretim faktörü entelektüel sermaye olarak da bilinen insan kaynağıdır. Bu kapsamda doğru işe doğru personel görevlendirilmesi hayati önemi haizdir. Liyakate dayalı bir personel seçimi ve görevlendirilmesi halinde, işletme kaynaklarının verimli kullanımı sağlanacak ve işletmenin nihai etkinliği olumlu etkilenerek rekabet üstünlüğünün önü açılacaktır. Günümüzde personel seçimi için çok çeşitli uygulamalar ve testler yapılmaktadır. Büyük çoğunluğu sezgisel ve kişisel yargılara dayalı olan bu yöntemler zaman zaman hatalı seçimi beraberinde getirebilmektedir. Kısa iş görüşmelerinin ve/veya iş deneme sürelerinin, bireyi kişiliğiyle birlikte tanımaya yetmeyeceği aşikardır. Bu kapsamda çalışmada farklı personel alternatifleri arasından en uygun olanı seçmekte sıklıkla yararlanılan çok kriterli karar verme tekniklerinin önemine değinilmiştir. Çok kriterli karar verme teknikleri çok farklı alanlarda olduğu gibi personel seçiminde de karar vericiler için önemli bir yardımcı durumundadır. Yöntemlerin önemli bir bölümü yine uzman görüşü gibi sezgisel yaklaşımlara ihtiyaç duymakla birlikte, çalışmada kullanılan PSI yöntemi tamamen rasyonel bir şekilde uygulama aşamalarıyla, alternatiflerin tarafsız olarak değerlendirilmesine ve sahip oldukları sayısal değerler üzerinde sonuca gidilmesine olanak sağlamaktadır. Yapılan çalışmada birbirinden farklı önem seviyesindeki çok sayıda kriterin etkisi altında verilecek bir personel seçim kararı, çok kriterli karar verme tekniklerinden biri olan ve son zamanlarda farklı alanlarda sıklıkla kullanılan PSI yöntemiyle çözülmüş ve sonuçlar paylaşılmıştır. Bu kapsamda biri maliyet yönlü (K1-Olumsuz Kişilik Özellikleri) ve diğerleri fayda yönlü (K2-Yabancı Dil Notu, K3-Tecrübe Yılı, K4-Takım Çalışma Becerisi, K5-Empati Yeteneği, K6-Problem Çözme Yeteneği ve K7-Dış Görünüş) olmak üzere toplam 7 kriter dikkate alınarak 6 aday arasından en uygun olanı belirlenmiştir.

Anahtar Kelimeler: Çok Kriterli Karar Verme Teknikleri, Personel Seçimi, PSI.

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1. INTRODUCTION

Human resources, or intellectual capital as it is expressed today, is among the most important inputs of a business. It is often not possible to compensate for a mistake that can be made in assigning the right employee to the right job. In this context, all personnel who will take part in any organization, talent, competence, etc., it is vital that the criteria are chosen correctly and assigned to the right position under appropriate conditions. The importance of a personnel to be selected in accordance with the purpose of existence of the organization and/or the position within the organization is extremely important in terms of sustainability and competitiveness. Therefore, "recruitment of the right personnel will provide many benefits for the business, and the wrong selection will have many negative effects on the business by reducing productivity" (Yıldız and Aksoy, 2015).

The competitive environment accelerated by the development of technology necessitated the continuous renewal of enterprises. No matter how much a business invests in its brand, the value of that business determines the personnel it employs. One of the primary objectives of human resources is to select personnel who can best meet the requirements of the business, adapt to the corporate culture, and are open to change and development. It is not easy for businesses to identify the candidates who meet the criteria they are looking for and to choose the most suitable one among them, and it is an important cost item. For this reason, the solutions of decision-making problems, which are at the core of the selection process, should be carried out with scientific methods (Bedir & Eren, 2015).

Most of the decisions taken on extremely mundane issues in daily life are affected by more than one criterion. This situation causes the decisions made by different people to differ from each other on the same issue. The decision-making problem, which becomes more complex as the number of criteria increases, becomes more complex if these criteria affect each other (Demirci, 2020).

For this reason, Multi-Criteria Decision Making Techniques, which provide ease of solving the problem in parts and produce relatively more rational results, enable the optimization of more than one criterion by including all the criteria affecting the decision in the solution at the same time, and offer a single decision distribution to the decision maker in the selection of the best alternative (Yaralıoğlu, 2010; Turan, 2015).

In this context, the aim of the study is; It is to assist decision makers who are faced with the decision of personnel selection with methods based on scientific principles. For this, there are a wide variety of methods that have undergone significant developments in recent years and their numbers are increasing day by day. These methods, which are gathered under the title of multi-criteria decision making techniques (MCDM), can find application in many different areas in the literature today.

The PSI method used in the study was found to be important and preferred in that it does not require expert opinion due to the application stages and therefore produces completely rational results.

2. LITERATURE REVIEW

In the literature, MCDM applications are encountered in the solution of decision-making problems in many different fields. In accordance with the subject of the study, a literature review on personnel selection problems was made and the criteria in the existing studies were preferred during the application phase. In this context;

Ilgaz (2018) selected the personnel to work in the logistics sector by using AHP and TOPSIS methods in his study. As personnel selection criteria in his study; technical competence (reference, foreign language knowledge, active computer use), professional competence (year of experience, logistics information technology knowledge, reporting skills, vocational training), physical competence (presentable appearance, physical endurance, being active) and social competence (team work) and harmony, effective communication skills, helpfulness) were used (Ilgaz, 2018).

Bedir and Eren (2015) in their study on the solution of a personnel selection problem for the retail sector; personal qualities (appearance, self-confidence, ability to cope with stress), interpersonal abilities (the ability to persuade, influence, empathize, teamwork and problem-solving), qualities necessary for the job (being active and dynamic, inclination to retail industry, knowledge about the product, taking initiative), experience (previously working time in the retail industry) and test result (personality inventory test result sent to the e-mail addresses of the candidates after the job application). They used AHP and PROMETHEE methods to select personnel for retail sector by usin these criteria (Bedir and Eren, 2015).

İbicioğlu and Ünal (2014) used the AHP method in their study. Accordingly, human resources managers were selected based on a total of 46 sub-criteria related to these, including corporate, demographic, professional, communication, managerial, mental and personality criteria (İbicioğlu and Ünal, 2014).

Doğan and Emre (2014) have brought a solution to the problem of human resources selection with the AHP and TOPSIS methods. 23 subjective and objective sub-criteria were used based on the main criteria of experience/work experience, education, professional requirements and individual characteristics, and external appearance, which were discussed in the study (Doğan and Emre, 2014).

Ünal (2011) presented examples of personnel selection belonging to different professions in his study. In his analysis with AHP, by using the main and sub-criteria required by the personnel to be selected; For the Engineering Department, it has brought solutions to the problems of selecting suitable personnel for the positions of manager candidate, Dean, Academic Staff, General Manager, Sales Representative and Marketing Manager, Nurse (Ünal, 2011).

3. METHOD

It is seen that methods that require expert opinion and depend on intuitive pre-assessment are generally used in personnel selection practices with MCDM in the literature. In this context, the PSI method applied in the study differs from the others in this respect.

The PSI (Preference Selection Index) method proposed by Maniya and Bhatt (2010) is a multi-criteria decision-making technique that produces solutions based on basic statistical information. Alternatives are ranked by taking into account a score value, known as the preference index, which is determined during the application process of the method.

In PSI method; there is no need to determine the relative importance of alternatives or criteria and to weight the criteria. Moreover, it does not require sensitivity analysis like some other multi-criteria decision making techniques. However, if the number of alternatives or criteria increases, the consistency of the results may become difficult (Attri & Grover, 2015). In this respect, criterion weights in PSI applications are determined using only the information provided in the decision matrix (Madic et al., 2017). Therefore, it also avoids possible disagreements about criterion weighting.

The application stages of the PSI method are as follows (Maniya & Bhatt, 2010; Vahdani et al., 2014; Chauhan et al., 2016);

Creation of Decision Matrix; At this stage, as in all other MCDM, an m x n-dimensional decision matrix is created with m decision alternatives and n decision criteria. The prepared decision matrix will be as seen in Equation 1.

$$X = \begin{matrix} x_{01} & x_{02} & \cdots & x_{0n} \\ x_{11} & x_{12} & \cdots & x_{1n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix} \tag{1}$$

Normalizing Decision Matrix; At this stage, the decision matrix is normalized (x_{ij}^*), taking into account the benefit and cost orientation of the criteria. Equation 2 is used for the normalization of the benefit-oriented criteria and Equation 3 for the normalization of the cost-oriented criteria.

$$x_{ij}^* = \frac{x_{ij}}{maks.\, x_{ij}} \tag{2}$$

$$x_{ij}^* = \frac{min.\, x_{ij}}{x_{ij}} \tag{3}$$

Determination of Average Performance Value; At this stage, the average values of the normalized performance values ($\bar{x}_{ij}^*$) for each criterion are determined with the help of Equation 4.

$$\bar{x}_{ij}^* = \frac{\sum_{i=1}^{m} x_{ij}^*}{m} \tag{4}$$

Calculation of Preference Variability Value; At this stage, the preference variability value (PV_j) between the values of each criterion is calculated with the help of Equation 5.

$$PV_j = \sum_{i=1}^{m} \left(x_{ij}^* - \bar{x}_{ij}^*\right)^2 \tag{5}$$

Calculating the Deviation in Preference Value; At this stage, the deviation (ϕ_j) in the preference variability value of each criterion is calculated with the help of Equation 6.

$$\phi_j = \left(1 - PV_j\right) \tag{6}$$

Calculation of Total Preference Value; At this stage, the total preference value (ω_j) for each criterion is calculated with the help of Equation 7, with the total value equal to 1 ($\sum_{j=1}^{n} w_j = 1$).

$$\omega_j = \frac{\phi_j}{\sum_{j=1}^{n} \phi_j} \tag{7}$$

Determination of Preference Selection Index; In this last stage, the preference selection index (I_i) of each alternative is determined with the help of Equation 8. Accordingly, among the alternatives ranked from the largest to the smallest, it is decided that the alternative with the highest preference index is the best alternative.

$$I_i = \sum_{j=1}^{n} \left(x_{ij}^* * \omega_j\right) \tag{8}$$

4. RESULTS AND CONCLUSION

In the study, a selection was made among 6 candidates according to the applications made to the staff needed by a business with the PSI method, which is a MCDM which is frequently used in different fields in the literature recently. For this, first of all, the job description of the said staff was examined and the criteria (7 criteria) that should be found in the candidates were determined bu literature. The criteria determined in this context are; C1-Negative Personality Traits (This criterion, which is considered as minimization-oriented, is expected to be low. Candidates are scored between 0-100 according to the results of the tests), C2-Foreign Language Grade (This criterion, which is maximization-oriented, is 0 in the form of a grade taken from the generally accepted foreign language exam. -100 were included in the analysis), C3-Year of Experience (This criterion, which is maximization-oriented, was determined as years according to the previous work experience of the candidate), C4-Team Work Skill, C5-Empathy Ability, C6-Problem Solving Ability and C7-Appearance (These criteria are maximization-oriented and included in the analysis by scoring between 1 and 9 according to the information obtained during the interview conducted by the Human Resources Department).

Then, the criteria values of the candidates were determined and the initial decision matrix was created and presented in Table 1.

Table 1. *Decision Matrix and Ranking of Alternatives*

Candidates	C1	C2	C3	C4	C5	C6	C7
	Min.	Maks.	Maks.	Maks.	Maks.	Maks.	Maks.
Candidate 1	25	80	13	7	6	7	5
Candidate 2	10	75	7	9	8	7	4
Candidate 3	20	60	9	8	5	6	4
Candidate 4	25	65	8	7	7	8	5
Candidate 5	50	95	9	8	6	8	3
Candidate 6	35	70	12	9	7	9	5

Then it is obtained the Normalized Decision Matrix by using the Equation 2 and Equation 3 and presented in Table 2.

Table 2. *Normalized Decision Matrix*

Candidates	C1	C2	C3	C4	C5	C6	C7
Candidate 1	0,4000	0,8421	1,0000	0,7778	0,7500	0,7778	1,0000
Candidate 2	1,0000	0,7895	0,5385	1,0000	1,0000	0,7778	0,8000
Candidate 3	0,5000	0,6316	0,6923	0,8889	0,6250	0,6667	0,8000
Candidate 4	0,4000	0,6842	0,6154	0,7778	0,8750	0,8889	1,0000
Candidate 5	0,2000	1,0000	0,6923	0,8889	0,7500	0,8889	0,6000
Candidate 6	0,2857	0,7368	0,9231	1,0000	0,8750	1,0000	1,0000
Mean	**0,4643**	**0,7807**	**0,7436**	**0,8889**	**0,8125**	**0,8333**	**0,8667**

After then by using the Normalized Decision Matrix and mean values of the column, it is obtained the Average Perfomance Value with the help of Equation 4.

***Table 3**. Average Performans Value*

Candidates	C1	C2	C3	C4	C5	C6	C7
Candidate 1	0,0041	0,0038	0,0657	0,0123	0,0039	0,0031	0,0178
Candidate 2	0,2870	0,0001	0,0421	0,0123	0,0352	0,0031	0,0044
Candidate 3	0,0013	0,0222	0,0026	0,0000	0,0352	0,0278	0,0044
Candidate 4	0,0041	0,0093	0,0164	0,0123	0,0039	0,0031	0,0178
Candidate 5	0,0698	0,0481	0,0026	0,0000	0,0039	0,0031	0,0711
Candidate 6	0,0319	0,0019	0,0322	0,0123	0,0039	0,0278	0,0178

Then it is calculated the Preference Variability Value, Deviation in Preference Value and Total Preference Value by using the Equation 5, Equation 6 and Equation 7, and presented in Table 4.

***Table 4.** Preference Variability Value, Deviation in Preference Value and Total Preference Value*

Parameters	C1	C2	C3	C4	C5	C6	C7	Total
PV_j	0,3983	0,0854	0,1617	0,0494	0,0859	0,0679	0,1333	
ϕ_j	0,6017	0,9146	0,8383	0,9506	0,9141	0,9321	0,8667	**6,0180**
ω_j	0,1000	0,1520	0,1393	0,1580	0,1519	0,1549	0,1440	**1,0000**

Finally it is determined the Preference Selection Index bu using the Equation 8, to rank all alternatives in order for selection decision. The Preference Selection Index values and rank values of alternatives presented in Table 5.

***Table 5**. Preference Selection Index and Rank Value of Alternatives*

Candidates	C1	C2	C3	C4	C5	C6	C7	Total	Rank
Candidate 1	0,04	0,13	0,14	0,12	0,11	0,12	0,14	0,8085	**3**
Candidate 2	0,10	0,12	0,08	0,16	0,15	0,12	0,12	0,8405	**2**
Candidate 3	0,05	0,10	0,10	0,14	0,09	0,10	0,12	0,6962	**6**
Candidate 4	0,04	0,10	0,09	0,12	0,13	0,14	0,14	0,7671	**4**
Candidate 5	0,02	0,15	0,10	0,14	0,11	0,14	0,09	0,7468	**5**
Candidate 6	**0,03**	**0,11**	**0,13**	**0,16**	**0,13**	**0,15**	**0,14**	**0,8589**	**1**

At the end of the prosess of PSI technique, it was determined that the most suitable candidate for the required staff of the enterprise was Candidate 6.

The issue of human resources procurement is considered to be an extremely complex and often subjective process by its nature. Keeping this process separate from personal approaches is extremely important for hiring the right staff for the right job. At this point, it would be appropriate to benefit from MCDMs, as in complex decisions to be made in many areas today. Because the decision to supply human resources is too important to be left to subjective approaches.

MCDM has become the focus of attention in recent years and the number of methods has increased day by day. In this context, it is possible to come across a large number of MCDMs with different application stages in the literature. MCDM, which is used in the selection of the most suitable one among various alternatives, is an important helper for decision makers in matters under the influence of many criteria with different weights. Personal perception, emotion, attitude, manners, etc. It is considered that MCDM, which paves the way for objective decision-making in a completely rational way, will maintain its importance in the coming period as well.

Due to its structure, MCDM achieves results rationally and objectively according to the criteria values obtained for the alternatives, therefore it is not affected by the personal attitudes and behaviors of the decision makers. In this respect, the decision to procure human resources, which is extremely important for businesses, should be determined with objective approaches.

At this point, the MCDM to be chosen has a special importance. Some of the methods in the literature are criticized for their structures that require expert opinion and are partially based on subjective foundations. In this context, the PSI method was preferred in the study. The PSI method is seen as a completely objective approach, as it is a method that is based only on the criteria values and produces results with this information.

However, considering the differences in practice, another MCDM can be selected in future studies, and it is considered that the results may be healthier if the same data are applied together with two or more MCDMs for confirmation purposes.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

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Detection of Sustainable Logistics Sub-Components and Determination of Impact Levels of Sustainable Logistics Components with Dematel Method

Sürdürülebilir Lojistik Alt Bileşenlerinin Tespiti ve Sürdürülebilir Lojistik Bileşenlerinin Etki Düzeylerinin Dematel Yöntemi ile Belirlenmesi

Onur DERSE[1]

Abstract

Sustainable logistics can be defined as all logistics activities carried out by preserving and maintaining the present and the future for generations in environmental, economic, and social dimensions. In the study, the impact levels and sub-components of the main components in environmental, economic, and social dimensions, which are important for sustainable logistics, are examined. When the environmental dimension is examined, it is seen that its sub-components are use of resource (energy, water, material, etc.), water/soil pollution, greenhouse gas emissions, noise pollution, and waste management. When the sub-components of the economic dimension are examined, it includes the components of product and service quality, cost minimization, recycling, market share/growth, and goods transport intensity. When the sub-components of the social dimension are examined, it is seen that the components of occupational health and safety, education and training, working conditions, and public health are covered. The impact levels of the main components of sustainable logistics are evaluated with the DEMATEL method, which is one of the MCDM methods. According to the DEMATEL method, while economic and environmental dimensions are in the affecting group, social dimension is in the affected group.

Keywords: Sustainable Logistics, MCDM, DEMATEL Method.

Öz

Sürdürülebilir lojistik, çevresel, ekonomik ve sosyal boyutlarda bugünü ve geleceği nesiller boyu koruyarak ve yaşatarak gerçekleştirilen tüm lojistik faaliyetler olarak tanımlanabilir. Çalışmada sürdürülebilir lojistik için önemli olan çevresel, ekonomik ve sosyal boyutlardaki ana bileşenlerin etki düzeyleri ve alt bileşenleri incelenmiştir. Çevre boyutu incelendiğinde, alt bileşenlerinin kaynak kullanımı (enerji, su, malzeme vb.), su/toprak kirliliği, sera gazı emisyonları, gürültü kirliliği ve atık yönetimi olduğu görülmektedir. Ekonomik boyutun alt bileşenleri incelendiğinde ürün ve hizmet kalitesi, maliyet minimizasyonu, geri dönüşüm, pazar payı/büyüme ve mal taşıma yoğunluğu bileşenlerini içermektedir. Sosyal boyutun alt bileşenleri incelendiğinde iş sağlığı ve güvenliği, eğitim ve öğretim, çalışma koşulları ve halk sağlığı bileşenlerinin kapsandığı görülmektedir. Sürdürülebilir lojistiğin ana bileşenlerinin etki düzeyleri, ÇKKV yöntemlerinden biri olan DEMATEL yöntemi ile değerlendirilmektedir. DEMATEL yöntemine göre ekonomik ve çevresel boyutlar etkilenen grupta yer alırken, sosyal boyut etkilenen grupta yer almaktadır.

Anahtar Kelimeler: Sürdürülebilir Lojistik, ÇKKV, DEMATEL Yöntemi.

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1. INTRODUCTION

Sustainability is all of the efforts applied to protect and maintain the existence of natural and human resources. Although sustainability is encountered in many areas of our lives, technological changes, globalization, increasing population, use of fossil fuels, and social and environmental pressures have integrated sustainability into the field of logistics. For this reason, it is seen that the logistics industry gains more importance than ever in terms of sustainability. The field of logistics is significantly impacted by Industry 4.0 in an accelerated manner and there is a constant need to use these new technologies to support sustainability by increasing efficiency, reliability, and flexibility along with saving energy and time by protecting the environment (Akkad et al., 2020).

There are different definitions of sustainable logistics. According to Chang and Qin (2008), sustainable logistics "planning, control, management and implementation of the logistics system through advanced logistics technology and environmental management aimed at reducing pollutant emission". Zhao et al. (2009), it is defined as "improving resource use, reducing resource consumption and waste, and minimizing environmental pollution through rational planning while implementing logistics activities, optimizing resource allocation and using environmental technology". Sbihi and Eglese (2010) state that "green logistics is concerned with the sustainable production and distribution of products, taking into account environmental and social factors". In general terms, sustainable logistics can be defined as all the logistics activities from the starting point to the end point of the products, which are carried out by preserving and continuing for the present and future generations in environmental, economic, and social dimensions.

A sustainable logistics system framework combines sustainable development with elements typically found in a traditional logistics system. Focusing on sustainable development and implementing a sustainable logistics system, can positively impact long-term performance goals. A sustainable logistics system will enable long-term performance goals to take steps to maximize profitability, minimize its environmental impact, and ensure that it has a positive impact on improving society's quality of life (Croom et al., 2009).

Sustainability is an essential issue in economic, social, and environmental fields. Two aims are considered in this study. As a first aim, the impact levels of the main components in environmental, economic, and social dimensions, which are essential for sustainable logistics, are taken into account. This purpose is used to help reveal which main component is affected by which conditions, which main components are affected, and which main components should be given weight. There is no study in the literature examining the effect levels of the main components. As a second aim of the study, sub-components for sustainable logistics were examined. It is thought that this aim will contribute to the development of sustainability.

In the Introduction section, which is the first part of the study, the introduction to sustainable logistics and the aim of the study is included. The literature review is handled in the second section. In the third part of the study, in the Methodology section, the definition of the problem and the details of the DEMATEL method are given. The fourth section of the study includes Results and Discussions. In the last section, the Conclusion section, the results of the study and suggestions for future studies are included.

2. LITERATURE REVİEW

Within the scope of Sustainable Logistics, there are current studies (Neto et al., 2008; Grant et al., 2017; Grzybowska and Awasthi, 2020; Lan et al., 2020; D'Amico et al., 2021; Hussein et al., 2022; Jayarathna et al., 2022) in the literature. Elkington (1997) proposes considering three closely related economic, ecological (environmental), and social aspects of sustainability. Wichaisri and Sopadang (2013) stated in their study that a sustainable logistics system takes into account three aspects and that economic, environmental, and social areas are necessary for a logistics system. This article provides a framework for a sustainable logistics system that will address these three criteria. In the study, social criteria include the sub-criteria of health and safety and quality of life. Environmental criteria include the sub-criteria of resource usage, pollution, emission, waste, and eco-efficiency. Economic criteria include the sub-criteria of quality, responsiveness, cost, profit, and mobility. Morana and Gonzalez-Feliu, J. (2015) state in their study that the evaluation of urban logistics projects should be viewed from the perspective of sustainable development, and three dimensions (economic, environmental, and social/social) should be taken into account. Alshubiri (2017) states in his study that green logistics includes three components, the independent variables of which are economic, social, and environmental, and that these components can be applied to clarify the effect of expansionary monetary policy indicators as an important signal in determining a country's economy. Qaiser et al. (2017) state to explore the current state of research in the field of Decision Support Systems for logistics, taking into account the sustainability aspects. As a result of the study, it is seen that social impact is given less importance compared to economic and environmental aspects. Zhu and Hu (2017) examine the sustainability optimization of corporate logistics networks from a strategic perspective and propose a multi-purpose sustainable logistics optimization model that takes into account three dimensions of sustainability: economy, environment, and society. In their work, Çetin and Sain (2018) aim to reveal the level of sustainability practices in the logistics sector, and the concepts of environmental, economic, and social sustainability are discussed in terms of the logistics sector investigated. Solomon et al. (2019) state that there are very few studies showing a clear relationship between economic, operational, and environmental performance. In this context, he considers the role of social performance (both in terms of society and employees) in his work. Ren et al. (2020) stated in their study that about a quarter of the literature they reviewed (71 out of 306 articles) focused on evaluating and measuring social, environmental, and economic criteria. Yontar (2021), discussed 15 articles that were studied with sustainable logistics criteria between 2008-2020 and determined the sustainable logistics criteria and ranked the criteria according to their importance with Pareto analysis. In the study of Mücevher (2021), priority strategies that can be used for sustainability in the logistics sector are examined. In the study, three priority strategies that can be used for sustainable logistics are emphasized. These strategies are reverse logistics, green logistics, and lean logistics approaches. Yontar (2022) deals with the logistics activities carried out by companies on the basis of sustainability and the aim of the article is to present a framework that will contribute to the sustainability initiative of companies that carry out logistics activities.

In order to ensure that the decision-making process operates smoothly with minimum error, Multi-Criteria Decision Making methods abbreviated as "MCDM" are used to obtain the solution (Singh and Pant, 2021). There are also studies using MCDM methods within the scope of sustainable logistics. Senir and Büyükkeklik (2017) aim to rank some logistics companies in terms of environmental performance within the scope of their sustainability reports. Environmental Performances of logistics companies are evaluated by the TOPSIS method, one of the MCDM Techniques. In the study of Broniewicz and Ogrodnik (2021), the application potential of Multi-Criteria Decision Making (MCDM) methods is used in decision-making problems in transportation in the light of sustainable development. Within the scope of literature studies, a review has been made of the latest applications of MCDM/MCDM methods for decision-making problems in the field of transportation. For this purpose, a mixed approach consisting of three selected MCDM methods was used: DEMATEL, REMBRANDT, and VIKOR. It is stated that multi-criteria analyses are performed to allow the final multidimensional evaluation of the most popular

MCDM methods currently applied in the field of transportation. Pamucar et al. (2021) present a long-term strategic perspective to reach a zero-carbon city by 2050. According to the results of the MCDM method proposed in the study, "introducing zero-emission zones" emerges as the first attempt to be applied. As a result of the study, it is revealed that the proposed method will be transferred to other cities aiming to provide zero-carbon transportation.

3. METHODOLOGY

3.1. Problem Definition

It is an approach that enables sustainable logistics products to be carried out from the starting point to the end point in an innovative and environmentally conscious manner. Sustainable logistics basically includes three main components: environmental, economic and social. In this study, the effect levels of the main components (environmental, economic, and social) are examined with the DEMATEL method, which is one of the Multi-Criteria Decision Making methods. It is aimed to generate effecting - effecting cause and effect diagrams of the main components. In addition, the sub-components of the main components are investigated in the study. It is planned to find out which sub-components each main component has. In this context, there are two main research questions in the study:

- What are the impact levels of the main components of sustainable logistics?
- What are the sub-components of sustainable logistics?

3.2. DEMATEL Method

MCDM methods are applied in a different way from statistical analysis techniques, that is, it is one of the methods in which objective and non-objective factors are evaluated together. Analyzes are carried out within the framework of and at the same time, a single expert opinion or The study can also be shaped according to the opinion of a group of experts (Korucuk, 2021).

Multi-Criteria Decision Making methods are methods used to rank, select, evaluate or determine the effect levels of different alternatives in accordance with the determined criteria. There are many Multi-Criteria Decision Making methods available. One of these methods is the DEMATEL method. The DEMATEL method is an effective method that examines the structure and relationships between system components or a valid number of alternatives. DEMATEL can arrange the criteria in order of priority in terms of the type of relations and the importance of their effects on each other.

The DEMATEL method has become popular mainly because it is a pragmatic approach to visualizing the structure of complex causal relationships. Specifically, the DEMATEL method is based on digraphs that can separate the relevant factors into cause group and effect group. Directed graphs, known as digraphs, are more useful than undirected graphs because digraphs can show directed relationships of subsystems (Wu and Lee, 2007).

The DEMATEL methodology consists of the following five steps (Gabus and Fontela, 1972; Fontela and Gabus, 1976):

1. Establishment of the direct relationship matrix. Five scales are used to measure the relationship between criteria: 0 (no impact), 1 (very low impact), 2 (low impact), 3 (high impact), and 4 (very high impact).
2. Normalization of the direct relationship matrix.
3. Calculation of the total relationship matrix.

4. Generating a cause and effect diagram.
5. Obtaining the internal dependency matrix.
6.

4. RESULTS AND DISCUSSIONS

4.1. Results

There are two main research questions in the study:

- What are the impact levels of the main components of sustainable logistics?
- What are the sub-components of sustainable logistics?

The main components of Sustainable Logistics are economic, social, and environmental. In this context, the effect levels of the main components of sustainable logistics in the research question in the first item are evaluated by The Decision Making Trial and Evaluation Laboratory (DEMATEL) method, which is one of the Multi-Criteria Decision Making methods. The direct relationship matrix, which is the first step of the applied DEMATEL method, is shown in Table 1. Table 2 shows the normalized direct relationship matrix.

Table 1. *Direct Relation Matrix*

	Social	**Environmental**	**Economic**
Social	0	1	1
Environmental	3	0	1
Economic	3	2	0

Table 2. *Normalization of The Direct Relationship Matrix*

	Social	**Environmental**	**Economic**
Social	0.00	0.17	0.17
Environmental	0.50	0.00	0.17
Economic	0.50	0.33	0.00

Prominence levels (D+R) and relation levels (D-R) are determined in Table 3.

Table 3. *The Prominence and Relation Axis for Cause and Effect Group*

	D (Sum)	**R (Sum)**	**D+R**	**D-R**
Social	0.872	2	2.872	-1.128
Environmental	1.4	1.127	2.527	0.273
Economic	1.727	0.872	2.599	0.855

Figure 1 shows the cause and effect graph. The figure is arranged according to Table 3. According to the figure, economic and environmental criteria are in the group that affects them. Social criteria are included in the affected group. In addition, when the prominence levels are examined, it is seen that each main component takes approximate values.

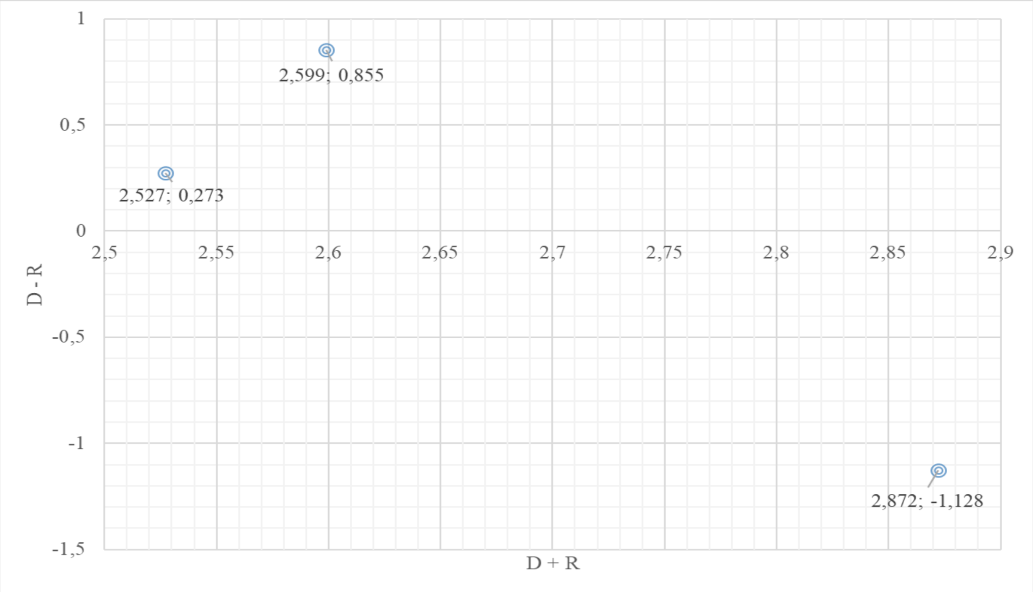

Figure 1. *Cause and Effect Graph*

Economic, social, and environmental main components are taken into consideration as the main components of Sustainable Logistics. When the sub-components of these main components are examined, they emerge as follows.

Sub-components of the environmental main component;

- ✓ Use of resources (energy, water, materials, etc.) (Chaabane et al., 2012; Large et al., 2013)
- ✓ Water/Soil pollution (Large et al., 2013)
- ✓ Greenhouse gas emission (Large et al., 2013)
- ✓ Noise pollution (Björklund and Forslund, 2019)
- ✓ Waste management (Large et al., 2013; Björklund and Forslund, 2019)

Sub-components of the main economic component;

- ✓ Product and service quality (Chaabane et al., 2012; Large et al., 2013)
- ✓ Cost minimization (Björklund and Forslund, 2019; Sidiropoulos et al., 2021)
- ✓ Recycling
- ✓ Market share/growth (Chaabane et al., 2012; Rota et al., 2012)
- ✓ Goods transport density (Large et al., 2013)

Sub-components of the social main component;

- ✓ Occupational health and safety (Gallego, 2006; Gimenez et al., 2012)
- ✓ Education and learning
- ✓ Working conditions
- ✓ Public health (Gallego, 2006)

4.2. Discussions

Sustainable logistics can be defined as all logistics activities carried out by preserving and sustaining the present and the future for generations in environmental, economic, and social dimensions. In the study, sustainable logistics are discussed within the scope of the main components. The main components of sustainable logistics: environmental, economic, and social aspects are discussed. These main components have been taken into account in many studies. Elkington (1997), Sopadang (2013), Morana and Gonzalez-Feliu, J. (2015), Cetin and Sain (2018), and Ren et al. (2020) discussed the environmental, economic, and social aspects of sustainable logistics in their work. There are two main aims of the study. The first purpose is to measure the impact levels of the main components of sustainable logistics (environmental, economic, and social components). As a result of the study, it is seen that the economic and environmental component is in the affecting group and the social component is in the affected group within the scope of sustainable logistics. In addition, when the degree of importance of the main components is examined, it is seen that they take approximately close values. In the study of Wichaisri and Sopadang (2013), the importance degrees of the main components were evaluated and it was seen that the main component with the highest importance was the economic component. Social and environmental components have taken close value.

The second aim addressed in the study is to determine the sub-components of the main components. When the sub-components of the main environmental component are examined, it is seen that the sub-components are use of resource (energy, water, material, etc.), water/soil pollution, greenhouse gas emissions, noise pollution, and waste management. When the sub-components of the economic main component are examined, they include the components of product and service quality, cost minimization, recycling, market share/growth, and goods transport intensity. When the sub-components of the social main component are examined, it is seen that the components of occupational health and safety, education, and training, working conditions, and public health are covered. These components are obtained by reviewing the literature.

5 CONCLUSION

Sustainability can be defined as all practices carried out to protect and maintain resources. Sustainability has begun to be taken into account in many different sectors with increasing environmental awareness. One of the leading ones in these fields is the logistics sector. Sustainable logistics can be defined as all logistics activities carried out by preserving and sustaining the present and the future for generations.

Two main problems are investigated in the study. First of all, environmental, economic, and social components, which are the main components of sustainable logistics, are taken into account, and the effect levels of the main components of sustainable logistics are evaluated with the DEMATEL method, one of the MCDM methods. According to the DEMATEL method, the economic and environmental components are in the affecting group. Social component is included in the affected group. When the importance degrees of the main components are examined in the study, it is seen that each main component takes approximate values. These components are listed from most to least as social, economic, and environmental. Secondly, the sub-components of the main components are determined by examining the literature. When the sub-components of the main environmental component are examined, it is seen that the sub-components are use of resource (energy, water, material, etc.), water/soil pollution, greenhouse gas emissions, noise pollution, and waste management. When the sub-components of the economic main component are examined, they include the components of product and service quality, cost minimization, recycling, market share/growth, and goods transport intensity. When the sub-components of the social main component are examined, it is seen that the components of occupational health and safety, education and training, working conditions, and public health are covered.

In future studies, the importance levels of the sub-components can be examined and comparisons can be made by applying different Multi-Criteria Decision Making Methods.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Rollover Prevention By Maximum Lateral Force Based On The Detection of Three-Dimensional Center of Gravity

Üç Boyutlu Ağırlık Merkezi Tespitine Dayalı Maksimum Yanal Kuvvetle Devrilme Önleme

Kailun YU[1] Yutaka WATANABE[2]

ABSTRACT

The center of gravity (COG) height is an important factor affecting rollover. Earlier studies by the authors assessed the theory of Detection of Three-Dimensional Center of Gravity (D3DCG), which provides an innovative and accurate method for COG height detection. This report describes development of D3DCG, which can be used to prevent rollover accidents by calculating the maximum height of COG and the maximum lateral force that can exist without causing rollover. For a fixed total weight of a vehicle, the COG height has an upper limit. Based on the law of energy conservation, if the COG height is lower than that upper limit, then the vehicle has potential energy against rollover. When the vehicle is running, road disturbances make its body shake. Some potential energy transfers to the spring energy to provide a restorative force and to make the COG return to its original position. Therefore, when the COG height reaches its maximum value, the potential energy disappears, causing rollover. The highest COG can be expressed according to the principle of the balance of rotational torque. To verify this theory, a COG adjustable experiment is designed with a table-top D3DCG device and a tower object. The total object weight does not change, but its COG height increases until the object cannot maintain stability on the device anymore. Comparison of the real COG and the highest COG confirmed that only when the COG is lower than the highest COG, the object will not roll over. If a lateral force is acting on a moving object such as a vehicle, then the object will tilt. At the same time, the restoring moment will resist the rolling moment. According to the theory of D3DCG, the lateral force has relation with the rolling angle. When the vehicle starts to roll over, based on the physical structure of moving vehicle, the critical lateral force can be represented by the rolling angle. Therefore, by eliminating the rolling angle as an unknown variable, the maximum lateral force can be expressed by two known variables: the actual COG height and the maximum height of COG. To verify this theory, a remotely controlled truck is made to rotate in a random rotation radius. Then its speed increases gradually until it rolls over. The real-time lateral force is recorded and compared with the calculated maximum lateral force. Results indicate that rollover occurs when the real-time lateral force reaches the maximum lateral force. This study examines a novel method of rollover prevention without knowing either the total weight, the vehicle speed or turning radius. The accuracy of this theory was well confirmed by comparing the real-time lateral force and the calculated maximum lateral force based on D3DCG.

Keywords: Accident prevention, D3DCG, motions of moving objects, safety of vehicles.

ÖZ

Ağırlık merkezi (COG) yüksekliği devrilmeyi etkileyen önemli bir faktördür. Yazarların daha önceki çalışmaları, COG yükseklik tespiti için yenilikçi ve doğru bir yöntem sağlayan Üç Boyutlu Ağırlık Merkezinin (D3DCG) Tespiti teorisini değerlendirdi. Bu rapor, maksimum COG yüksekliğini ve devrilmeye neden olmadan var olabilecek maksimum yanal kuvveti hesaplayarak devrilme kazalarını önlemek için kullanılabilecek D3DCG'nin gelişimini açıklamaktadır. Bir aracın sabit toplam ağırlığı için COG yüksekliğinin bir üst sınırı vardır. Enerji korunumu yasasına göre, eğer COG yüksekliği bu üst sınırdan daha düşükse, o zaman aracın devrilmeye karşı potansiyel enerjisi vardır. Araç çalışırken yoldaki bozulmalar vücudunu sallar. Bazı potansiyel enerjiler, onarıcı bir kuvvet sağlamak ve COG'nin orijinal konumuna geri dönmesini sağlamak için yay enerjisine aktarılır. Bu nedenle, COG yüksekliği maksimum değerine ulaştığında, potansiyel enerji kaybolur ve devrilmeye neden olur. En yüksek COG, dönme torku dengesi ilkesine göre ifade edilebilir. Bu teoriyi doğrulamak için, bir masa üstü D3DCG cihazı ve bir kule nesnesi ile COG ayarlanabilir bir deney tasarlanmıştır. Toplam nesne ağırlığı değişmez, ancak COG yüksekliği, nesne artık cihaz üzerinde dengeyi koruyamayacak duruma gelene kadar artar. Gerçek COG ve en yüksek COG'nin karşılaştırılması, yalnızca COG en yüksek COG'den düşük olduğunda nesnenin devrilmeyeceğini doğruladı. Taşıt gibi

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hareketli bir nesneye yanal bir kuvvet etki ediyorsa, nesne eğilir. Aynı zamanda, geri yükleme momenti, yuvarlanma momentine direnecektir. D3DCG teorisine göre, yanal kuvvet yuvarlanma açısı ile ilişkilidir. Araç devrilmeye başladığında, hareket eden aracın fiziksel yapısına bağlı olarak kritik yanal kuvvet, yuvarlanma açısı ile temsil edilebilir. Bu nedenle, yuvarlanma açısını bilinmeyen bir değişken olarak ortadan kaldırarak, maksimum yanal kuvvet bilinen iki değişkenle ifade edilebilir: gerçek COG yüksekliği ve maksimum COG yüksekliği. Bu teoriyi doğrulamak için, uzaktan kumandalı bir kamyon rastgele bir dönüş yarıçapında dönecek şekilde yapılır. Sonra devrilene kadar hızı kademeli olarak artar. Gerçek zamanlı yanal kuvvet kaydedilir ve hesaplanan maksimum yanal kuvvet ile karşılaştırılır. Sonuçlar, gerçek zamanlı yanal kuvvet maksimum yanal kuvvete ulaştığında devrilmenin gerçekleştiğini göstermektedir. Bu çalışma, toplam ağırlığı, araç hızını veya dönüş yarıçapını bilmeden yeni bir devrilmeyi önleme yöntemini incelemektedir. Bu teorinin doğruluğu, gerçek zamanlı yanal kuvvet ve D3DCG'ye dayalı hesaplanan maksimum yanal kuvvet karşılaştırılarak iyi bir şekilde doğrulandı.

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1. INTRODUCTION

Road traffic is the most common and widely used mode of transportation. Therefore, road safety should attract more attention. Based upon data from the US National Highway Traffic Safety Administration (NHTSA, USA), rollover accidents have become the second most dangerous road traffic accident type, after crash accidents. Figure 1 shows that the number of occupants killed in all road traffic accidents and rollover accidents declined from 2007, but the percentage of rolloveraccidents in all road accidents showed no marked decrease. Consequently, preventing rollover accidents is necessary for promoting road traffic safety.

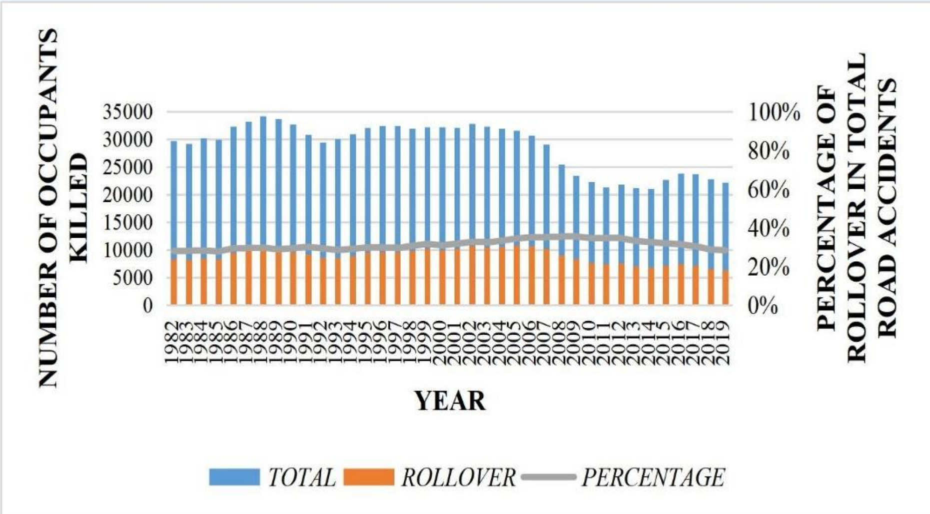


Figure 1. *Statistics data of death in road accidents and rollover accidents in the USA during 1982–2019.* ***Data source****: Traffic Safety Facts Annual Report Tables from National Highway Traffic Safety Administration (NHTSA,USA)*

Rollover accidents invariably occur on curved sections of roads because they are caused by external horizontal force. In this case, the most important factors that affect rollovers include the curve radius, velocity, and the center of gravity (COG) height. Vehicles are loaded with a wide variety of goods. Also, the COG changes before and after loading and unloading.For that reasons, detecting the COG height, let alone the real-time COG height, is difficult.

Some researchers have reported effective methods for detecting the COG height of objects that have large mass. Watanabe created the theory of Detection of Three-Dimensional Center of Gravity (D3DCG) by applying the principle of ship buoyancy to moving vehicles. The buoyancy supports a ship as it stays on the water surface in a vertical direction, although no definite force acts in the horizontal direction. Even a breeze or a ripple can make a ship shake. Such a shaking process is permanent. The shaking frequency depends on the ship's COG height. Watanabe found that, when avehicle moves, road surface disturbances will make the vehicle body shake. This phenomenon is similar to that for a ship. Later, Watanabe combined the equations of vertical and horizontal oscillation to obtain an expression of COG height. The theory provides an innovative means of detecting the COG height without the need to ascertain the object's mass.

Dang and Watanabe conducted experiments to verify the D3DCG theory accuracy. They first designed an experiment that incorporates a truck model. The model was hung from three directionsby a line. The intersection of the lines' extensions showed the COG position. Compared to the intersection height, the D3DCG calculation result was verified accurately. Then they detected the COG height of an actual truck. The results were also satisfactory.

Yu and Watanabe conducted controlled experiments to prove, based upon D3DCG, the COG height effect on rollover. They detected the COG heights of truck models that had the same load but different COG heights by D3DCG. Then they calculated the critical rollover radii with the full speed.

The experiment radius was chosen between the larger one and the smaller one. The model withlower COG passed through the curve safely, although model with higher COG rolled over. Theexperiments demonstrated that an object with higher COG rolls over easily.

Merely knowing the COG height of a moving object is insufficient to avoid rollover. This study is a development of D3DCG theory. It proposes the maximum lateral force of rollover by combining the dynamic rolling angle in a shaking process and a moving vehicle's geometric structure of critical rollover state. The study can produce a means of preventing rollover by comparison of the maximum lateral force with the real-time lateral force.

2. MAXIMUM HEIGHT OF COG DETECTED USING D3DCG

2.1. Theory of the maximum height of COG

Every object's COG height has an upper limitation. Even though it is in a static state, the object cannot remain steady if its COG height is beyond the upper limitation. Actually, D3DCG theory can detect the real-time COG height; it can also be used to detect the maximum height of the COG of a moving object.

When a vehicle is moving, disturbances from the road surface make the vehicle' s body shake around the oscillation center. Figure 2 presents an oscillation diagram of a moving vehicle at a certain point during shaking.

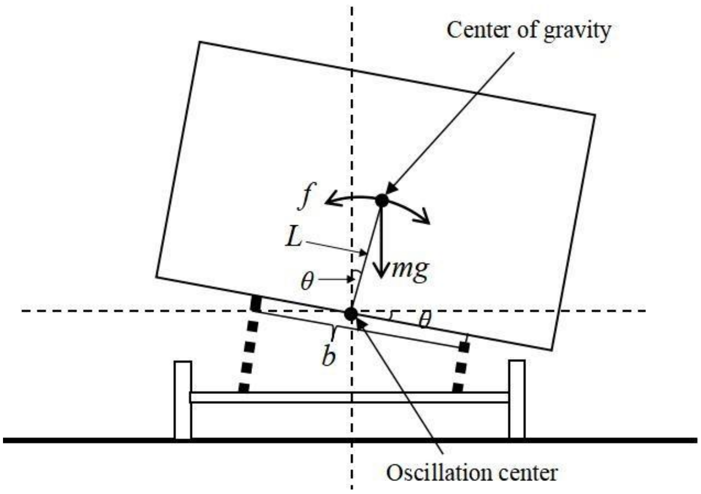


Figure 2. *Oscillation diagram of a moving vehicle*

When the vehicle body tilts to one side, springs on this side are squeezed, whereas the springs on the other side are stretched. Therefore, the direction of elastic moment is in the opposite direction of rolling. However, because of the inertia, the direction of gravity moment is consistent with the rolling direction.

The elastic moment and gravity moment are not equal. Therefore, the balance of the rotational moment is expressed as

$$Lf = -k\left(\frac{b}{2}\sin\theta\right)\frac{b}{2} + mgL\sin\theta - k\left(\frac{b}{2}\sin\theta\right)\frac{b}{2}\ , \qquad (1)$$

which equals

$$f = \left(-\frac{kb^2}{2L} + mg\right)\sin\theta, \qquad (2)$$

where L denotes the COG height from the oscillation center, f represents the force perpendicularto the connecting line between COG and oscillation center, k denotes elastic coefficient of spring, b represents the width of the portion that supports the whole weight, θ stands for the rolling angle,

m denotes the whole mass of the vehicle, and g signifies the gravitational acceleration which is 9.8 m/s^2.

The direction of force f depends on the gravity moment and elastic moment. In this case, if the gravity moment is dominant, then f will have a positive value; the vehicle will roll over. However, if elastic moment is dominant, then f will have a negative value. Here f can be regarded as restoring force to return the COG to its original position.

When rollover does not happen, the restoring moment direction reverses the gravity moment. In other words, the value of f should be no more than 0, so Equation (3) exists as

$$-\frac{kb^2}{2L} + mg \leq 0, \qquad (3)$$

When f becomes 0, in a static condition, L becomes the maximum height of COG denoted as L_{max}, which can be expressed as shown below.

$$L_{max} = \frac{kb^2}{2L}, \qquad (4)$$

It can be found from Equation (4) that because the spring constant and the width of supportingpart does not change, the maximum height of COG depends only on the total mass. In other words, if the total weight does not change, then the maximum height of the object is constant.

Based on the basic equations of D3DCG, the COG height can be detected through the natural frequencies of simple harmonic oscillation of a moving object caused by elastic structures. The formula of vertical simple harmonic motion is therefore

$$V' = \frac{1}{2\pi}\sqrt{\frac{2k}{m}}, \quad (5)$$

where V' denotes the frequency of vertical simple harmonic oscillation of the vehicle body. Therefore, k/m can be expressed by V' as

$$\frac{k}{m} = 2\pi^2 V'^2, \quad (6)$$

If Equation (6) is put into the Equation (4), then Equation (4), then the expression of themaximum height becomes

$$L_{max} = \frac{\pi^2 V'^2 b^2}{g}, \quad (7)$$

2.2. Verification of the maximum height of COG by experimentation

The experiment uses a table-top device shown in Figure 3 to simulate the vehicle structure. The device comprises two plates and four springs. Springs represent the elastic structures of a vehicle. When the disturbances act on the wheels, the vehicle body starts shaking. Similarly, when an external force is given from the vertical direction to the table-top device, the object on the upper plate starts shaking. Furthermore, the shaking frequency depends on the COG height. The experiment object is a tape tower consisting of nine tapes with a metal component. The metal mass is much greater than that of the tape. Therefore, the COG height of the tape tower changesas the position of the metal changes. The tapes are numbered from the bottom to the top. First, themetal is put under Tape 1; then it is lifted one tape height to the position between Tape 1 and Tape 2. This process is repeated until the metal reaches the top of tape tower. At every different position, the tape tower is provided with a vertical force to make it shake. At the same time, the motion sensor records the motion data. The tape top device and the COG height changing processare shown in Figure 3.

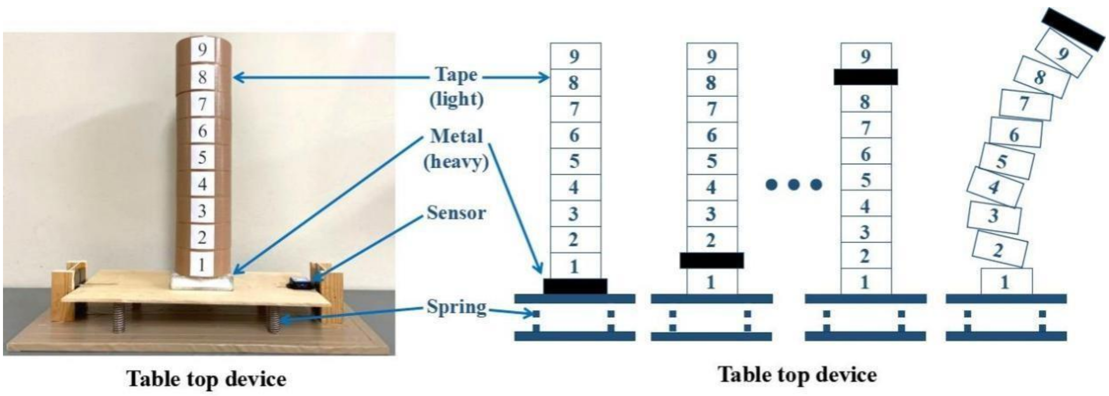


Figure 3. *Picture and diagram of table-top device and tape tower.*

The sensor can record the motion data including acceleration, angular velocity and angle from three directions, front and back, up and down, and left and right. Eight sets of data were collected when the metal is settled on one position. Table 1 presents the average of heaving frequency, rolling frequency, COG height and the maximum height of COG with the metal settled on different positions. Appendix 1 presents the specific data of each stage.

Table 1. Results of tape tower experiments with the table-top device

	Number of tapes under the metal								
	0	1	2	3	4	5	6	7	8
***V'* (hz)**	3.614	3.593	3.591	3.560	3.565	3.551	3.572	3.520	3.553
***V* (hz)**	0.870	0.850	0.773	0.681	0.583	0.486	0.390	0.264	0.165
***b* (m)**	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160	0.160
***L* (m)**	0.206	0.207	0.218	0.229	0.245	0.261	0.281	0.295	0.315
SD of *L*	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.002
L_{max} (m)	0.337	0.333	0.332	0.327	0.328	0.325	0.329	0.320	0.325
SD of L_{max}	0.002	0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.002

To eliminate the effects of errors, both L and $Lmax$ are calculated with the average values of heaving frequency and rolling frequency on different stages. The standard deviations of L and $Lmax$ are no more than 0.002, which means that the results are not discrete. Therefore, these datasets are accurate. Figure 4 intuitively shows the change of L and $Lmax$ and the relation between$L$ and $Lmax$ as the metal position rises.

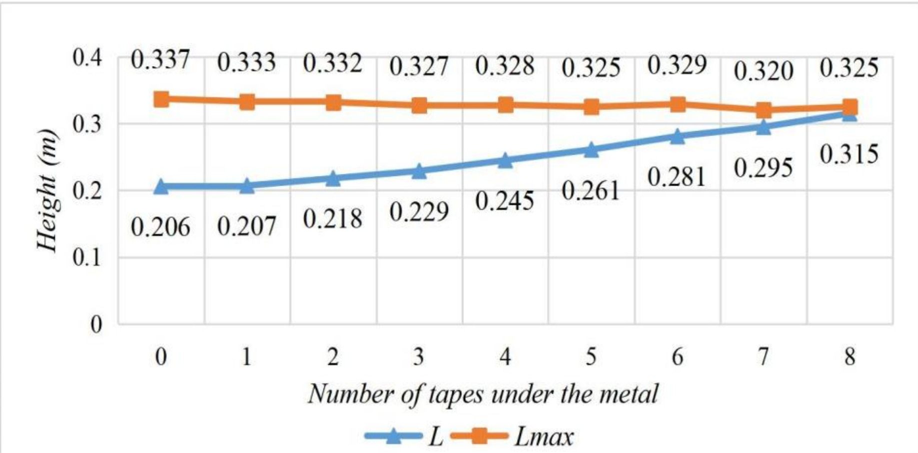


Figure 4. *Height of COG and maximum height of COG.*

The total weight of the object is fixed. Therefore, the maximum height of COG should be constant. Because of the errors, the calculated values of $Lmax$ are not absolutely the same, but they do not change a lot. It is statistically satisfactory. As the metal position rises gradually, the COG height increases. The object becomes increasingly difficult to keep steady. When there are eight tapes under the metal, the COG height is very close to the maximum height of COG. In this case, if the object is given an external force, then it is very easy for a rollover to occur. Furthermore, even if there is no existing external force, it is impossible to lift the weight to the top of the tape tower (nine tapes under the metal).

This experiment proves that an upper limitation of COG height exists. Objects with lower COG height are easier to keep steady than the higher ones. As the COG height increases, the stability lessens. In addition, the COG height cannot be greater than the maximum height of COG without rollover. The closer the COG height is to the maximum height of COG, the easier the object is to roll over.

3. MAXIMUM LATERAL FORCE OF ROLLOVER

3.1. Equation of rotational moment

Based on Figure 5 and Equation (2), the gravity moment and elastic moment are not always the same. Therefore, a force that can make COG keep rolling or return it to the original position exists. This force is presumed to be perpendicular to the contact line between COG and the oscillation center and is presumed to have a relation with gravity, which is expressed as

$$f = qmg\cos\theta, \tag{8}$$

where q stands for the multiple of lateral force relative to gravity in horizontal direction. Because the force is perpendicular to L, q should be multiplied by $cos\theta$.

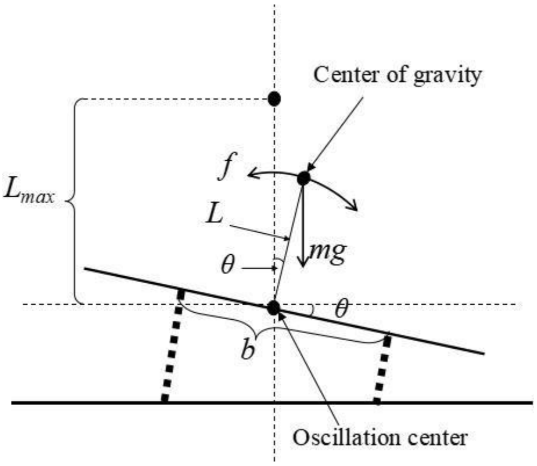


Figure 5. *Simplified sketch of oscillation*

If this force is replaced by its expression, then Equation (2) will become

$$qmg\cos\theta = \left(-\frac{kb^2}{2L} + mg\right)\sin\theta, \tag{9}$$

or

$$q = \left(-\frac{kb^2}{2Lmg} + 1\right)\tan\theta, \tag{10}$$

If unknown variables m and k are eliminated by the expression of L_{max} in Equation (4), then the relation between rolling angle θ and the multiple of lateral force q becomes

$$\theta = tan^{-1}\left(\frac{Lq}{L-L_{max}}\right), \tag{11}$$

3.2. Maximum lateral force without rollover

When a vehicle moves steadily along a road, the vehicle body is able to maintain a simple harmonic motion; the COG shakes around the oscillation center, which is located on the supporting portion. The line connecting it and the COG is perpendicular to the support.

When a moving vehicle is given an external force from lateral direction, for example, when a vehicle is affected by the centrifugal force when passing through a curve, the vehicle body willtilt to the opposite direction.

If the lateral force is sufficiently strong, then the vehicle will roll over. Figure 6 shows the criticalstate of the start of rollover.

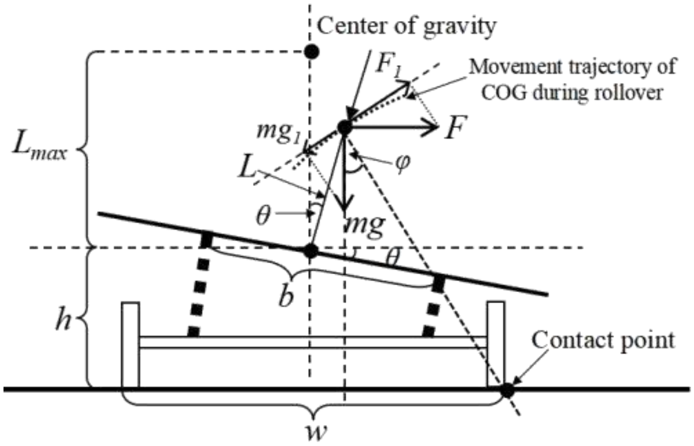


Figure 6. *Diagram of the start of the rollover critical state.*

According to the geometric structure of vehicle, when rollover starts, the rolling center is the contact point between the outer wheel and the road surface.

The lateral force is presumed as *F*. Its expression is

$$\boldsymbol{F = q_{\varphi} mg}, \tag{12}$$

where q represents the multiple of lateral force relative to gravity.

As Figure 6 shows, $F1$ is the component of lateral force on the tangent line of COG's movement trajectory. To prevent rollover occurrence, $F1$ should not be greater than the component of gravity denoted as $mg1$ in Figure 6. That is

$$mgsin\varphi \geq q_{\varphi} mgcos\varphi, \tag{13}$$

which is also written as

$$tan\varphi \geq q_{\varphi}, \tag{14}$$

where φ stands for the angle between the vertical direction and the connecting line of COG andthe contact point between the outer wheel and the road surface.

Therefore, at the critical state of rollover, the maximum value of $q\varphi$ equals the minimum value of

$tan\varphi$, which is expressed as

$$q_{\varphi max} = tan\varphi_{min}, \tag{15}$$

where $q\varphi max$ is the maximum multiple of lateral force relative to gravity, and φmin is the minimum angle between the vertical direction and the connecting line of COG and the contact point.

According to the geometric structure shown in Figure 6, $tan\varphi$ is expressed as

$$tan\varphi = \left|\frac{\frac{w}{2} - Lsin\theta}{Lcos\theta + h}\right|, \tag{16}$$

where w denotes the distance between the outer sides of the wheels on both sides, and where h represents the oscillation center height.

In Equation (15), $tan\varphi$ decreases as θ increases. Therefore, when θ reaches θmax, $tan\varphi$ becomes $tan\varphi min$ so that the multiple of lateral force becomes maximum. By combining Equation (15) and Equation (16), the maximum multiple of lateral force becomes

$$q_{\varphi max} = \frac{\frac{b}{2} - Lsin\theta_{max}}{Lcos\theta_{max} + h}, \qquad (17)$$

Based on Equation (11), the only unknown variable θmax can be replaced. Thereby, Equation (17) becomes

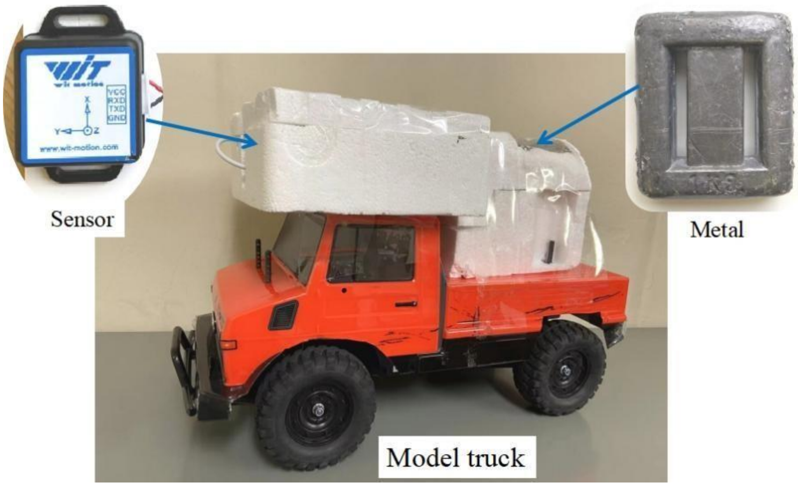
$$q_{\varphi max} = \frac{\frac{w}{2} - Lsin\left[tan^{-1}\left(\frac{Lq_{\varphi max}}{L-L_{max}}\right)\right]}{Lcos\left[tan^{-1}\left(\frac{Lq_{\varphi max}}{L-L_{max}}\right)\right] + h}, \qquad (18)$$

Therefore, the expression of the maximum lateral force without rollover has been found.

3.3. Rollover experiment verification

To verify the theory of the maximum lateral force, a rollover experiment is conducted. The experiment object is a model truck on which a motion sensor is settled, as Figure 7 shows.

Figure 7. *Object of rollover experiment.*



The model truck runs straight for a while so that the COG height and the maximum height of COG can be detected according to D3DCG. The detection process is repeated 10 times. The results are presented below.

Table 2. *Detected results of model truck by D3DCG*

Experiment number	V' (hz)	V (hz)	b (m)	w (m)	L (m)	L_{max} (m)
Exp. 1	9.473	3.516	0.150	0.170	0.192	2.033
Exp. 2	8.203	3.516			0.165	1.525
Exp. 3	8.398	3.516			0.169	1.598
Exp. 4	8.008	3.613			0.157	1.453
Exp. 5	9.668	3.516			0.196	2.118
Exp. 6	9.863	3.809			0.186	2.204
Exp. 7	8.301	3.613			0.163	1.561
Exp. 8	8.594	3.906			0.157	1.673
Exp. 9	9.473	3.809			0.178	2.033
Exp. 10	9.961	3.613			0.197	2.248
Average	8.994	3.643	-	-	0.176	1.845

As Table 2 shows, the COG height of the model truck is 0.176 m. The maximum height of the COG is 1.845 m. The distance between the outer sides of the wheels on both sides (w) ismeasured as 0.170 m. The oscillation center height (h) is 0.005 m. When these values are put into Equation (18), the maximum lateral force without rollover is found to be 0.481 g.

Based on the expression of maximum lateral force in Equation (18), neither the spring constant, total mass, speed nor curve radius is considered. Consequently, the experiment is designed to make the model truck continue turning with a random but fixed turning angle. Initially, the model truck speed is low. It speeds up gradually until the truck rolls over.

(a) (b) (c)

Figure 8. *Motion process of model truck.*

The motion process of the model truck is shown in Figure 8. First, the model truck speed is very low; the lateral force (centrifugal force herein) is weak. Therefore, the truck body merely tilts outward slightly. As the truck speeds up, the outward inclination of the truck body increases. Then, the truck body shakes dramatically. Finally, it rolls over.

During the experiment period, the motion sensor continues recording data. The original data are regarded as those for real-time lateral force after processing. The data processing process is shown in Figure 9. Panel (a) presents the original data, which have both positive and negative values. The plus and minus marks merely demonstrate the direction of the lateral force. This study does not take the marks into consideration. Consequently, the original data are transferred to their absolute value, as Panel (b) shows. The sampling frequency of the motion sensor is 200. To reduce the errors, the average value in a half second is chosen for this research. In other words,the data in Panel (c) are the average of every 100 data. To make the results more convincing, the real-time lateral force is the average absolute value of original data plus a 2.5 multiple of standard deviation, as Panel (d) shows.

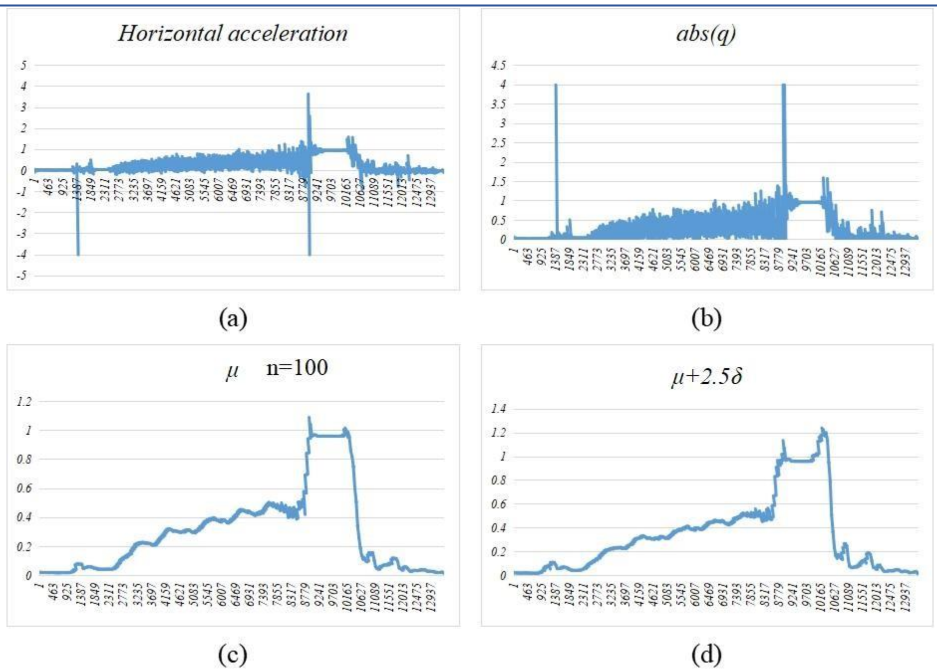


Figure 9. *Process of lateral force data processing.*

Both the real-time lateral force and the maximum lateral force without rollover are portrayed together in Figure 10. Two lines intersect on the red point, with rollover starting at the purple point. This phenomenon indicates that after the intersection the model truck loses control; it is at the critical state of rollover. In this condition, if the driver does not take some measure such as lowering the speed or turning the steering wheel, then the truck will roll over. The experiment is repeated seven times. Other results are presented in Appendix 2

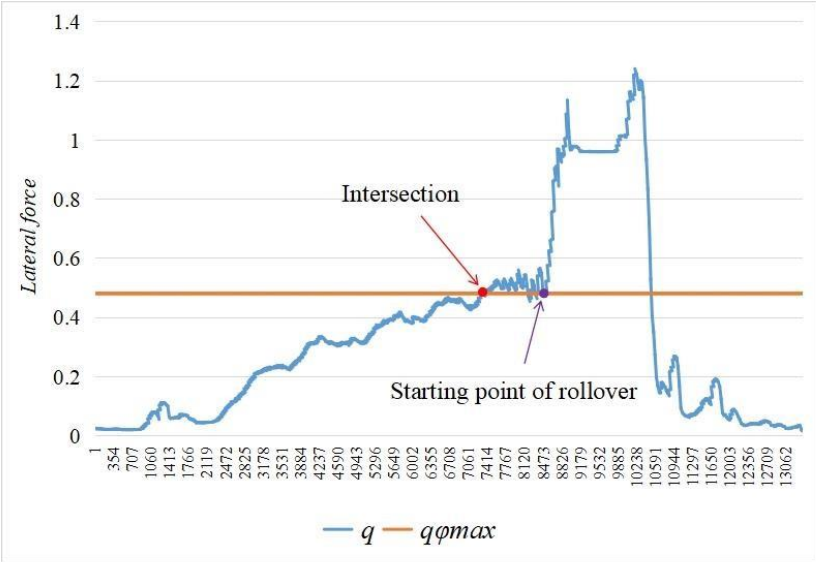


Figure 10. *Real-time lateral force and maximum lateral force without rollover*

4. CONCLUSION

This research first derives the equation of the maximum height of COG according to the basic equation of D3DCG. The tape tower experiment verifies the theory that the COG height closer to the maximum height of COG makes it more difficult for the object to remain stable and makes it easier to roll over. Furthermore, the object can not avoid rollover if the COG is higher than the maximum height of COG.

Based on the rotational moment of a moving vehicle, the lateral force has a relation with the rolling angle. Rollover often occurs in curved sections of a road because of lateral forces such as centrifugal force. When rollover starts, the rolling center changes from the oscillation center tothe contact point between the outer wheel and the road surface. At this critical state, according to vehicle ’ s geometric structure combined with the relation between the lateral force and rolling angle, the maximum lateral force which does not cause rollover is expressed by the COG height, the maximum height of COG and some basic parameters. The COG height and the maximum height of COG can be detected based on D3DCG. The basic parameters can be measured directly.Therefore, no unknown variable exists in the equation of the maximum lateral force without rollover.

The process of detection and calculation takes only a few seconds, therefore allowing real-time usability. Furthermore, when the lateral force acting on the vehicle reaches the maximum lateral force calculated, the vehicle will not roll over immediately. It just loses control. Nevertheless, some time remains for a driver to take some measures to avoid rollover accidents such as slowing the speed or adjusting the direction.

This research provides a method for vehicle rollover prevention while using simpler calculations and fewer errors. Because the sensor repeats collection of data, both the real-time lateral force andthe calculated maximum lateral force without rollover are renewed continuously. The results updated in real time can greatly reduce the influence of external factors. This research has great prospects for application to vehicles of all types, even trains and aircraft, and especially to vehicles for which the COG position changes frequently.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Sürdürülebilir Pazarlamada Ekonomik, Sosyal ve Çevresel Faktörlerin Önem Derecesinin Belirlenmesi: Süt Ürünleri Üreticisi Firma Örneği

Determining the Importance of Economic, Social and Environmental Factors in Sustainable Marketing: Dairy Producer Company Example

Zeynep ERDOĞAN[1] İsmail Çağrı KILIÇ[2] Yasin AFŞAR[3] Arzum BÜYÜKKEKLİK[4]

ÖZ

Günümüzde tüketicinin değişen davranışları, istekleri, çevreye karşı artan hassasiyetleri işletme ve markaları bu değişimlere ayak uydurmaya ve faaliyetlerini sürdürülebilir bir pazarlama anlayışı ile gerçekleştirmeye zorlamaktadır. İşletmelerden faaliyetlerinde ekonomik, sosyal ve çevresel boyutları göz ardı etmeden tüketicinin ihtiyaç ve isteklerini karşılaması beklenmektedir. Ancak, işletmelerin sektörleri ve ürünlerinin özellikleri açısından sürdürülebilir pazarlama faaliyetlerinde hangi boyut ve kriterleri önceledikleri farklılaşmaktadır. Bu bağlamda yapılan araştırmanın ana amacı, süt ürünleri üreticisi bir firmanın sürdürülebilir pazarlama kapsamında ekonomik, sosyal ve çevresel boyutların hangisine ne derecede önem verdiklerinin belirlenmesidir. Bunun için önce sürdürülebilirliğin ekonomik, sosyal ve çevresel boyutlarının alt kriterleri belirlenmiş, sonrasında çok kriterli karar verme tekniklerinden analitik hiyerarşi yöntemi kullanılarak alt kriterlerin önem düzeyleri hesaplanmış ve hangi boyut ve alt kriterlerin firma özelinde önemli olduğu ortaya konmuştur. Araştırmayla ilgili firmanın ekonomik faktörlere yönelik önem düzeyinin, sosyal ve çevresel faktörlere göre daha yüksek olduğu sonucuna ulaşılmıştır. Firmanın sürdürülebilir pazarlama anlayışını bütüncül açıdan ele almadığı, çevresel faktörler için henüz örgüt kültürü ve yapılanmalarının olmadığı, buna yönelik devlet destek ve teşvikleriyle birlikte ancak bu sürece dahil olabileceklerini belirlenmiştir.

Anahtar Kelimeler: Sürdürülebilir pazarlama, ekonomik faktörler, sosyal faktörler, çevresel faktörler, AHP.

ABSTRACT

Today, the changing behaviors of the consumers, their demands and increasing sensitivity towards the environment force businesses and brands to keep up with these changes and to carry out their activities with a sustainable marketing approach. It is expected that the businesses will meet the needs and demands of the consumers without ignoring the economic, social and environmental factors in their activities. However, the dimensions and criteria that businesses prioritize in sustainable marketing activities differ in terms of their sectors and the characteristics of their products. In this context, the main purpose of the research is to determine to what extent a dairy producer company attaches importance to the economic, social and environmental dimensions within the scope of sustainable marketing. For this, first the sub-criteria of the economic, social and environmental dimensions of sustainability were determined, then the importance levels of the sub-criteria were calculated using the analytical hierarchy method, which is one of the multi-criteria decision-making techniques, and it was revealed which dimensions and sub-criteria are important for the company. It has been concluded that the level of importance of the company related to the research for economic factors is higher than that of social and environmental factors. It has been determined that the company does not consider the concept of sustainable marketing from a holistic perspective, that there is no organizational culture and structures for environmental factors yet, and that they can only be involved in this process with government support and incentives.

Keywords: Sustainable marketing, economic factors, social factors, environmental factors, AHP.

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1. GİRİŞ

Tüketicinin bilinçlendiği, doğayı korumaya yönelik duyarlı yaklaşımların benimsendiği, tüketicilerin olumlu/olumsuz tepkilerinin hızlı bir şekilde yayıldığı günümüz dünyasında işletmelerin sadece tüketimi karşılamak yerine topluma daha fazla fayda sağlayacak çalışmalar yapması, sosyal ve çevresel açıdan da değer yaratması beklenmektedir. Çevreye yönelik oluşturulan stratejiler birçok işletmeye rekabet avantajı sağlamaktadır (Vafaei vd., 2019). Toplumların ve ekonomilerin yirminci yüzyılın sürdürülemez düşünce, uygulama ve teknolojilerinden çok daha sürdürülebilir bir dönüşüm içinde olduğu görülmektedir ve bu yolda ilerleyen işletmeler artmaktadır (Chomová, 2022). Diğer yandan, toplumdaki bilinç arttıkça bireysel açıdan kişisel gereksinimlerin karşılanması ve tatmin edilmesinin yanı sıra sosyal ve çevresel açıdan insanların duyarlılıkları da artmaktadır. İşletmelerin ve markaların sürdürülebilir bir dünya içerisinde ayakta kalabilmesi ve yeni normlara ayak uydurabilmesi gerekmektedir. Bu kapsamda, işletmeler sürdürülebilirlik faaliyetlerine geçmişe kıyasla daha fazla önem vermek zorunda kalmış, sürdürülebilirlik ve sürdürülebilir pazarlama yönünde çalışmalar işletmelerin öncelikli konuları halini almıştır.

Sürdürülebilirlik yapısının bir bütün olarak ele alınarak işletmenin tüm faaliyetlerinde benimsenmesinin gerekli olduğunun bilincinde olunması ve buna yönelik adımların planlanması işletmelerin rekabetçiliklerini devam ettirmelerine yardımcı olmaktadır. Bu durum çevresel, ekonomik ve sosyal eşitlik ilkelerinin aynı anda benimsenmesini gerektiren "üçlü temel model (triple bottom-line)" perspektifi olarak ele alınmaktadır (Elkington, 1998; Stankeviciute ve Savaneviciene, 2013). Sürdürülebilir kalkınma yaklaşımında sosyal, çevresel ve ekonomik boyutlar bütünleştirmeli ve birlikte kullanılmalıdır (Goodland, 1995). Bu çerçevede sürdürülebilirlikle ilgili çaba gösteren işletmelerin ekonomik, sosyal ve çevresel faktörlere bütünsel yaklaşması önemlidir. Her ne kadar sürdürülebilirlik çerçevesinde sosyal ve çevresel yapının önemli olduğu dile getirilse de hala geleneksel yaklaşım benimseyerek ekonomik faktörleri önceleyen salt bir üretim ve tüketim anlayışı ile hareket eden işletmeler de bulunmaktadır. Toplumsal anlayışa sahip işletmeler sürdürülebilirlik konusunda önemli sorumluluklar üstlenirken; geleneksel pazarlama anlayışıyla toplumu sürekli olarak tüketime zorlayan ve daha fazla üretmeyi hedefleyen işletmeler de bulunmaktadır. Gelecek nesilleri düşünmeksizin sadece kendi menfaatleri doğrultusunda hareket eden, topluma ve çevreye verdiği olumsuz etkilere göz ardı eden bu tip işletmeler daha fazla pazar payı almanın ve daha fazla kar elde etmenin çabası içindedirler. İşletmeler tarafından sergilenen bu yöndeki tutum ve davranışlar hem işletmelerin kendi varlıklarını sürdürmelerine hem de dünyaya ve insanlığa önemli tehlikeler yaratmaktadır (Sarıkaya ve Kara, 2007).

Sürdürülebilir pazarlama tüketicilerin ihtiyaç ve isteklerini karşılama, toplumsal refahı artırma, çevreyi korumayı birlikte amaçlar (Kayıkçı vd., 2019). Geleneksel pazarlama tüketici ihtiyaçlarını tatmin ederek uzun vadeli ilişki kurmayı temel alırken; sürdürülebilir pazarlama tüketiciler, sosyal çevre ve doğal çevre ile sürdürülebilir ilişkiler kurmayı hedefler (Önce ve Marangoz, 2012). Sürdürülebilir pazarlama yaklaşımında ise pazarlamaya makro pazarlama perspektifinden bakılarak müşteri değeri ile birlikte sosyal ve çevresel değerler de yaratılmakta, işletme ile ekolojik çevrenin birbirleriyle ilişkisi dengelenmektedir (Kayıkçı vd., 2019).

Araştırmada, süt ürünleri üreticisi bir firmanın pazarlama faaliyetlerinde sürdürülebilirliğin ekonomik, sosyal ve çevresel boyutlarına verdikleri önem derecesinin belirlenmesi amaçlanmıştır. Bu kapsamda önce sürdürülebilirliğin ekonomik, sosyal ve çevresel boyutlarının alt kriterlerinin belirlenmesi, alt kriterlerin önem düzeylerinin sıralanması ve bunun sonunda hangi boyut ve alt kriterlerin firma özelinde önemli olduğunun ortaya konması hedeflenmiştir. Araştırmada Çok Kriterli Karar Verme Tekniklerinden (ÇKKV) Analitik Hiyerarşi Süreci (AHP) kullanılarak firma açısından önceliklendirilen kriterler ve bunların önem dereceleri belirlenmiştir. Yapılan literatür incelemesinde Türkiye'de süt ürünleri üretimindeki işletmeler özelinde sürdürülebilir pazarlama boyutlarına yönelik bir araştırmaya rastlanamamıştır. Bu kapsamda çalışmanın farklı bir sektör uygulamasıyla literatüre katkı sağlamasıöbeklenmektedir.

Altı bölümden oluşan bu çalışmada, girişten sonra ilk olarak kavramsal olarak sürdürülebilirlik ve boyutları ile sürdürülebilir pazarlama hakkında bilgi verilmiş, literatürden örnekler sunulmuştur. Daha sonra araştırmanın metodolojisi açıklanmış, uygulamanın bulguları yorumlanmıştır. Çalışma sonuç ve öneriler bölümü ile tamamlanmıştır.

2. SÜRDÜRÜLEBİLİRLİK

1987 yılında Birleşmiş Milletler Dünya Çevre ve Kalkınma Komisyonu tarafından yayınlanan "Ortak Geleceğimiz (Our Common Future)" raporunda sürdürülebilir kalkınma gelecek nesillerin ihtiyaçlarını karşılayabilmesinde zorluk yaşanmayacak şekilde bugünün ihtiyaçlarının karşılanabilmesi olarak tanımlanmıştır. Sürdürülebilirlik toplumun, ekosistemin işleyişini kesintisiz bozulmadan aşırı kullanımla tüketmeden veya kaynakları tüketmeden sürdürme kabiliyeti olarak anlaşılmalıdır (Kaypak, 2010). Sürdürülebilir kalkınma, herkesin temel ihtiyaçlarının karşılanması ve daha iyi yaşam standartlarına sahip olunması için fırsatların genişletilmesini önerir ve aşağıda açıklanan iki anahtar kavramı içerir (Nations, 1987):

İhtiyaçlar: Dünyadaki yoksulların temel ihtiyaçları olup, her şeyden önce bunlara öncelik verilmeli,
Sınırlamalar: Teknoloji çevresinin mevcut ve gelecekteki tüketici ve işletme ihtiyaçlarını karşılayabilme yeteneğine dayattığı engeller.

Sürdürülebilirlik; ekonomik kalkınma ile refah artışını, çevrenin korunması, çevresel zararın azaltılmasını ve sosyal adaletin sağlanmasını amaçlayan temel, bütünsel bir yaklaşımdır (Büyükkeklik ve Özoğlu, 2021). Sürdürülebilirlik, ekonomik ve yönetişim faaliyetlerini içine alarak, toplumsal sorunları, ekolojik ve çevresel meseleleri de kapsayacak şekilde genişlemiştir. Bu durum şimdiye kadar ticari faaliyetlerin bir parçası olarak sürdürülen sürdürülemez üretimi ve tüketimi durdurmak veya tersine çevirmektir. Sürdürülebilir kalkınma kaynaklara olan ihtiyacın insanların refahının ekonomik gelişmesi ile sosyal ve ekonomik çevresinin birlikte ele alınarak geniş bir perspektiften bakılmasını gerektirir. Buna göre sürdürülebilir kalkınmanın 3 boyutu vardır.

Ekonomik Boyut: Sürdürülebilirlik, ulusal ve/veya uluslararası düzeylerdeki ekonomik şartlara ve sistemlere bağlıdır. Ekonomik olarak sürdürülebilir bir sistemde, işletmelerin sürekli olarak mal ve hizmet üretmesi ve üretim gerçekleştirirken sektörel dengesizliklerden uzaklaşması gerekmektedir (Harris, 2000).

Sosyal Boyut: Sosyal olarak sürdürülebilir bir sistemde işletmeler ve kurumlar; gelir dağıtımında eşitlik, sağlık ve eğitim dahil olmak üzere daha birçok açıdan yeterli sosyal hizmet sunumu, iş ortamında ve toplumda cinsiyet eşitliğinin ve çoğulcu katılımın sağlaması yönünde çaba sarf etmelidir (Harris, 2000). Sosyal sürdürülebilirliğin sağlanmasında, çevresel sürdürülebilirlik veya yaşam destek sistemleri birer ön koşul oluşturmaktadır (Goodland, 1995).

Çevresel Boyut: Çevresel açıdan sürdürülebilirlik yenilenebilir kaynak kullanımını temel alan atmosferik dengenin, biyolojik çeşitliliğin sağlanması ve ekosistemin korunması olarak ifade edilebilir (Soydan ve Başkol, 2022). Sağlıklı bir toplum ve ekolojik çevre olmadan, ekonomiler başarısız olacak ve ekonomilerin parçası olan işletmeler de varlıklarını kısa süreli devam ettirebilecektir.

İklim değişikliği, hava kirlilik, çevresel bozulma, tükenen kaynaklar, dünyadaki kalıcı açlık ve yoksulluğu karakterize eden sosyo-ekonomik eşitsizliklerle bağlantılı sayısız sorunu ele almak için işletmelerin birlikte hareket etmesi ve 3 boyutu bütüncül değerlendirmesi gerektiği düşünülmektedir. Sürdürülebilirlik, bu üç boyutun birlikte ele alınmasıyla sağlanabileceğinden işletmeler; sosyal faaliyetler ve çevre koruma çalışmaları gibi finansal/mali olmayan performanslarını ekonomik gelişimindeki karar verme ve stratejik planlama çalışmalarına dahil etmelidir (Orlitzky, 2008). Sosyal ve çevresel iyileştirmelere yapılan yatırımlar işletmelerin sadece güvenilirliklerini artırmakla kalmayıp; aynı zamanda uzun vadeli karlılıklarını da artırmaktadır.

Sürdürülebilir kalkınma için her sektör veya işletme kendi bünyesinde farklı çözümler ve cevaplar üretmelidir. İşletmelerin çözüm odaklı işbirlikleri değer yaratmaktadır. Örneğin, otomotiv sektöründe pek çok marka elektrikli otomobilleri desteklemekte, kimya alanında petrol bazlı malzemeler yerine organik ürünlerin kullanımına odaklanılmakta, enerji sektöründe yenilenebilir enerjilere doğru bir geçiş söz konusu olmaktadır. Hızlı tüketim ürünlerinde Unilever karbon ayak izlerini azaltmaya yönelik faaliyetler yapmaktadır (Cirik, 2010). Walmart hammaddeden atıklara kadar bir ürünün yaşam döngüsündeki her aşamayı sürdürülebilir üretim anlayışı doğrultusunda şekillendirmektedir.

Aslında sürdürülebilirlik bakış açısını tetikleyen birçok unsurdan bahsetmek mümkündür. Şirketler, kendilerini çevreye karşı daha sorumlu ve duyarlı hissetmeye başlamakta; tüketiciler ise bu sorumluluğu üzerine almak istemeyen, bu konuları göz ardı eden şirketler üzerinde ise baskı kurmaktadır. Bir başka tarafta ise, tüm bu sürdürülebilir çalışmalar tasarruf ve verimliliği artırmaktadır (Tayman, 2010). Pazarlama faaliyetleri de bu kapsamda tüketici ve pazar ihtiyaçlarına yanıt verirlikten, pazarları sürdürülebilir ürün ve hizmetlere yönlendiren ve sürdürülebilir toplumlar inşa eden daha sorumlu bir yaklaşıma doğru değişmektedir (Sheth ve Parvatiyar, 2021).

3. SÜRDÜRÜLEBİLİR PAZARLAMA VE LİTERATÜR ÖZETİ

Sürdürülebilir pazarlama, pazarlama faaliyetlerinde müşterilerin ihtiyaç ve isteklerine cevap verirken üretim ve tüketim arasındaki dengenin çevreye zarar vermeden sağlanmasıdır (Kirchgeorg ve Winn, 2006). Sürdürülebilir pazarlama, modern pazarlamanın kısa vadeli işlem odağının aksine, ilişkisel pazarlamanın uzun vadeli yönelimini esas almaktadır (Peattie ve Belz, 2010). Sürdürülebilir pazarlama yalnızca ürün geliştirme, satış ve pazarlamanın değil, bir işletmenin tüm eylemlerine rehberlik edecek bir stratejinin parçası olarak anlamlıdır.

İşletmelerin doğal kaynakların tüketilmesi ve küresel ısınmadan dolayı sürdürülebilir pazarlama faaliyetlerine önem vermesi gerekmektedir (Reutlinger, 2012). Tüketiciler, işletmelerden sürdürülebilir pazarlama stratejileri geliştirmesini beklemektedir. Sürdürülebilir pazarlama, her sektörde büyüyen bir endişe haline gelmiş, sosyal medyanın yükselişi ve milyonlarca tüketici üzerindeki etkisiyle, hem şirketler hem de halk arasında hızla kabul görmektedir (Charter vd., 2002).

Sürdürülebilirlik ile kast edilen sadece şirketlerin iyi yönetilmesi, doğru strateji ve taktiklerin oluşturulması değil, bunun daha ötesinde çevre ve toplumdan kaynaklanan riskleri ve fırsatları iş modellerinin içerisine entegre etmektir (Cirik, 2010). Şirketlerin ve tüketicilerin sosyal ve çevresel açıdan verdikleri etkilerinden dolayı üretim ve tüketimde sorumluluk almaları gerektiğini savunan sürdürülebilir pazarlama, kilit oyuncuların çevrelerini etkileyici bir güce sahip olduğunu kabul etmekte ve bugünün kararlarının gelecek nesil tüketiciler, vatandaşlar, yatırımcılar ve yöneticiler üzerindeki etkisinin olduğunu vurgulamaktadır (Peattie ve Belz, 2010). Bunun için işletmenin yürüttüğü faaliyetler nedeniyle çevrenin uğradığı zararların oluşturduğu maliyetlere yönelik bütçe ayrılması, ürün yaşam eğrisi yaklaşımının kullanımı, sıfır-atık sistemlerinin geliştirilmesiyle kirliliğin engellenmesi ve kaynak geri kazanımının sağlanması, israfın engellenmesi gibi uygulamalar sürdürülebilir pazarlamada kullanılabilmektedir (Ayyıldız ve Genç, 2010). Sürdürülebilir pazarlama için Wal-Mart, Ikea, P&G, Bosch gibi pek çok dünya devi iş ve üretim süreçlerini gözden geçirmekte, yöneticiler bütünleşik uygulamaları işaret etmektedir. Örneğin; Siemens Ceo'su Peter Löscher dev şirketlerin üretim süreçlerinde, iş yapma şekillerinde ve hatta iş ortamlarında yeşil bir değişim gerçekleştiğinden bahsetmektedir. Walmart'ın eski Ceo'su ise, en büyük amaçlarının sürdürülebilir bir üretim yaklaşımıyla çevreci hareket eden tedarikçilerle çalışmak istediğini vurgulamıştır (Tayman, 2010). Buradan şirketlerin, tedarikçilerini de sürdürülebilirlik perspektifinden değerlendirme ihtiyacının da arttığı anlaşılmaktadır (Dai ve Blackhurst, 2011).

Şirketlerin sürdürülebilir pazarlamaya dair uygulamalarının yanı sıra literatürde sürdürülebilirlik ve sürdürülebilir pazarlama (Trivedi vd., 2018; Vafaei, 2019; Sun vd., 2019; Iqbal vd., 2020; Vinuesa vd., 2020; Jamwal vd., 2021; Ruggerio, 2021; Khandai vd., 2022; Rastogi vd., 2022) konuları ele alınıp araştıran çok sayıda çalışma bulunmaktadır. Sürdürülebilirliğin boyutlarına yönelik çalışmalarda ÇKKV yöntemleri sıklıkla kullanılmaktadır. Örneğin Fettahlıoğlu ve Birin (2016) Kahramanmaraş ilinde bulunan ambalaj atıklarından geri dönüşüm gerçekleştirerek plastik sanayi sektöründe faaliyet gösteren bir işletmenin sürdürülebilir pazarlamayı etkileyen faktörlerini ÇKKV yöntemleri kullanarak incelemiştir. Analiz sonuçlarına göre, karar verici firmanın sürdürülebilir pazarlamayı etkileyen en önemli temel faktörün ekonomik gereksinimler kriteri olduğu belirlenmiştir. Birin (2015), plastik sanayi sektöründe sürdürülebilir pazarlamayı etkileyen faktörlerin belirlenmesine yönelik bir uygulama yaparak, ÇKKV yöntemiyle kriterlerin önem düzeyini tespit etmiştir.

Doğrudan sürdürülebilirliğin boyutlarının önemine yönelik bu çalışmaların yanı sıra ÇKKV yöntemlerini kullanarak sürdürülebilirlik performansını boyutlar çerçevesinde ele alan farklı sektörlerden de çok sayıda çalışmaya rastlanmıştır. Bunlardan Öztel vd. (2012) kimya sektöründen Henkel firmasında sürdürülebilirlik performansının ölçümünde, Alp vd. (2015) yine kimya sektöründe Linde firmasının kurumsal sürdürülebilirlik performansının değerlendirilmesinde ÇKKV yöntemlerini kullanmışlardır. Ersoy (2016) Arçelik firmasının kurumsal sürdürülebilirlik performansının ekonomik, çevresel ve sosyal sürdürülebilirlik göstergeleri çerçevesinde analizinde, Aksoylu ve Taşdemir (2020) metal eşya, makine ve gereç yapımı sektöründe çalışmalar yapan 6 işletmenin sürdürülebilirlik raporları çerçevesinde ekonomik, sosyal ve çevresel boyutlarını incelemiş olup, işletmelerin sürdürülebilirlik performanslarını değerlendirmede ÇKKV yöntemlerinden faydalanmışlardır. Oral ve Geçdoğan (2020) Borsa İstanbul’da işlem gören ve kurumsal sürdürülebilirlik çalışmalarına yönelik rapor düzenleyen bankaların sıralanmasında ÇKKV yöntemlerini kullanmıştır. Özevin (2022), araştırmasını yaptığı çalışmada şirketlerin çevresel sosyal ve ekonomik olmak üzere üç boyuttan oluşan kurumsal sürdürülebilirlik performanslarının ölçülmesinde hangi kriterlerin etkili olduğu ve oluşturulan kriterlerin hangi şirketlerin kurumsal sürdürülebilirlik performansı kapsamında daha etkili sonuçlar sağladığı yine ÇKKV metodlarıyla analiz etmiştir.

4. ARAŞTIRMA YÖNTEMİ

Araştırmanın bu bölümünde çalışmanın amacı, önemi ile veri toplama süreci ve kullanılan yönteme ait bilgiler sunulmuştur.

4.1. Araştırmanın Amacı

Araştırmada, süt ürünleri üreticisi bir firmanın pazarlama faaliyetlerinde sürdürülebilirliğin ekonomik, sosyal ve çevresel boyutlarına verdikleri önem derecesinin belirlenmesi amaçlanmıştır. Bu kapsamda önce sürdürülebilirliğin ekonomik, sosyal ve çevresel boyutlarının alt kriterlerinin belirlenmesi, alt kriterlerin önem düzeylerinin sıralanması ve bunun sonunda hangi boyut ve alt kriterlerin firma özelinde önemli olduğunun ortaya konması hedeflenmiştir. Çalışmada sürdürülebilir pazarlama boyutlarının önem dereceleri süt ürünleri üreticisi bir firma üzerinden ele alınarak incelenmiştir.

4.2. Araştırmanın Önemi ve Katkısı

Sürdürülebilirliğin kazandığı önem dolayısıyla işletmelerin sürdürülebilir pazarlama faaliyetlerine odaklandıkları bilinmektedir. Diğer yandan, akademik araştırmalarda da yoğun olarak sürdürülebilirlik ve sürdürülebilir pazarlama konuları ele alınıp araştırılmaktadır. Ancak literatür incelendiğinde geçmişte yapılan çalışmalarda Türkiye’de süt ürünleri üretimindeki işletmeler özelinde sürdürülebilir pazarlama boyutlarına yönelik bir araştırmaya rastlanamamıştır. Bu kapsamda çalışmanın farklı bir sektör uygulamasıyla literatüre katkı sağlaması beklenmektedir.

4.3. Veri Toplama ve Analiz Yöntemi

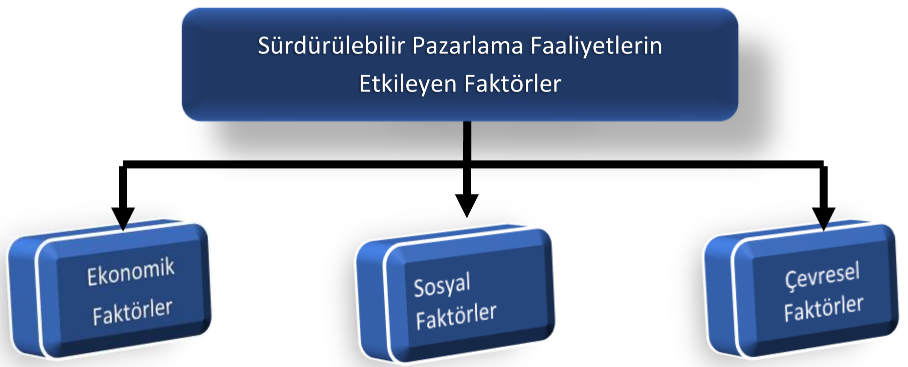
Araştırmada veri Niğde İlinde faaliyet gösteren süt ürünleri üreticisi firmanın uzmanlarıyla yüz yüze görüşülerek toplanmıştır. Firma uzmanlarından sürdürülebilir pazarlama boyutları ve alt kriterlerine Satty Ölçeği kullanılarak 1 ile 9 arasında puan vermeleri istenmiştir. Kriterler ve boyutlar arasında kıyaslama yapılarak faktör ve alt boyutların önem dereceleri süt ürünleri üreticisi işletme özelinde değerlendirilmiştir.

Çalışmada, ÇKKV yöntemlerinden AHP (Analitik Hiyerarşi Prosesi) kullanılarak uygulama yapılmıştır. ÇKKV yöntemleri karar vericiler açısından birden fazla sayıda ve birbirine bağımlı olmayan faktörlerin ne derecede etkili olduğunu dikkate alarak, araştırma problemlerine ve oluşturulan faktörlere göre en optimal kararın verilmesinde yol gösteren yöntemlerdir (Hamurcu ve Eren, 2018). ÇKKV yöntemleri içerisinde yer alan AHP ise, alternatifler arasında bir tercih ve seçimde bulunabilmek için ikili karşılaştırma prosedürünü kullanan çok amaçlı, çok kriterli bir karar verme yaklaşımıdır. AHP bir problem çözme çerçevesi olup, her bir değişkenin göreli önemine ilişkin yargılara sayısal değerler atamak, hangi değişkenlerin en yüksek önceliğe sahip olduğunu belirlemek ve buna göre karar vermek amacıyla yargıları sentezlemede kullanılır (Satty, 1984).

5. BULGULAR

Niğde ilinde faaliyet göstermekte olan süt ürünleri üreticisi firmanın sürdürülebilir pazarlamayı etkileyen faktörlerinin önem düzeyinin tespit edilmesini amaçlayan uygulamanın adımları aşağıda verilmiştir.

Hiyerarşik Yapının Oluşturulması: Çalışmada sürdürülebilir pazarlamayı etkileyen ana faktörler sürdürülebilirliğin temel boyutları olan ekonomik, sosyal ve çevre boyutları olarak ele alınmış; Moshood vd., 2002; Çoşkun, 2011; Terzi vd., 2020; Sağer, 2019'den faydalanarak da bu boyutların altında on üç alt kriter belirlenmiştir. Boyutlar ve alt kriterler Şekil 1'de sunulmuştur.



- Süt Tedarik Maliyetleri
- Üretim Maliyetleri
- Hijyen

- Çalışanların sağlık ve güvenliği
- Dezavantajlı Grupları destekleme
- Hesap Verilebilirlik
- Çalışanlar arasındaki eşitlik

- Hava Kirliliğini Azaltma
- Çevresel Düzenlemelere Uyma
- Atık Oluşumunu Azaltma
- Yenilenebilir Enerji

***Şekil 1:** Sürdürülebilir Pazarlama Faaliyetlerini Etkileyen Faktörler*

İkili karşılaştırma matrislerinin oluşturulması: Süt ürünleri üretici işletmenin sürdürülebilir pazarlama faaliyetlerini etkilediği düşünülerek literatürden edinilen bilgiler doğrultusunda faktörlerin belirlenmesi için oluşturulan hiyerarşik yapıda bulunan kriterlerin kıyaslanmasına yönelik ikili karşılaştırma matrisleri Satty Ölçeği kullanılarak meydana getirilmiştir. Araştırmanın ana kriterleri olan ekonomik, sosyal ve çevresel boyutlarının ikili karşılaştırma matrisi Tablo 1'dedir.

Tablo 1. *Sürdürülebilir Pazarlama Ana Kriterleri Arasında İkili Karşılaştırma Matrisi*

Ana Kriterlerin Karşılaştırıldığı Matris			
	EF	**SF**	**ÇF**
EF	1	4	3
SF	0,25	1	2
ÇF	0,33	0,5	1
Tutarlılık Oranı		0,06	

*EF: Ekonomik Faktörler; SF: Sosyal Faktörler; ÇF: Çevresel Faktörler

Tablo 1'de incelendiğinde, ekonomik faktörlerin sosyal faktörlere göre ''orta düzeyde önemli'' olduğu, ekonomik faktörlerin çevresel faktörlere göre de ''orta derecede önemli'' olduğu görülmektedir. Araştırma yapılan firmadaki uzmanlara göre süt ürünleri üretimi gerçekleştirirken ekonomik faktörler diğer faktörlere göre daha yüksek önemde; sosyal faktörler ve çevresel faktörler kıyaslandığında ise sosyal faktörler çevresel faktörlere göre daha yüksek önemde bulunmaktadır.

Kriterler İçin Ağırlıkların Hesaplanması: Sürdürülebilir pazarlama faaliyetlerini etkileyen ana faktörler incelendiğinde Tablo 2'ye göre üzerinde araştırma yapılan bu firma için ana kriterlerden olan ekonomik faktörler 0,62 önem derecesine sahiptir. Ekonomik faktörler birinci derecede firma için öneme sahip olduğu görülmüştür. Ekonomik faktörlerden sonra gelen önem derecesi yüksek olan faktörler sırasıyla 0,22 ile sosyal faktörler, 0,16 önem derecesi ile çevresel faktörler olarak tespit edilmiştir.

Tablo 2. *Sürdürülebilir Pazarlama Ana Kriterlere Göre Önem Derecesi*

Kriterler	**Önem Derecesi**
Ekonomik Faktörler	**0,62**
Sosyal Faktörler	0,22
Çevresel Faktörler	0,16

Tablo 3'te görüldüğü üzere ekonomik faktörlerin alt kriterlerinden süt tedarik maliyetlerinin 0,43 önem düzeyi ile firma için en önemli kriter olduğu sonucuna ulaşılmıştır. Üretim maliyetleri de 0,21 ağırlık değeri ile ikinci sırada önemlidir. En az öneme sahip maliyet kriteri ise hijyen maliyeti (0,11) olarak görülmektedir.

Tablo 3. *Ekonomik Faktörlerin Alt Kriterine Göre Önem Değeri*

Alt Kriterler	**Önem Değeri**
Süt Tedarik Maliyetleri	**0,43**
Üretim Maliyetleri	0,21
Hijyen Maliyetleri	0,11
Teknoloji Maliyetleri	0,17

Sosyal faktörlerin alt kriterlerinin ağırlık düzeyleri sıraladığında (Tablo 4) 0,40 önem değeri ile en yüksek önemin hesap verilebilirlik olduğu görülmektedir. Daha sonra sırasıyla 0,25 değerle çalışanlar arasında eşitlik, 0,17 ile çalışan eğitimi, 0,12 sağlık ve güvenlik; 0,06 ağırlık oranı ile dezavantajlı grupları destekleme gelmektedir.

***Tablo 4**. Sosyal Faktörlerin Ana Kriterinin Alt Kriterine Göre Önem Değeri*

Alt Kriterler	Önem Değeri
Çalışan Sağlığı ve Güvenliği	0,12
Dezavantajlı Gruplar	0,06
Hesap Verilebilirlik	**0,40**
Çalışanlar arasında eşitlik	0,25
Çalışan Eğitimi	0,17

Çevresel faktörlerin alt kriterlerinden yenilenebilir enerji 0,46 önem değeri ile en fazla öneme sahiptir. Yenilebilir enerjiden sonra ise ikinci sırada 0,27 önem değeri ile atık oluşumunu azaltma kriteri yer almaktadır (Tablo 5).

***Tablo 5.** Çevresel Faktörlerin Esas Kriterinin Alt Kriterine Göre Önem Düzeyi*

Alt Kriterler	Önem Düzeyi
Hava Kirliliğini Azaltma	0,18
Çevresel Düzenlemelere Uyma	0,09
Atık Oluşumunu Azaltma	0,27
Yenilebilir Enerji	**0,46**

Tutarlılık Hesaplaması: Tablo 6'da sürdürülebilir pazarlama faaliyetlerine ait ana kriterlerin ve alt kriterlerin tutarlılık değerleri gösterilmektedir. Ana kriterlerin tutarlılık değeri 0,06 olarak bulunmuştur.

***Tablo 6.** Sürdürülebilir Pazarlama Ana Kriterlerin Matrislerinin Tutarlılık Değerleri*

Kriterler	Tutarlılık Değeri
Ana Kriterler	0,06
Ekonomik Kriterler	0,09
Sosyal Kriterler	0,06
Çevresel Kriterler	0,08

Ekonomik faktör kriterleri 0,09, sosyal faktör kriterleri 0,06 ve çevresel faktör kriterleri 0,08 tutarlılık değerlerine sahiptir. Ana kriterlerin karşılaştırma matrisi için tutarlılık değerleri hesaplanmış olup 0,10'un altında değere sahip olması nedeniyle karşılaştırma matrislerinin yeterli derecede tutarlılığa sahip olduğu söylenebilir. Tutarlılık oranı 0,10 ve altında bir değere sahip olması matrisin tutarlı olduğunu göstermektedir (Satty, 1994).

*Kriterler İçin Nihai Önceliklerin Hesaplanması: S*ürdürülebilir pazarlamayı etkileyen faktörler firmadaki uzmanlar tarafından değerlendirildiğinde Tablo 7'de verildiği gibi en önemli değere sahip faktörün 0,62 önem derecesi ile ekonomik faktör kriteri olduğu görülmektedir. İkinci sıradaki önemli faktör ise 0,22 ağırlık değeri ile sosyal faktör kriteridir. 0,16 ağırlık değeri ile en az önem değerine sahip kriter ise çevresel faktör kriteridir.

Tablo 7. *Sürdürülebilir Pazarlamanın Ana Faktörleri ve Alt Kriterleri Önem Düzeyi*

Ana Faktörler	Önem Değerleri	Alt Kriterler	Önem Düzeyleri
Ekonomik	**0,62**	**Süt Tedarik Maliyetleri**	**0,43**
		Üretim Maliyetleri	0,21
		Hijyen Maliyetleri	0,11
		Teknolojik Maliyetler	0,17
Sosyal	0,22	Sağlık ve Güvenlik	0,12
		Dezavantajlı Gruplar	0,06
		Hesap Verilebilirlik	**0,40**
		Çalışanlar Arasında Eşitlik	0,25
		Çalışan Eğitimi	0,17
Çevresel	0,16	Hava Kirliliğini Azaltma	0,18
		Çevresel Düzenlemelere Uyum	0,09
		Atık Oluşumunu Azaltma	0,27
		Yenilenebilir Enerji	**0,46**

6. TARTIŞMA VE SONUÇ

Bu çalışmada süt ürünleri üreticisi bir firma için sürdürülebilir pazarlamayı etkileyen faktörler ve alt kriterleri literatürden alınan bilgiler ve uzman görüşleri doğrultusunda belirlenmiş, bunun akabinde hem ana boyutlar olan ekonomik, sosyal ve çevresel boyutların hangisine ne derecede önem verdikleri hem de alt kriterlerin önem düzeyleri hesaplanmıştır. Buna göre en önemli temel faktör 0,62 önem düzeyi ile ekonomik boyuttur. İkinci sırada önemli boyut 0,22 değeri ile sosyal boyuttur. En az önemdeki ise 0,16 önem düzeyi ile çevre boyutudur. Bu durum geleneksel yapıda olan firmanın hala ekonomik faaliyetlere öncelik verdiğini, sosyal ve özellikle çevresel çalışmaları daha geri plana aldığını göstermektedir. Buna göre firmanın Türkiye'deki pek çok firma gibi sürdürülebilir pazarlama anlayışını bütüncül açıdan ele almadığı, çevresel faktörler için henüz örgüt kültürü ve yapılanmalarının olmadığı ifade edilebilir. Diğer yandan firma yetkilileri ile yapılan görüşmelerde, uzmanlar firmanın öncelikli olarak gelir ve kar açısından iyi durumda olması ve bu temel ekonomik faktörlerini rahatlıkta karşılayabilmesi gerektiğini dile getirmişlerdir. Herhangi bir işletmenin bu temel düzeydeki ekonomik faktörleri karşılayabilmede yaşadığı sorunlar, sıkıntılar varken çevresel faktörler içerisinde yer alan faaliyetleri yerine getiremeyeceklerini belirterek, ekonomik faktörlerine daha fazla önem verdiklerini de ifade etmişlerdir. Çevresel faaliyetlere yönelik çalışmalar yapılabilmesi için de devletin bu yöndeki destek ve teşviklerinin kendileri açısından motive edici olabileceğini belirtmişlerdir.

Sürdürülebilirliğin ana boyutlarına bağlı alt kriterler açısından bakıldığında ise ekonomik boyutun alt kriterlerinden süt tedarik maliyetleri 0,43 değeri ile en önemli kriter olmuştur. Bu durum Türkiye'de son yıllarda yaşanan yem maliyetlerinin yükselişi nedeniyle artan süt üretim maliyetlerine bağlanabilir. Diğer taraftan ekonomik boyut altında yer alan hijyen maliyetlerinin 0,11 değeri ile en düşük önemde görülmesi, gıda sektöründe bulunulması ve toplum sağlığı açısından dikkat çekicidir. Sosyal boyuta bakıldığında en önemli alt kriterin 0,40 değeri ile hesap verilebilirlik olduğu görülmektedir. Çevre boyutunun alt kriterlerinden en önemlisi ise 0,46 ağırlık değeri ile yenilenebilir enerji, ikinci olarak da 0,27 değeri ile atık oluşumunu azaltma kriteri olmuştur. Aslında bu iki kriter de sağlanmaları durumunda maliyetleri düşüreceğinden ekonomik yansıması da olacak kriterlerdir. Dolayısıyla firmanın çevresel boyutta da önceliği aslında ekonomik boyutla ilişkilendirilebilecek kriterler yönünde olmuştur.

Bu sonuçlar çerçevesinde uzman görüşlerinden faydalanılan ve uygulamanın yapıldığı firmanın, günümüz rekabet koşullarına ayak uydurabilmesi ve çevreye duyarlı bir işletme kültürü oluşturması için sürdürülebilirlikle ilgili ivedilikle çalışmalara başlanması gerekmektedir. Bu çalışmaların da sürdürülebilirliğin sadece ekonomik boyutunda değil tüm boyutlarında ve sürdürülebilir pazarlamaya bütünsel bir yaklaşımla planlanması önerilebilir. Bu konuda hızlı bir şekilde yol alınması için çalışanlara yönelik sürdürülebilirlikle ilgili bilgilendirici, farkındalık yaratıcı ve yeni uygulamalar geliştirebilme becerisi kazandırmaya yönelik eğitimlerin verilmesi çok faydalı olacaktır. Firmanın kendi bünyesindeki çalışmalarını artırmasının yanı sıra, tedarikçilerinden de sürdürülebilirlik yönünde faaliyetler talep etmesiyle her üç boyut için de kazanımların artacağı ve ivme kazanacağı söylenebilir. Ayrıca, firma yetkilileri sürdürülebilirlikle ilgili faaliyetler için devlet destek ve teşviklerinin olumlu etkisi olacağını belirttiğinden otoriterlerin bu talepleri dikkate almaları da işletmeler açısından fayda sağlayıcı olacaktır.

Gelecek çalışmalarda, süt ürünleri üretimi alanında birden çok işletmeyi kapsayan daha geniş çaplı araştırmalar planlanabilir. Bu araştırmalarla alt kriterlerde çeşitlenme sağlanarak ve aynı sektörde yer alan farklı işletmelerin sürdürülebilir pazarlama kriterlerine verdiği önem düzeylerinin kıyaslanmasıyla ve nedenlerinin araştırılmasıyla literatür zenginleştirilebilir. Diğer yandan farklı ÇKKV yöntemleri kullanılarak yeni çalışmalar planlanabilir.

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Optimization of Platoon Formation Center Location for Truck Platooning in Turkey

Türkiye'de Kamyon Müfrezesi için Müfreze Oluşturma Merkezi Konumunun Optimizasyonu

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ABSTRACT

In Road Transportation, truck transportation is commonly being categorized into Less Than Truckload (LTL), Partial Truckload and Full Truckload (FTL). The standard LTL transportation is carried out by means of consolidated freight at optimized depots of designation, in the form of single or multiple assignment. Nowadays, freight transportation industry is now facing a serious problem of scarce labor force and environmental concerns. One solution for that is truck platooning. Truck Platooning is a grouping of freight vehicles into connected vehicle convoys using electronic coupling as an application in automated driving technology with the aim of saving fuel, reducing travel costs, and improving infrastructure efficiency. Platoon planning is required to obtain the best results of platooning. Therefore, the objective of this study is to find the optimal locations of Platoon Formation Center (PFC) in Turkey for (de)formation truck platoons by using discrete mathematical optimization.

Keywords: Truck Platooning, Logistics, Discrete Mathematics, Transportation, Optimization, Facility Location.

ÖZ

Karayolu Taşımacılığında, kamyon taşımacılığı yaygın olarak Kamyon Yükünden Az(LTL), Parsiyel Kamyon Yükü ve Tam Kamyon Yükü(FTL) olarak sınıflandırılmaktadır. Standart LTL taşımacılığı, tek veya çoklu atama şeklinde optimize edilmiş atama depolarında konsolide navlun vasıtasıyla gerçekleştirilir. Günümüzde yük taşımacılığı sektörü, artık kıt işgücü ve çevresel kaygılar gibi ciddi bir sorunla karşı karşıyadır. Bunun için bir çözüm kamyon müfrezesidir. Kamyon Müfrezesi, yakıt tasarrufu sağlamak, seyahat maliyetlerini azaltmak ve altyapı verimliliğini artırmak amacıyla otomatik sürüş teknolojisinde bir uygulama olarak elektronik kuplaj kullanan yük araçlarının bağlı araç konvoyları halinde gruplandırılmasıdır. Takım oluşturmanın en iyi sonuçlarını elde etmek için takım planlaması gereklidir. Bu nedenle, bu çalışmanın amacı, ayrık matematiksel optimizasyon kullanarak (de)formasyon kamyon takımları için Türkiye'deki PFC'nin en uygun yerlerini bulmaktır.

Anahtar Kelimeler: Kamyon Takımı, Lojistik, Ayrık Matematik, Taşıma, Optimizasyon, Tesis Yeri.

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1. INTRODUCTION

Road transport occupies a vital role of this transport system. It has high flexibility in trip scheduling, allowing a more frequent freight transport service. Road transport can be served as the initial and final transport phase in supply chain process, thus serving a bridge to connect with other transportation modes.

Nowadays, road freight transportation industry is now facing a serious problem of scarce labor force while, on the other hand, the transportation demand is growing very rapidly (Watanabe et al. 2021). Moreover, air pollution and global warming have become top concerns in freight transportation. To tackle such challenges, truck platooning technology has been adopted. A truck platoon is a convoy of electronically connected vehicles, which can be achieved by using Cooperative Adaptive Cruise Control(CACC).

In Japan, field operational tests on expressways have been conducted with manned following vehicles since 2017 and unmanned following vehicles since 2018 respectively. The optimal location models for truck platooning considering the case in Japan were presented by a continuous approximation model(Watanabe et al.2021) and a discrete mathematical optimization(Watanabe and Aung 2022). It is necessary to consider the optimal facility location that corresponds to the deployment of truck platooning in various countries. Therefore, the objective of this study is to find the optimal locations of Platoon Formation Center (PFC) in Turkey for (de)formation of truck platoons by using discrete mathematical optimization.

2. TRUCK PLATOONING CHARACTERISTICS

In fact, truck platooning is not a novel technology, and it has been reasonably researched since the 1940. So far, the focus area has been on the vehicle connection and sensor technology. Bhoopalam et al.2018 provided a framework to classify various new transportation planning problems that arise in truck platooning, as well as surveying relevant operational research models for these problems in the literature. Truck platooning scenario can be different depending upon trip information management. A platoon plan generally requires information such as (1) which trucks will form a platoon, (2) where and when the platoons will be created, (3) which routes they will travel, and (4) what is the order of the trucks in that platoon. Nevertheless, based on truck platooning management and trip information, three platoon formation scenarios have been mainly considered as follows (Janssen, 2015).

(1) Scheduled platooning: Trip information is obtained before travel and platoon management is made in advance. Therefore, this is also known as off -line or static planning.

(2) Opportunistic platooning: Platoons are formed spontaneously on the road between the trucks travelling at a proximity. This type of platoon planning does not require much trip information early or before departure. Since this platooning system does not need prior platoon planning, it is called spontaneous or on-the-fly platooning.

(3) Orchestrated Platooning: It is a platooning managed by Platooning Service Providers(PSPs). Platoon Formation Center(PFC) for (de)formation of platoons plays a vital role in this platooning technology.

It should be noted that platooning technology is still at its early stage, and it still needs a lot of infrastructure development and legal maturity for large-scale business operation and spontaneous platoon formation. There are still compatibility challenges existing for platoon creation among different truck makers. In addition, a simulation study by Liang et al. 2014 showed that there can be tremendous amount of economic and environmental benefits due to precise planning of platoons before their departure. Therefore, it can be concluded that some of platooning management is required to obtain the best results of platooning.

3. PLATOONING FACILITY CENTER (PFC) LOCATION MODELLING USING DISCRETE MATHEMATICAL OPTIMIZATION

3.1. Truck Platooning and Hub Location Research

Hub Location is a fertile area for multi-disciplinary research such as operation research, transportation, geography, network design, telecommunications, regional science, economics etc. (Campbell et al. 2012). Therefore, hub location research can also be applied to logistics industry in order to solve various economical and sociological problems(Kara and Tansel 2003, Alumur et al. 2009, Kara and Tansel 2009).

There is a need to locate the PFC for the formation of truck platooning to run unmanned operation in platoon (Watanabe et al. 2021). Larsen et al. (2019) presents a model for optimizing truck platoons formed at a PFC at a fixed location using a dynamic programming based local search heuristics. PFC optimizing problem can be considered as hub location problems (HLPs) and there are a lot of related studies for hub location optimization for logistics operation (Laporte et al. 2015). Considering discrete optimization scheme, truck platooning operation can be modelled by using inter-hub travel (inter-PFC in the case of truck platooning). There will be cost efficiency benefit for inter-PFC travel, due to fuel saving and reduction in aerodynamic drag between trucks. There have been a lot of research about discount factor calculation in hub location research. Almost all researchers consider discount factor calculation on the grounds of economies of scale. When we model truck platooning scenario, it will be reasonable to consider the discount factor calculation due to other factors rather than freight consolidation. The factors that can reduce the cost in truck platooning can be the number of trucks in a platoon and the driving system of the truck platooning and so on. So far, there has been almost no research which discusses about truck platooning discount factor except a recent study by Watanabe et al. (2021) and Watanabe and Aung (2022) about unmanned platooning system in Japan. He considered discount factor calculation based on the number of trucks in a platoon and the vehicle driving system such as manual or automated. Apart from that, there has been very few research about PFC optimization for truck platooning.

3.2. Modelling

The hub location model has started gaining its popularity since O'Kelly (1987) adopted a single allocation P-hub location problem. Almost all later hub location models and heuristics algorithms are developed based on this model. In this model, it is necessary to locate exact number of hubs exogenously. This is a discrete mathematical model problem where the number of participant nodes is finite. As the model's name suggests, each non-hub node is allocated to exactly one hub node out of p nodes. This model assumption is also based on complete graph in which there is a complete connection between each and every hub node. There is also a constraint that travelling between two non-hub nodes needs to go through two hubs at most, i.e. there is no direct connection between non-hub nodes. The fixed cost of locating hubs is not considered. There is no consideration of capacity limit of the hubs as well. All decision variables of the model are binary variables.

The problem with the above formulation is that there is a quadratic term, which makes the optimization relatively difficult to be solved. Since O'Kelly (1987) first introduced such discrete hub location problem, there were rapid advances in mathematical models which attempted to locate the exact solutions in several hub location networks. A large number of research was also carried out and an example of this was that Campbell (1994) reviews over 70 papers on hub network optimization. O'Kelly and Miller (1994) also identified several prototype models for hub network design analysis. The two most well-known versions of design networks are based on completely connected hubs, with two types of spoke-hub connectivity— single allocation and multiple allocation. In both assignments, the hubs are assumed to be completely connected and all flow must be through hubs. A linearization developed by (Skorin-Kapov et al., 1995) gives an effective method of finding solutions especially in case of small hub and spoke network models.

3.3. Multiple Allocation

As the name suggests, all the origin and destination nodes are assigned to more than one PFC node. There can be multiple network assumptions based on how PFC nodes are connected with each other. In our analysis, we will consider the complete connection among all PFC nodes as shown in the following figure.

In Fig 3.1, all the yellow nodes serve as origin, blue as PFC and orange as destination. The thick red arrows represent the complete connection among PFC nodes without any detour. In the multiple assignment hub location (Campbell, 1994), each origin-destination pair is allowed to utilize the hub that will give the lowest travel cost, independent of how this flow can produce a large amount of interaction. As a result, the objective function can minimize the total travel cost for the system. A compact formulation of that model, known as HUBLOC (Skorin-Kapov et al. 1997) is as follows, which is used in our analysis.

$$\text{Minimize } \sum_{i,j} \sum_{k,m} t_{ij} c_{ij}^{km} z_{ij}^{km}, \text{ where } c_{ij}^{km} = c_{ik} + \alpha c_{km} + c_{mj} \qquad [3.1]$$

Subject to

$$\sum_{k} X_k = P \qquad [3.2]$$

$$\sum_{k,m} z_{ij}^{km} = 1 \;\forall\, i,j \qquad [3.3]$$

$$\sum_{m} z_{ij}^{km} - X_k \leq 0 \;\forall\, i,j,k \qquad [3.4]$$

$$\sum_{m} z_{ij}^{km} - X_m \leq 0 \;\forall\, i,j,k \qquad [3.5]$$

$$X_k = [0,1] \;\forall\, k \qquad [3.6]$$

Let's consider the transportation networks modelled by complete graphs *G=(V,E)*, where the node set *V = {1,2,….,n}* represents the origin, destination and possible hub locations. Let tij be the number of trucks (the total flow in the classical model) travelling from node i to node *j*. The cost c_{ij}^{km} is a total cost of (from origin i to PFC k), αc_{km} (discounted inter-PFC cost) and c_{mj} (from PFC *m* to destination *j*). Constraint (3.2) ensures that the number of PFCs (*P*) is determined exogenously. Constraint (3.3) ensures that all flow be routed via exactly one path. Constraints (3.4) and (3.5) prevent flow from being routed via a non-PFC node. All flow must travel through at least one PFC. Constraint (3.6) ensures the integrity of the decision variable.

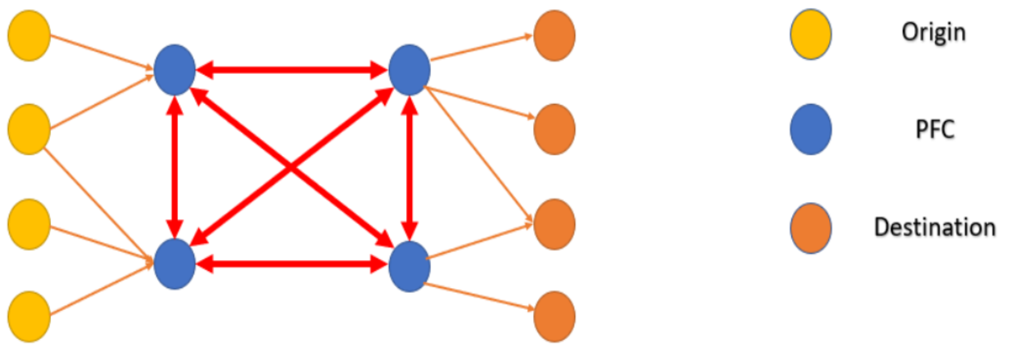

Fig 3.1 *Complete Connection among PFC nodes (Multiple Assignment)*

3.4. Multiple Allocation

Similar to multiple allocation, the complete connection among the PFC nodes is assumed as in the following figure.

It can be noted that in Fig 3.2, all origin and destination nodes are connected to each respective PFC node via a single link. From the modelling perspective. the following model by Skorin-Kapov (1996) is used for single assignment in our study. This model is a LP relaxation of Campbell (1996b).

Minimize $\sum_{i,j}\sum_{k,m} t_{ij} c_{ij}^{km} z_{ij}^{km}$, where $c_{ij}^{km} = c_{ik} + \alpha c_{km} + c_{mj}$ [3.7]

Subject to

$\sum_k X_{kk} = P$ [3.8]

$\sum_k X_{ik} = 1 \; \forall \; i$ [3.9]

$X_{ik} \leq X_{kk} \; \forall \; i, j$ [3.10]

$\sum_m z_{ij}^{km} = X_{ik} \; \forall \; i, j, k$ [3.11]

$\sum_m z_{ij}^{km} = X_{jm} \; \forall \; i, j, m$ [3.12]

$z_{ij}^{km} \geq 0 \; \forall \; i, k$ [3.13]

$X_{ik} = [0,1] \; \forall \; i, k$ [3.14]

Constraint (3.8) ensures that the number of PFCs, which is *P*, is determined exogenously. Constraint (3.9) forces single assignment. Constraint (3.10) ensures that no node is assigned to a location unless it is a PFC. Constraints (3.11) and (3.12) determine that there must be only one flow through the link *i-k-m-j*. Constraints (3.13) and (3.14) determine the decision variables. The objective is to minimize the total transportation cost for the trucks travelling through the *i-k-m-j* link.

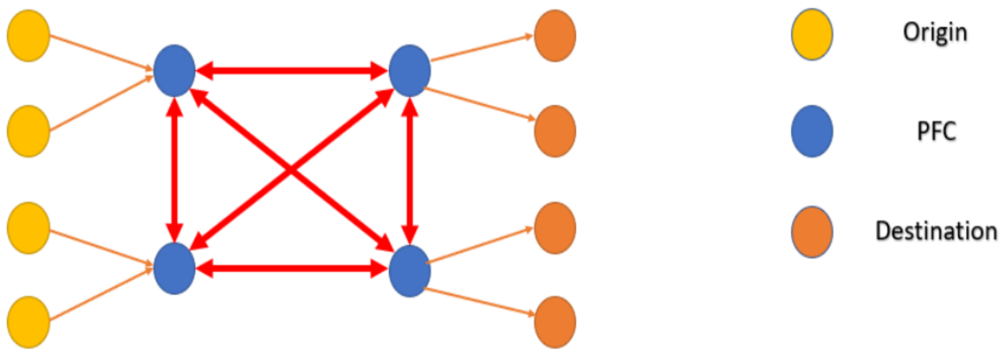

***Fig 3.2** Complete Connection among PFC nodes (Single Assignment)*

3.5. Platooning Discount Factor Calculation

Watanabe et al. (2021) considers the discount factor calculation thanks to truck platooning. The discount factor calculation in truck platooning should be different from the traditional calculation of discount factor which highly depends on trade flow due to economies of scale. Truck platooning mainly benefits from the platoon in which trucks travel together, which must be included in the discount factor calculation. Driving at a close distance between trucks reduces the aerodynamic drag between them, which leads to the reduced fuel emission and cost saving.

The normal truck travel costs without platooning can be calculated as follows.

$Ts = sn$ [3.15]

The truck travel costs without platooning (Ts) can be calculated as the single truck travel cost (s) multiplied by the number of trucks (n). In the case of platooning, there will be two different types of truck travel costs— the first leading truck travel cost and the following truck travel costs because these two types of costs are different due to aerodynamic properties. The truck travel costs in the case of platooning can be calculated as follows.

$Tp = a + (n - 1)b$ [3.16]

The platooning truck travel cost is calculated by the leading truck travel cost (a), the following trucks travel cost (b) and the number of vehicles (n). We will always assume that s>a, s>b and a>b. The discount factor (α) is simply the ratio of the platooning truck travel costs (Tp) to the normal traveling truck costs (Ts), which can be calculated as follows.

$\alpha = \frac{T_p}{T_s} = \frac{a+(n-1)\,b}{sn}$ [3.17]

From the equation (3.17), it is obvious that the discount factor (α) is highly dependent on platooning trucks travel costs (a and b) and the number of platooning trucks (n). If we can decrease a and b, and increase n; we can hypothetically assume that we can enjoy more of the benefits of the platooning discount factor (α).

3.6. Platooning Scenario

In this section, we will consider the parameter settings for calculating discount factor (α). Watanabe et al (2021) assumes that based on Japan condition, the ratio of the labor costs in the trucking industry is around 40 % , which implies the cost difference between unmanned and manned driving. When it comes to the fuel saving due to platooning, leading vehicle can enjoy around 10% and the following vehicles around 20%.We assume the same parameter settings based on the aforementioned Japan condition. As a result, three platooning scenarios can be considered as follows.

In the table 3.1, for scenario I, when there are all manned trucks in a platoon, there will be cost saving benefit solely due to the platooning. When the trucks are unmanned in the scenario II and III, the platooning benefits can be added by the labor cost saving benefits, leading to more saving in total travel cost. Therefore, in scenario II, the cost saving for the following trucks becomes 60% (20% + 40%), leading to the discount value 0.4. In the case of unmanned scenario III, not only the leading vehicle has the discount value benefit of 50% (10% + 40%), but also the following vehicles have the discount value benefit of 60% (20% + 40%). The number of platooning trucks is restricted depending upon each country's regulation requirement. In our analysis, the number of platooning trucks is hypothetically varied from 3 to 10 in order to provide a wide range of discount factor value, which can be analyzed for its impact on total travel cost in both single and multiple assignments. As a result, the following table 3.2 is obtained.
In the table 3.2, for platooning scenario I, although the number of platooning trucks is hypothetically varied from 3 to 10, α value does not change much and stays around 0.8. Therefore, we assume the average α value as 0.8 in manned platooning scenario, for all number of platooning trucks from 3 to 10. For unmanned following vehicles in scenario II, the number of platooning trucks from 4 to 10 provides α value around 0.5. For almost all the instances at which our optimization are made, α values 0.6 and 0.5 give the same PFC. Similarly, the platoon of all automated vehicles gives the α value of around 0.4. Therefore, it can be summarized that in each platooning scenario, the discount factor value does not change very much for a range of number of platooning trucks from 3 to 10 and hence, it gives almost the same optimal PFCs for each instance in each scenario. In other words, the number of platooning trucks do not have much impact on discount factor for each different platooning scenario.

Table 3.1 *Three platooning scenarios based on different driving systems*

No	Scenario	s	a	b
I	Platoon with all manned vehicles	1	0.9	0.8
II	Platoon with unmanned following vehicles	1	0.9	0.4
III	Platoon with all fully automated vehicles (FAVs)	1	0.5	0.4

Table 3.2. *Three different platooning scenarios based on the number of platooning trucks*

Scenario		s	a	b	n	α
I	Platoon of all manned vehicles	1	0.9	0.8	3—10	0.8
II	Platoon with unmanned following vehicles	1	0.9	0.4	3	0.6
					4—10	0.5
III	Platoon of all fully automated vehicles (FAVs)	1	0.5	0.4	3—10	0.4

3.7. Computational Environment

All optimization instances are carried out by using XpressIVE 8.11 commercial optimizer. Regarding the device specification, Intel Xeron Bronze 1.9 GHz (16 CPUs) computer with 32768 MB RAM, and 1 MB Cache was used for data analysis. Computation time highly depends upon computational complexity. It was found out that single assignment takes a wide range of duration, ranging from half an hour to even more than 12 hours in rare cases. In addition, more PFC node assignment also lead to more computational duration, regardless of single and multiple allocation. Multiple assignment generally takes about 2-3 hours as an average.

4. OPTIMIZATION

4.1. Dataset

The dataset is the Turkish Network Dataset with Freight Transported provided by Kara, B.(https://ie.bilkent.edu.tr/~bkara/dataset.php), which includes 81 cities as demand nodes. This includes different data for travel distance, travel times, freight flow and fixed link costs for Turkish 81 cities. As a benchmark size, we took 20 cities which represent uniform distribution across the region as shown in Figure 4.1. For the simulation of truck platooning, we took the freight flow in Table 4.1 and travel time data.

Figure 4.1. *Turkish Dataset Spatial Distribution Pattern*

***Table 4.1**. Decreasing Order of Trade Flow*

City	Outflow	Inflow	Total
Ankara (PFC)	737202	704085	1441286
Adana (PFC)	389583	389236	778819
Antalya (PFC)	364921	365405	730326
Balikesir (PFC)	236571	239346	475917
Aydin (PFC)	210361	213233	423594
Afyon (PFC)	181059	183908	364967
Adapazari (PFC)	169016	171817	340833
Sivas (PFC)	168785	171585	340369
Adiyaman (PFC)	140386	142986	283372
Ağri (PFC)	119571	121949	241520
Batman (PFC)	103664	105833	209497
Aksaray	90174	92138	182312
Bitlis	88521	90458	178979
Amasya	83279	85129	168408
Bingöl (PFC)	58180	59563	117744
Bilecik	44689	45788	90477
Artvin	44144	45231	89375
Bartin	42377	43425	85801
Ardahan	30852	31636	62488
Bayburt	22497	23080	45576

4.2. Optimization Analysis

Multiple PFC allocation can also reduce the travel cost considerably. Figure 4.2 is the graphs which show the total travel cost of the different datasets in cases of single and multiple assignment with respect to the number of PFCs. For all platooning scenarios, increasing the number of PFCs can significantly reduce the total travel cost, no matter whether the PFC assignment pattern is single or multiple allocation. However, the decline rate of the cost becomes less steep when the number of platooning trucks becomes larger. For example, the travel cost reduction rate is quite noticeable from two to five platooning trucks but becomes less significant when the number of PFCs becomes larger.

The nodes with the larger trade flows mostly serve as PFCs. The trade flow here is defined by the total value of incoming and outgoing flows. Incoming trade flow of a node is the total value of the trade flows coming to that node from the other nodes. Outgoing trade flow of a node is the total value of the trade flows going out of that node to the other nodes. Therefore, trade flow value of a node shows how much trade is flowing through that certain node and how strategically important that node can be in terms of trade volume for the whole transport system. In table 4.1, all nodes which appear as PFCs in optimization instances are described as PFC besides their names. The table is sorted in decreasing order of trade flows, i.e. the nodes in the top positions have a larger trade flow than the ones in the bottom positions. It is easily noticeable that the nodes with the larger trade flows mostly appear as PFCs in most optimization instances with some exceptions. Moreover, most of the nodes with the lower trade flows never appear as PFCs as well. Therefore, it can be reasonably concluded that the nodes which have greater importance in terms of trade flow have high possibility to become PFCs in all platooning scenarios and assignment systems.

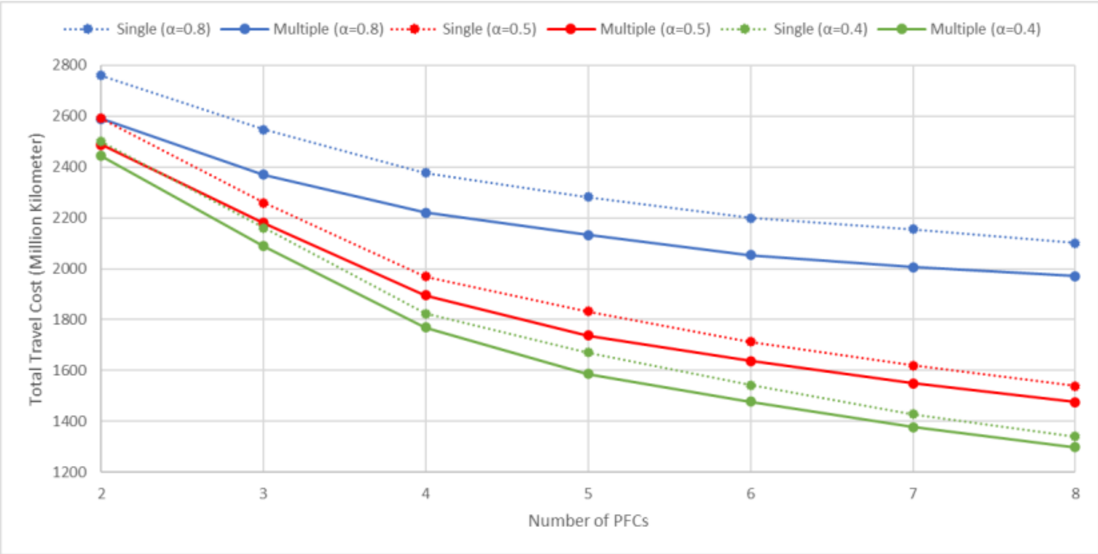

Fig 4.2 *Travel Cost with respect to the number of PFCs in Turkey*

4.3. Optimal Location

As discussed above, the platoon driving system has high impact on α value. That α value, in turn, has a certain degree of impact on PFC location. The lower α value makes PFC locate at a far distance between two PFCs. The reason is that when there is much inter-PFC benefit, the trucks have much interest to travel by platooning for a larger distance. Therefore, in other words, unmanned platooning scenarios tend to have further PFCs than manned platooning scenario.

From figures 4.3 and 4.4, when α value is 0.8, PFCs tend to locate closely, with not much great distance between them. When it comes to α value 0.5, even for the same number of PFCs which is 4, PFCs tend to locate at a far distance. The PFC location at Sivas from figure 4.3 shifts towards Bingöl in figure 4.4. This same characteristic can also be found in Japan dataset as well(Watanabe and Aung 2022).
When it comes to multiple assignment, PFCs do not change a lot depending upon α value, at least as frequently as what it happens in single assignment. For example, when we will decide to assign four PFCs in multiple assignment, the same four PFCs appear no matter what α value is, which in other words, no matter what the platooning scenario is. This finding is same for all these three datasets. So, it can generally be concluded that multiple assignment is less sensitive to platooning scenario variation which can lead to different α values.

Fig 4.3 *PFC location (yellow-colored) in Turkey when α value is 0.8 and the number of PFCs is 4 with single assignment*

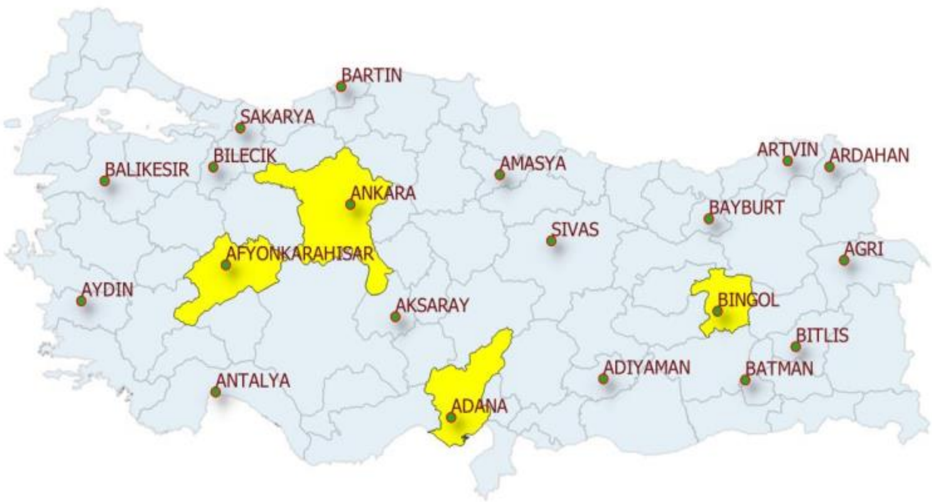

Fig 4.4 *PFC location (yellow-colored) in Turkey when α value is 0.5 and the number of PFCs is 4 with single assignment*

5. CONCLUSION

For platooning operation, it is very important to strategically locate PFCs for several objectives and one of which includes reduction in total transportation cost, just like any other hub location problems. However, for PFC location problem, it is also very important to include the assumption of cost reduction due to platooning in our PFC location model to better reflect the realistic benefit of the truck platooning, unlike economic scales in other normal hub location models. From our analysis, the conclusions including the following points but not limited to, can be made.

(i) Increasing the number of platooning trucks in each platoon cannot significantly bring down the inter-PFC travel cost between two platooning hubs. Changing the platooning system from completely manned driving to semi-unmanned or totally unmanned driving system can reduce the inter-PFC travel reasonably.

(ii) If trucks from a specific origin can be assigned to more than one single PFC, it can reduce the total travel cost considerably as well. Therefore, it can be summarized that increasing the number of PFCs or allowing multiple PFC assignment system can reduce the total travel cost more than increasing the number of platooning trucks in a platoon.
(iii) Lower inter-PFC discount factor means that truck platoons can enjoy more of the platooning benefit. Therefore, lower inter-PFC discount factor can generally lead to larger inter-PFC distance. This characteristic is more commonly found for single assignment. In other words, optimal PFC location in multiple assignment is less sensitive to discount factor variation or different platooning scenarios.
(iv) Nodes with the larger trade flows tend to appear as PFCs repeatedly in almost all optimization instances, regardless of the spatial distribution pattern of the dataset. Most of the nodes with lower trade flows never appear as PFCs in all optimization instances.
For future study, we need to consider the optimal location model for a large scale model with the actual transport demand and road networks.

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ARAŞTIRMA MAKALESİ/ **RESEARCH ARTICLE**

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Three-Dimensional Path Planning of UAVs in Complex Urban Terrains: A Case Study of Emergency Medicine Delivery in Shanghai (China)

Karmaşık Kentsel Arazilerde İHA'ların Üç Boyutlu Yol Planlaması: Şanghay'da (Çin) Acil Tıp Teslimatına İlişkin Bir Vaka Çalışması

Yutaka WATANABE[1] **Shan XU**[2]

ABSTRACT

Unmanned aerial vehicles (UAVs), widely known as drones, are used in various domains for tasks including geological prospecting, e-commerce business, and emergencies. Because of the necessity for fast and efficient delivery for emergency medicine distribution, drones can play crucially important roles by their ability to pass through complex urban environments. Drones might therefore aid people living under strict lockdown conditions during surges cases of COVID-19 or other communicable diseases. Nevertheless, distribution routes are usually planned in two-dimensional space. Moreover, restricted areas in urban aerial domains might be overlooked because of complex environmental considerations. To boost the feasibility of drone use, three-dimensional (3D) path routing can be applied when planning aerial distribution routes for drones, such as those used for delivering emergency medicines. This study specifically examines a more reliable method of using heuristic algorithms and software ArcGIS. After collecting location data of chronic patients in lockdown areas from the Shanghai official information system database, 3D visualization of the terrain and complex airspace was done using ArcGIS. Secondly, UAV routing constraints are summarized according to current laws and regulations for UAV operation at low altitudes. Furthermore, feasible solutions are incorporated into this model. Finally, after improved ant colony optimization (ACO) application to 3D route planning problems, programming was done using MATLAB (ver. 2017b). Assuming guaranteed safety and compliance with regulations, the solutions demonstrate the algorithmic efficiency and provide a satisfactory route plan for emergency medicine delivery that might guide emergency delivery system routing design in similarly complex urban environments.

Keywords: 3D route planning; emergency; geographic information system; heuristic algorithm; medical emergency; unmanned aerial vehicle.

ÖZ

Yaygın olarak insansız hava araçları olarak bilinen insansız hava araçları (İHA'lar), jeolojik arama, e-ticaret işi ve acil durumlar dahil olmak üzere çeşitli alanlarda kullanılmaktadır. Acil ilaç dağıtımı için hızlı ve verimli teslimat gerekliliği nedeniyle, dronlar karmaşık kentsel ortamlardan geçme yetenekleriyle çok önemli roller oynayabilir. Bu nedenle drone'lar, COVID-19 veya diğer bulaşıcı hastalıkların dalgalanma vakaları sırasında katı karantina koşulları altında yaşayan insanlara yardımcı olabilir. Bununla birlikte, dağıtım yolları genellikle iki boyutlu uzayda planlanır. Ayrıca, kentsel hava alanlarındaki kısıtlı alanlar, karmaşık çevresel hususlar nedeniyle gözden kaçabilir. Drone kullanımının fizibilitesini artırmak için, acil durum ilaçlarının teslimi için kullanılanlar gibi dronlar için hava dağıtım rotaları planlanırken üç boyutlu (3D) yol yönlendirme uygulanabilir. Bu çalışma özellikle sezgisel algoritmaları ve ArcGIS yazılımını kullanmanın daha güvenilir bir yöntemini incelemektedir. Şanghay resmi bilgi sistemi veri tabanından karantina bölgelerindeki kronik hastaların konum verileri toplandıktan sonra, ArcGIS kullanılarak arazinin ve karmaşık hava sahasının 3 boyutlu görselleştirilmesi yapıldı. İkinci olarak, İHA'nın düşük irtifalarda çalışması için mevcut yasa ve yönetmeliklere göre İHA yönlendirme kısıtlamaları özetlenmiştir. Ayrıca, uygulanabilir çözümler bu modele dahil edilmiştir. Son olarak, 3B rota planlama problemlerine geliştirilmiş karınca kolonisi optimizasyonu (ACO) uygulamasından sonra MATLAB (ver. 2017b) kullanılarak programlama yapılmıştır. Güvenlik ve düzenlemelere uygunluğu garanti eden çözümler, algoritmik verimliliği gösterir ve benzer şekilde karmaşık kentsel ortamlarda acil durum dağıtım sistemi yönlendirme tasarımına rehberlik edebilecek acil ilaç dağıtımı için tatmin edici bir rota planı sağlar.

Anahtar Kelimeler: 3D rota planlaması; acil Durum; coğrafi Bilgi Sistemi; sezgisel algoritma; tıbbi acil durum; insansız hava aracı.

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1. INTRODUCTION

With advancements in unmanned aerial vehicles (UAVs) intended for use in various domains, they are applicable in times of emergency. For emergency medicine delivery, drones can play a crucially important role by passing through complex urban environments because of the urgent necessities of fast and efficient delivery. Particularly in traffic-restricted areas, drones can be substituted easily for traditional transportation in lockdown areas. On March 29, 2022 ,with the advent of the Omicron pandemic and the surge in the confirmed cases, the local government of Shanghai, China chose to prevent all human travel and commuting in the city. Subsequently, 25 million people in Shanghai lived under strict lockdown for two months. In the lockdown area, roads were closed by fencing, making it impossible to continue the use of traditional traffic methods. Patients were confined to their homes, where they waited for volunteers to deliver medicines on foot. Along with extension of the lockdown, delivery services become increasingly overwhelmed, leading to inability to deliver medications to patients as quickly as possible in emergency situations. In such cases, drones can be deployed to deliver emergency medicines. However, earlier studies of drone emergency medicine delivery presented several limitations in its application to real practice. Primarily, the complex urban terrain conditions and the high density of buildings increase the difficulty of transporting emergency medicines by drones. Secondly, the flight path nodes of drones fluctuate severely, increasing power consumption and instability during transport. Therefore, carrying out a new safe and efficient method for drones is important to overcome those obstacles and serving patients who urgently need medication during a lockdown period. Otherwise, there might be no way for medicines to be delivered to patients in an emergency.

This study uses heuristic algorithms and ArcGIS software for specific examination of a more reliable distribution method. First, location data of patients in lockdown areas are collected from the Shanghai official information system database. Then three-dimensional visualization of the terrain and the complex airspace was done using ArcGIS. Secondly, a complex urban flight environment within a blocked area is modelled and simulated for actual terrain ground conditions. Flight constraints on UAV performance are summarized. Integrated cost functions are established. Threat areas are added. Optimal paths are calculated. The drone path planning environment is assessed, including representation.s of paths and search spaces, threat space models involved in the path planning, and the main constraint models for track planning. Drone routing constraints are summarized according to the current laws and regulations for drone operation at low altitudes. Finally, heuristic features of the ant colony algorithm are analyzed. After the algorithm parameter factors are improved to address shortcomings in the algorithm, a mathematical model of the problem and a flow chart of the algorithm are presented to model the drone's three-dimensional path planning problem. The improved ant colony optimization (ACO) was applied to three-dimensional path planning problems, with programming done using MATLAB (ver.2017b). Assuming guaranteed safety and compliance with regulations, the solutions demonstrate algorithmic efficiency and provide a satisfactory route plan for emergency medicine delivery that might be useful to guide emergency delivery system routing design, which can be resolved similarly to complex urban terrain problems.

The conceptual framework of this study is shown as Figure 1:

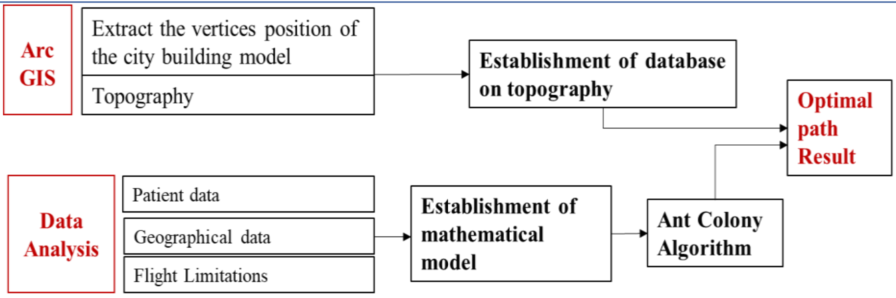


Figure 1. *The conceptual framework*

2. LITERATURE REVIEW

2.1. Drone path planning

In the mid-twentieth century, several economically developed countries began researching drone path planning technology. By the 1970s, a series of basic theories on flight had been constructed in this research area. Along with the widespread application and rapid development of computer technology, it was applied to remote control and remote sensing in the middle and late 1980s, leading to a qualitative change in operational planning systems. The United States, as a global military technology powerhouse, has continued to increase its investment in intelligent path planning and other aspects of research, taking the Predator as an example and establishing a ground control station system for drones. The newest model, the Air guard, can generate new paths in real-time based on navigation systems. Its drones can already fly independently around the world, across regions such as the Pacific and Atlantic Oceans, applying and performing various functions such as target surveillance and image processing. Rosner et al. (2018) designed a sensor that judges electromagnetic fields during UAV flight and which reduces the destructive power of magnetic fields during disruptive flights. Hirsch et al. (2011) developed a method of geometric mathematics to resolve difficulties of constraining the radius of a turn and choosing a direction in the trajectory planning process. This method allows the shortest path to be planned quickly, but it does not add a threat factor. Moreover, it is unsuitable for practical applications. Voos et al. (2018) investigated the detection and recognition of obstacles in complex and changing environments, using rapid commands through the autonomous judgment of flight control systems for collision-free navigation. Lobo et al. (2018) developed three-dimensional models to estimate drone trajectories using predictive models, to simulate wind speeds, and to calculate the likelihood of flight direction, with adjustment of the flight attitude to reduce crash probability. The research directions related to drone path planning mainly follow real-time planning, multi-aircraft collaborative planning, and ground station software system planning. In response to the difficulties posed by slow speed and flawed accuracy in the calculation of route length in path planning, the following shortcomings are readily apparent: Control must be maintained in a complex environment with a certain degree of randomness, with little assumed stability, with cooperation among different drones, and with monitoring of the emergency environment, in addition to strong requirements for technical personnel operation skills. Secondly, in response to the frequency of multiple events, operators must carry out re-planning and manual adjustments to change the path offsets. In summary, research on drone path planning in terms of algorithm accuracy and simulation of the real environment must still be enhanced, technical development is still limited, and research on drone path planning technology is urgently necessary.

2.2. Applications of drones for medical needs

Literature related to drones in medicine and healthcare studies is increasing. The rapid development of drone technology has led to a revolution in the medical domain. Major drone applications include pre-hospital emergency care, pre-laboratory diagnostic testing, and first aid. Choi et al. (2021) developed a UAV-AED flight simulation using topographic information such as natural terrain and buildings in Seoul, South Korea. Saeed et al. (2021) developed an Android application for patients through which the patient can send a request to the control centre whenever the patient must test for COVID-19. Khan et al. (2021) studied effective path planning methods applied to provide medical first aid in real-time with efficacy. Ling et al. (2019) studied a NASA medical supply delivery test conducted at a medical clinic in rural Virginia for the first government-approved drone delivery in the United States. The role of healthcare is crucially important for humanity. Therefore, research in this field is extremely important because it can save many lives, especially during urban lockdowns under epidemics. Therefore, we also emphasize ideas of applying drones for emergency medicine delivery.

3. METHODOLOGY

3.1. Basic methodology for path planning

3.1.1. Data sources and analysis

(1) Geographical data

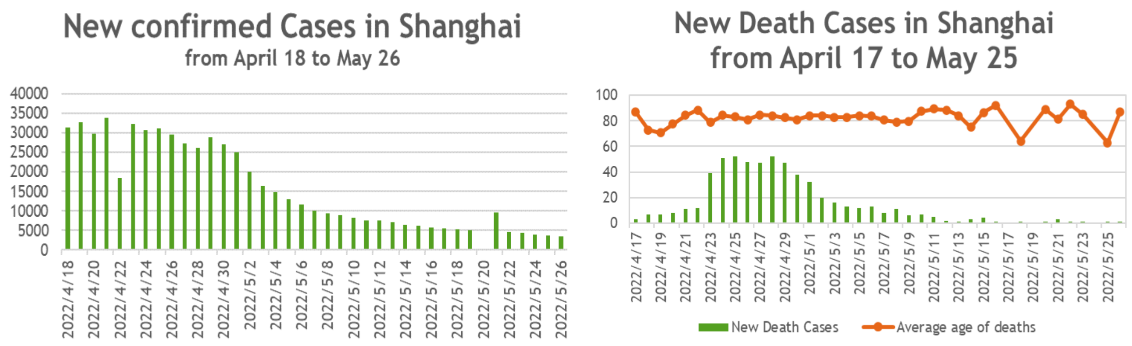
To develop drone flight path planning and simulation, we compiled a geographic information database that includes building height by combining data related to the altitudes of terrain features with the altitudes of all buildings in the lockdown area.

The geodatabase includes not only urban geospatial data (e.g., rivers, slopes) but also data from elevation models (e.g., buildings, roads) in the area. Geographic information can be collected in various ways: photogrammetry, field surveys, extraction of existing digital maps and extraction of existing Digital Elevation Model (DEM) databases. Because of the terrain complexity and the density of buildings in the lockdown area, photogrammetry and field surveys are difficult and time-consuming, although they might provide complete data. Therefore, we extracted data related to the topography and altitude of Shanghai city from Open Topography. The existing DEM database was chosen for this study. The data were then vectorized in ArcGIS: vertex positions of the building models in the city area were extracted. Data structures of two types are useful to represent urban geospatial data for experiments in ArcGIS, raster data structures and vector data structures. The chosen data structures differ among the types of data in the study area. The chosen data structure differs for each type of data in the study area. For this study, the raster data structure was chosen because of its ease of describing terrain undulations, the convenience of overlaying and combining spatial data, and the ease of performing spatial analyses of various types. The raster data structure is used to describe the topographical environment of the city. Because this study elucidates the route planning of drones in complex urban environments, accurate three-dimensional models of sensitive airspace and parametric modelling of feature data are required. Therefore, to describe the flight environment of drones in cities, it is necessary to use the vector data structure with its small data volume, easy processing of graphic data and attribute data, and high accuracy of geographic information data.

(2) Patient data

The data of COVID-19 patients in lockdown areas were collected from the Shanghai Municipal Health Commission using programs in Python. The data include the locations of newly confirmed cases and reported death cases from April 17 through May 25, 2022.

Data for causes of death in lockdown areas were also collected. More than half of the deceased were chronic patients who required timely use of medicines daily, and who might even need emergency medicine in a case of sudden illness. As presented in Figure 2, the line in orange shows the average ages of newly reported deaths. Almost all new death cases in the Shanghai lockdown area were elderly people. Data related to newly reported deaths were analyzed. Results in Figure 3 were obtained, indicating that more than half were patients with chronic diseases (e.g., hypertension). Greater attention must be devoted to elderly people, and especially to older people with chronic illnesses.



(a) New confirmed cases *(b) New death cases*

Figure 2. *Cases in Shanghai Lockdown Area.*[*1]

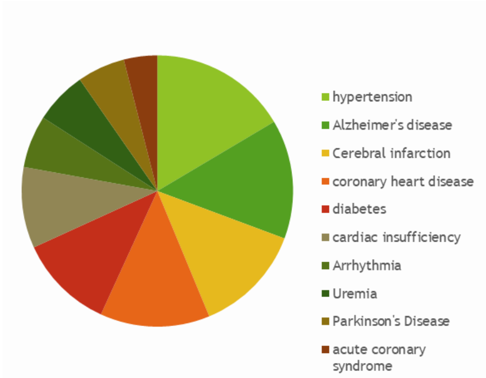


Figure 3. Top 10 Causes of death in Shanghai lockdown area.[*2]

[*1,2] *Data Source: Daily Reports from Shanghai Municipal Health Commission (up to 2022.5.26)*

3.1.2. ArcGIS Technology

With powerful data storage, spatial analysis and data visualization, ArcGIS is a highly scalable, comprehensive software platform that is able to describe complex urban geographic environments and to provide a good database. Therefore, this study uses ArcGIS for route planning. At the same time, the geographic information database used for this study is a data table form that can convert a large range of geographic information into an information model, and which can store and manage geographic information in a simple data table line book. Finally, the information model can be managed in a hierarchical manner according to the different needs of users, thereby ensuring the data effectiveness.

3.1.3. Modelling of complex urban terrain

Description of the complex urban environment for drones consists of two parts: creation of spatial terrain and representation of flight constraints. Digital elevation models of three types are in common use: the contour model, the irregular triangular network model, and the regular network model. The contour model is a map that represents the undulations and height conditions of the ground by joining adjacent points of the same elevation to form a collection of closed curves. The model shortcomings are that it does not represent all elevations, and that it is insufficiently three-dimensional. Calculating and representing some fine terrain features between two contour lines is difficult. An irregular triangulation model consists of a continuous triangular surface on which the surface shape and size depend on the sampling point location and density. Compared to regular grid cells, the map resources required for construction and processing are greater. For that reason, the costs of acquiring the original map data can be high. Also, the computational efficiency is low. The regular grid model is used widely for the creation of terrain environments because of its structural gridding characteristics. Actually, the model can be represented by a matrix that is easy to process by computer and which can better reflect the actual terrain topography.

As described herein, the regular grid model approach is used to achieve a spatial description of complex urban terrain. Furthermore, the relevant literature shows that the interpolation algorithm can restore the real terrain better. The initial map data are constructed using the original terrain map generated according to this method, as shown in Figure 4.

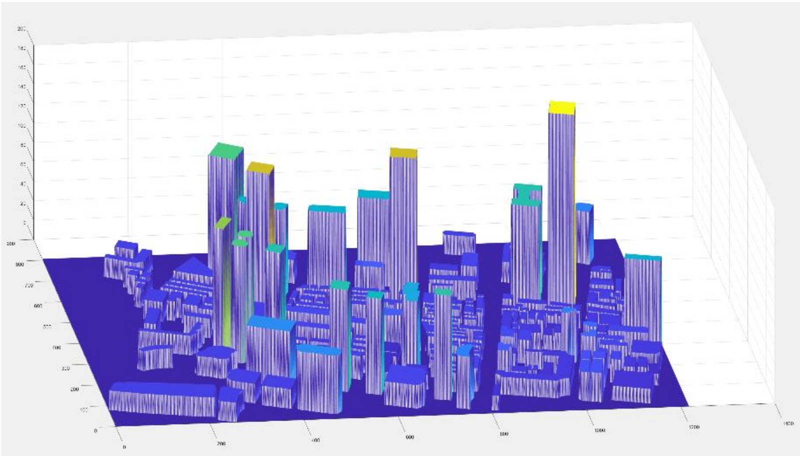


Figure 4. Three-dimensional mathematical model of complex urban terrain.

3.1.4. Ant colony algorithm

The ant colony algorithm (ACO) is an intelligent optimization algorithm that simulates an ant colony's foraging activities. Biologists have demonstrated that ants have no visual system and that they mutually communicate by releasing pheromones along the paths they travel. By sensing the presence and concentrations of pheromones during movement, ants can guide their movements, and those of ants following later, and ultimately find the best path to food. The ACO algorithm is based on the method used by real ants to find an optimal path. It is a simulation of evolutionary algorithms, which simulates ant behaviors in finding paths during their food searching.

The ACO algorithm has been used widely for solving hard combinatorial optimization problems in several domains, such as the traveler problem, resource scheduling, and other problems. The ACO algorithm has excellent robustness, making it an effective method for solving drone path planning problems. In the drone path planning problem and the simulation algorithm, the ants represent the drones. Furthermore, the probabilities for choosing the next spatial coordinate location are related to the pheromone. Dorigo et al. (2005) established the transition probabilities, which are defined as presented below.

$$p_{ij}^{k}(t)\begin{cases}\frac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum_{s\in allowed_k}\tau_{is}^{\alpha}(t)\eta_{is}^{\beta}(t)}, j \in allowed_k \\ 0, \quad\quad\quad\quad otherwise\end{cases} \quad (1)$$

Therein, $p_{ij}^{k}(t)$ stands for the transfer probability of ant k from node i to node j at time t. The following variables are also used:$\tau_{ij}(t)$ denotes the amount of pheromone on path (i, j) at time t; $\eta_{ij}(t)$ expresses the heuristic function indicating the expected degree of transfer of ant k from node i to node j; $\tau_{is}(t)$ signifies the amount of pheromone from node i to destination s at time t; $\eta_{is}(t)$ denotes the expected degree of transfer of ant k from node i to node j; and node i to node j; α and β respectively represent the information-inspired and expectation-inspired factors. Also, $allowed_k$ denotes the set of transfer nodes allowed by ant k.

The ACO algorithm is influenced by the pheromone update model, which tends to cause the population to lose diversity and fall into a local optimum. To overcome that tendency, some research is conducted to propose a three-dimensional path planning method to improve the ant colony algorithm and to ascertain the guiding factors of ants and the nodes to be transferred. The new regeneration mechanism and pheromone diffusion mechanism are established. The feasibility and effectiveness of the proposed algorithm are verified through realistic examinations. The feasibility and validity of the proposed algorithm are verified through real-life tests.

3.2. Study setting

3.2.1. Problem description

First, data on the topography and altitude of Shanghai city are extracted from Google maps (Figure 5). Secondly, a 2 km × 2 km lockdown area in Shanghai is chosen. In this area, there are 1034 buildings, including one hospital (red building), two government offices (pink buildings), and three residential buildings (blue buildings) in which the patients reside. As shown in Figure 6, the drone takes off at the red point and ends at three blue points. The route involves traversing a complex of urban terrain while avoiding pink government buildings.

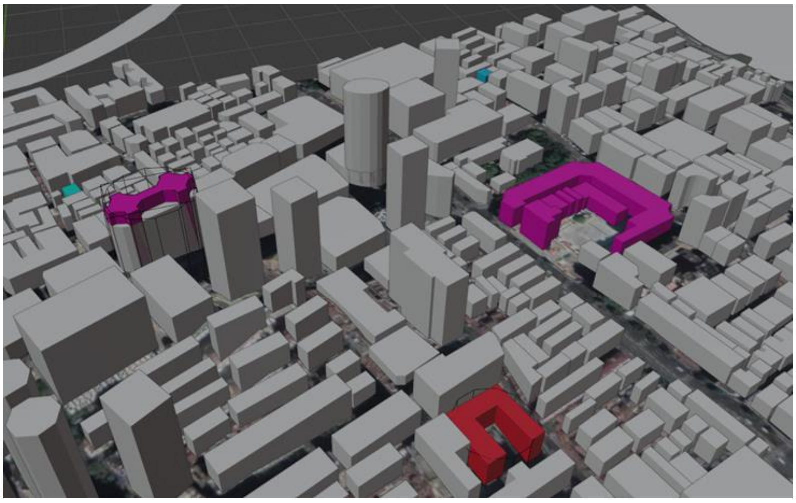


Figure 5. *Three-dimensional model of complex urban terrains in Shanghai lockdown area.*

Figure 6. *Locations of buildings in google maps.*

3.2.2. Problem description

The drone constraints are the performance indicators of the airframe itself. These indicators measure the maximum distance travelled, the maximum altitude flown, the maximum speed flown, etc. The indicators limit whether the drone can safely traverse the area, whether a possibility of flight failure exists, and whether the attitude and speed adjustments are restricted during flight. As described in this paper, the performance indicators above are regarded together. The constraints of the corresponding mathematical model are established.

(1) Minimum step length

The drone might shift its flight attitude during performance of its delivery. In the process of completing an attitude shift, it will perform a straight flight to a distance necessary for an actual safe flight. This distance is designated as the minimum step length. At the same time, the minimum stride length is also the minimum value of the stride length of the drone to maintain the inertial state in an unexpected situation, which, in general is the length of one second flown at the current speed conditions. The constraint of minimum stride length is determined mainly by the flexibility of the drone itself and the compactness of the airframe, but is also related to the navigation performance of the vehicle. If the attitude is not adjusted correctly or if it is adjusted too slowly, then the remote control and guidance functions will fail during subsequent flights. The aircraft might crash in treacherous terrain.

Letting L_i represent the total route length in segment i and letting L_{min} denote the minimum total route length, then the minimum step lengths can be defined as shown below.

$$L_i \geq L_{min}(i = 1,2,\ldots,n) \tag{2}$$

(2) Maximum voyage

The drone range is the main indicator of the maximum flyable distance of a drone during flight. The maximum range is the maximum distance a drone can fly with a full charge, assuming the maximum range as L_{max} . The total route length of the drone must meet the following conditions.

$$\sum_{i=1}^{m-1} L_i \leq L_{max} \tag{3}$$

(3) Minimum height from the ground
When carrying out distribution tasks, drones should be operated at as low a height as possible to prevent effects their operations, but too low a height from the ground can easily pose a threat to people on the ground. Therefore, a minimum height from the ground should be set in conjunction with relevant legislation. Letting $[x_i, y_i, h(x_i, y_i)]$ be the elevation coordinates of the route point, and letting $Z(x_i, y_i)$ be the elevation of the geographical model point corresponding vertically to the route point, and letting h_{min} and h_{max} respectively denote the minimum and maximum flight altitudes, then the constraint can be expressed as shown below.

$$h(x_i, y_i) - Z(x_i, y_i) \geq h_{min}, \quad h(x_i, y_i) \leq h_{max} \qquad (4)$$

(4) Total route length
The maximum power storage and power consumption determine the maximum distance that the drone can fly. From a flight safety perspective, the total range of the drone must be as short as possible. Letting d_{max} be the maximum route length, then the total route length constraint is the following.

$$\sum_{i=1}^{n} L_i \leq d_{max} \qquad (5)$$

3.2.3. Implementation process of the improved algorithm

The specific implementation steps of the improved ant colony algorithm are presented as shown below.
Step 1: First initialize the parameters. Empty the forbidden table. Then set the number of iterations; place the ant in the initial node.
Step 2: Place the ants at an initial node in the neighborhood space and start iterating.
Step 3: Increase the number of ants.
Step 4: Calculate the probability of state transfer from node i to node j based on the transfer probability formula. Then move the ant from node i to node j. Add the coordinates of node j to the taboo table of k ants.
Step 5: Return to step 3. If $k <$ m , then perform step 6 if this condition does not hold.
Step 6: If the ant traverses all nodes, then find the paths of all ants. Follow the update node pheromone method to find the number of pheromone increases. Then update the pheromones on all paths for updating and empty the taboo table of all ants.
Step 7: Determine whether it falls into a local optimum. If so, then dynamically adjust the volatility factor according to the distribution.
Step 8: If the maximum number of iterations is reached, then the search ends. Compare the resulting paths after each search and output the shortest path. If this condition does not hold, then go back to step 2 and search again.

3.2.4. Improvement Strategies

After a certain number of iterations of the ant colony algorithm, the search for the optimal solution is fundamentally the same. A stagnation phenomenon occurs. This phenomenon can reflect an excessive pursuit of optimal solutions, resulting in overly rapid convergence and a gradual decrease of the solution space. Reasons for this phenomenon are explained hereinafter: the algorithm lacks blind search capability at the beginning of the iteration; moreover, the direction of travel cannot be determined, therefore increasing the search time. The pheromone size determines the choice of subsequent ants. With an extreme increase in pheromone concentration, the algorithm falls into a local optimum. The pheromone concentration is constantly volatile along the paths along which the ants pass. The volatility per unit of time affects the guidance function of subsequent ants. The basic idea of the improved ant colony algorithm is to adjust the pheromones during the search process dynamically, and thereby to influence the decisions of the ants which follow later.

As shown in Figure 7, no better result was obtained using the traditional ant colony algorithm. Most ants showed a local optimum solution on the route of operation and a large jump when traversing the buildings. Such simulation results are not conducive to a smooth drone ride. The Unimproved ant colony algorithm cannot be used directly for drone path planning problems.

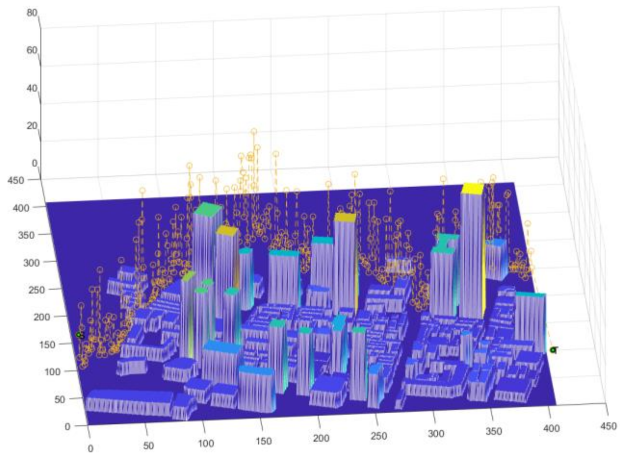


Figure 7. *Path results obtained using the unimproved algorithm.*

As described herein, the following improvements have been undertaken to address the shortcomings of the ant colony algorithm described above. Our calculated path makes the drone to deftly avoid obstacles when it encounters buildings along the way, as shown in Figure 8. A target node bootstrap factor was added to the state transfer probabilities of the algorithm. First, a target node bootstrap factor was added. It reduces the blind search of ants at the early stage of the algorithm, determines the main direction of feasible solutions, makes the ant colony move in that direction, determines the feasible solution range as soon as possible, reduces the iteration time of the algorithm and improves the convergence speed of the algorithm. Second, the pheromone on the path is updated reasonably dynamically. As the number of iterations of the algorithm increases, the paths of the respective iterations of the ants are sorted according to their length. The results are fed back to the ant colony for learning, thereby reducing the pheromones of the inferior ants and increasing that of the superior ants. The ranking is then weighted according to the degree of contribution, therefore expanding the path space available to the ant and increasing the diversity of solutions.

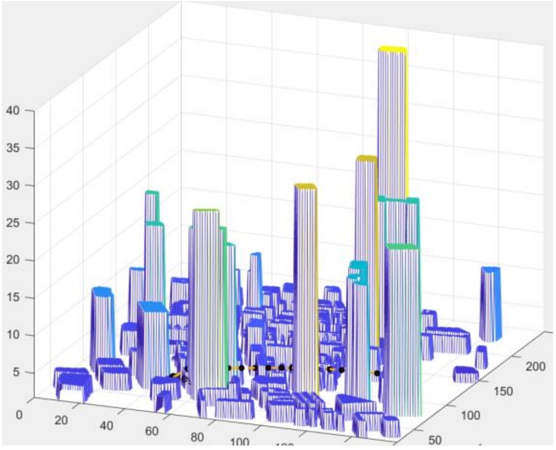


Figure 8. Path results obtained using the ımproved algorithm.

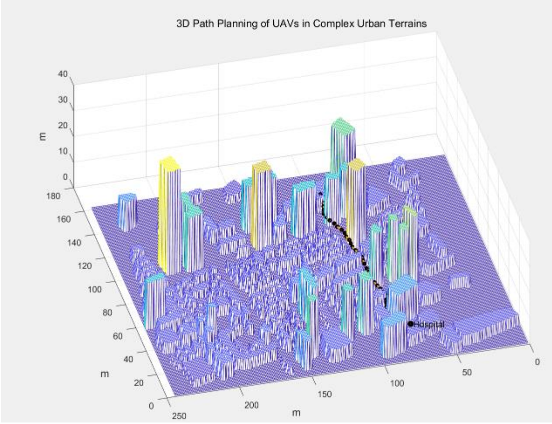
3.3. Simulation and analysis of results

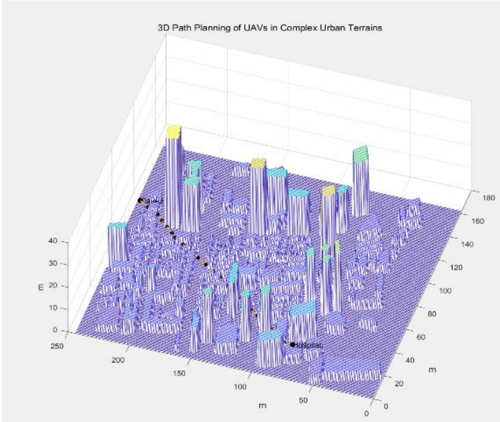
To validate the simulation of emergency medicine delivery using quadcopter drones, several tests were conducted in the software. The Shanghai Renji Hospital was chosen as the test site, mainly because it is the only highest-level hospital in the lockdown area which had no shortage of medicines. In addition, three randomly selected emergency medicine demand nodes with different positions and different directions were chosen from within the lockdown area. In addition, two government buildings must be avoided. Detailed information of the building model is presented in Table 1.

Table 1. *Building model ınformation*

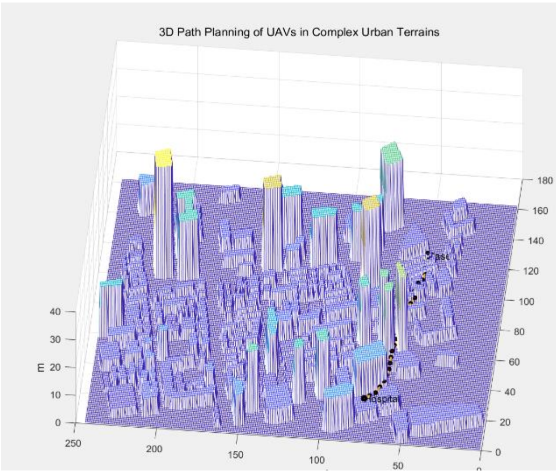
No.	Address	Coordinate points of the model
Case 1	No. 556 Changping Road Jiangning Road Street	135.96.2
Case 2	Lane 420, Changhua Road, Jiangning Road Street	120.240.3
Case 3	No. 145, Shandong Middle Road	120.50.5
Hospital	Lane 99, Yongxing Road Baoshan Road Street	20.75.5
Government 1	No. 31 Shanxi Road	37.63.5
Government 2	No. 215 Jiangxi Middle Road	35.95.5

The paths for cases 1–3 can be derived using the algorithm. As shown in Figure 9, the improved ACO algorithm's route paths have better smoothness than the paths planned using the traditional ACO algorithm, as well as avoiding obstructions of buildings in complex urban terrains.





(a) Path for case 1 *(b) Path for case 2*



(c) Path for case 3

Figure 9. *Rendering for cases 1–3 using the ımproved algorithm.*

4. FINDINGS AND DISCUSSION

The advent of drones has led to huge technological advances in the 21st century. They offer numerous benefits for almost every area of life. These drones can also play a role in saving time and valuable lives by delivering emergency medication during the widespread pandemic of COVID-19. A similar study was conducted by the authors with the aim of safely and efficiently delivering medicines by drone to patients who are compelled to stay at home. In addition to simulate a realistic drug delivery scenario, we conducted a study to analyze data related to newly reported cases of infection and newly reported deaths in Shanghai during the outbreak. The study showed that elderly people with underlying medical conditions needed more help and attention during the epidemic. We developed a method for hospitals and medicine delivery volunteers to derive efficient and safe routes for drone delivery when patients need emergency medication, even in complex urban terrain. Based on the problem of three-dimensional path planning for drones in complex urban terrain environments, this paper first proposes a method for transforming GIS data models into mathematical models that extract urban geography and terrain conditions into polyhedra, making the simulation environment more closely resemble the real complex urban environment. Secondly, an improved ant colony algorithm is proposed to solve the three-dimensional path planning problem of drones. Characteristics of the traditional ant colony algorithm were analyzed. To improve the algorithm in terms of the search direction and the optimization heuristic function, the algorithm was improved based on the traditional ant colony algorithm to keep the algorithm from falling into a local optimum solution. The simulation experiment results confirm that the improved algorithm provides marked improvement in both optimal calculation results. The experimentally obtained data of route planning for the same task start point (hospital) and delivery target points (patients) indicate that the flight route of the improved ant colony algorithm is more stable. Moreover, it can obtain a better solution than the traditional ant colony algorithm under the same conditions.

5. CONCLUSION

The results obtained using Google Maps and algorithms for path planning are shown in Figure 10 and Table 2. However, it is readily apparent that a difference exists in cumulative times of walking and drone travel. The distance of the algorithm is shorter than that presented by Google Maps. When a patient needs medication, drones can get to a destination faster than a volunteer can reach it by walking. The advanced ACO solves the drone path planning problem effectively in complex urban terrains. As a future work, we are going to improve the stability and safety of drone in bad weather by combined with three-dimensional center of gravity. Also, we will improve the accuracy of the algorithm by comparing multiple heuristics algorithms.

Table 2. *Comparison between two methods of medicine delivery*

Case No.	Start coordinate points (hospital) of the model	Destination coordinates points of the model destination position	Distance of drone path (m)	Cost time of drone path (min)	Distance of Google map by walk (m)	Cost time of Google map by walk (min)
1	20.75.5	135.96.2	566.76	1.7	953.72	19.07
2	20.75.5	120.240.3	984.53	2.95	1893.78	37.88
3	20.75.5	120.50.5	454.68	1.36	923.62	18.47

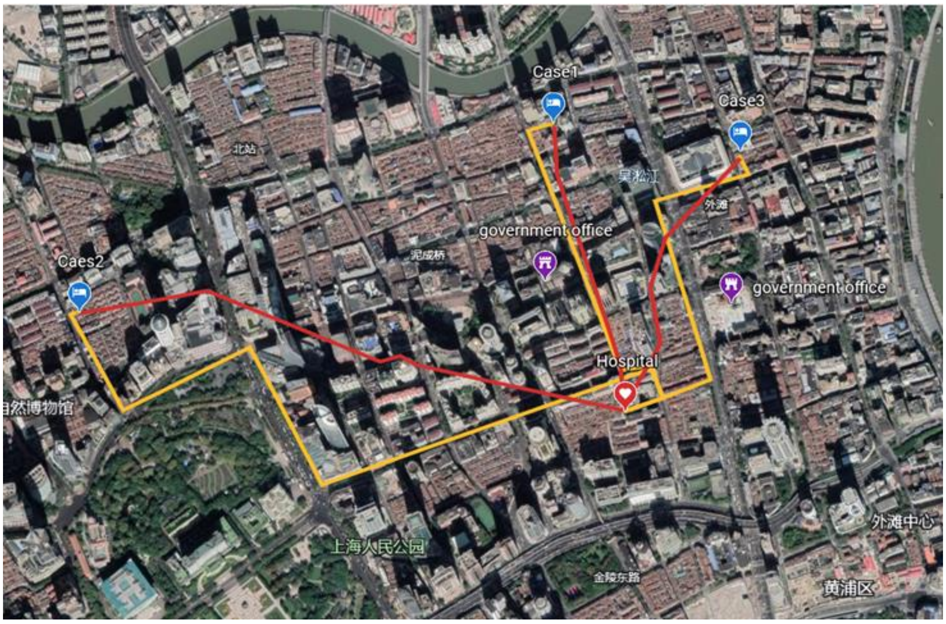


Figure 10. *Emergency medicine delivery paths in a lockdown area*

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

An Analysis on the Atmospheric Effects During the COVID-19 Pandemic: A Ro-Ro Port Example

COVID-19 Pandemisi Sırasındaki Atmosferik EtkilerÜzerine Bir Analiz: Bir Ro-Ro Limanı Örneği

Fırat BOLAT[1]

ABSTRACT

One of the most difficult issues that the world is currently facing is the pollution caused by greenhouse gases (GHG), which is caused by the transportation industry. All of the international transportation organizations, such as the International Maritime Organization (IMO), the International Civil Aviation Organization (ICAO), and others, have implemented climate change mitigation and adaptation measures. After that obliged the shipping industry to take particular measures after the 1st of January 2020, the International Maritime Organization (IMO) laid out a plan and provided an initial strategy for reducing GHGs in 2018. Emissions caused by humans are a well-established contributor to both the progression of climate change on a global scale and the deterioration of public health. It is an inescapable fact that ports, which serve as one of the touchpoints between different modes of maritime transportation, will also be impacted by these emissions. At Ro-Ro ports, the presence of air pollution is caused by anthropogenic emissions that are produced when ship generators are used in the process of handling goods. Because of this, it is essential to investigate the movements of ships in Ro-Ro ports as well as the quantity of fuel and its features that are consumed by the generators utilized in these ships. Ship movements of a Ro-Ro port that is operational in the Tuzla administrative port region were obtained by using the data from 19 distinct ships' hotelling times by day at the quays in 2019 and 2020. At 2019 and 2020, ship movements in the relevant port were analyzed, and data regarding the length of time that vessels spent at the quays was collected. The data on fuel usage for these ships was used in conjunction with an estimating model that was presented by the European Environment Agency (EEA) in its Air Pollutant Emission Inventory Guidebook. In this study, comparisons were made between ship emissions in different years at the berths of a Ro-Ro port.

Keywords: Maritime, Atmospheric Effect, Ro-Ro Port.

ÖZ

Dünyanın şu anda karşı karşıya olduğu en zor sorunlardan biri, ulaşım endüstrisinin neden olduğu sera gazlarının (GHG) neden olduğu kirliliktir. Uluslararası Denizcilik Örgütü (IMO), Uluslararası Sivil Havacılık Örgütü (ICAO) ve diğer tüm uluslararası taşımacılık örgütleri, iklim değişikliğini azaltma ve uyum önlemlerini uygulamaktadır. 1 Ocak 2020'den sonra denizcilik endüstrisini belirli önlemler almaya mecbur bırakan Uluslararası Denizcilik Örgütü (IMO), 2018'de sera gazlarını azaltmak için bir plan hazırlamış ve bir başlangıç stratejisi sağlamıştır. İnsanların neden olduğu emisyonlar, hem iklim değişikliğinin küresel ölçekte ilerlemesine hem de halk sağlığının bozulmasına köklü bir katkıda bulunmaktadır. Farklı deniz taşımacılığı modları arasında temas noktalarından biri olan limanların da bu emisyonlardan etkileneceği kaçınılmaz bir gerçektir. Ro-Ro limanlarında, hava kirliliğinin varlığı, malların taşınması sürecinde gemi jeneratörleri kullanıldığında üretilen antropojenik emisyonlardan kaynaklanmaktadır. Bu nedenle Ro-Ro limanlarındaki gemilerin hareketlerinin ve bu gemilerde kullanılan jeneratörlerin tükettiği yakıt miktarı ve özelliklerinin araştırılması gerekmektedir. Tuzla idari liman bölgesinde faaliyette olan bir Ro-Ro limanının gemi hareketleri, 2019 ve 2020 yıllarında 19 ayrı geminin rıhtımlarda günlük konaklama süreleri verileri kullanılarak elde edilmiştir. 2019 ve 2020 yıllarında ilgili limandaki gemi hareketleri analiz edilerek, gemilerin rıhtımlarda geçirdikleri sürelere ilişkin veriler toplanmıştır. Bu gemiler için yakıt kullanımına ilişkin veriler, Avrupa Çevre Ajansı (AÇA) tarafından Hava Kirletici Emisyon Envanteri Kılavuzunda sunulan bir tahmin modeli ile birlikte değerlendirilmiştir. Bu çalışmada bir Ro-Ro limanı rıhtımlarındaki farklı yıllardaki gemi emisyonları arasında karşılaştırmalar yapılmıştır.

Anahtar Kelimeler: Stratejik Denizcilik, Atmosferik Etki, Ro-Ro Limanı

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1. INTRODUCTION

Ports are junction points of different transportation modes connecting international and domestic markets. This propriety of ports makes them home to industrial clusters and thus high emission zones. It is recognised that auxiliary marine engines powering hotelling, mooring and unmooring operations of ships are accounted for a considerably big part of port emissions. Exhaust gases and particles emitted by marine engines are considered to be highly harmful for human health and environment, therefore reducing emissions has been at the top of the International Maritime Organization's (IMO) agenda.

Istanbul with 15,4 million habitants is one of the most congested European cities where air and marine pollution is an increasing threat to economy and public health. Ports are very close to residential spaces and densely populated neighbourhoods. Mucilage events and foul-smell observed in several coastal districts frequently make news by invoking public backlash.

Moreover, Istanbul's urban expansion towards the neighbouring cities fuelled by its relatively higher rates of economic growth and waves of rural exodus has meant a significant increase in the port activity in Northern Marmara making pollution the problem of a wider region. Hence, reducing the port emissions in Istanbul and in the wider Marmara Region is becoming one of the prominent environmental issues which is to be tackled by the Turkish national and local authorities.

In this paper, ship emissions at the quay of an international Ro-Ro port located in Tuzla, Istanbul were compared according to years. Firstly, previous work on port emissions and possible solutions were reviewed and measures to reduce shipping emissions assessed. Then, methodology explained and the data was analysed. In the final section, conclusions summarized.

2. LITERATURE REVIEW

According to IMO estimates, maritime emissions accounted for 2,89% of global anthropogenic emissions in 2018 (IMO, 2020), and is expected to increase its share significantly over the next 30 years, although a decline related to COVID-19 is likely to be recorded in 2020 and 2021 (IMO, 2020). The maritime transport sector is estimated to be responsible of almost one fourth of all SOx and NOx emissions in 2018 as a proportion of EU emissions from all industries (EU, 2021).

The International Council for Clean Transport (ICCT) has recognized that the majority of ship emissions occur in seas where ships are dependent on their main engines in the face of heavy seas and severe weather conditions. (Olmer, et al., 2017).

The cruising speed of a ship approaching port decreases, reducing fuel consumption and carbon emissions. At the quay, the main engines are shut down, but the auxiliary engines that power the handling operations continue to run and emit pollutants such as, particulate matter (PM), nitrous oxides (NOx), volatile organic compounds (VOC) and sulphur oxides (SOx) emissions which are main contributors to acidification and eutrophication.

Emissions from a single ship can be relatively higher during the navigation, but ports are places where pollutants are concentrated and have serious environmental and public health impacts threatening densely populated coastal cities. While greenhouse gas (GHG) emissions from ships are associated with global warming, research shows that exhaust gases and particles emitted from marine engines are closely linked to premature deaths, cardiovascular and respiratory diseases (Anenberg, et al., 2019).

One of the most important measures addressing the ship emissions in ports is the "IMO 2020" sulphur cap which decreases the sulphur limitation of fuel oils from 3.5% to 0.5% outside emission control areas (ECA) and to 0.1% in ECAs. Use of low sulphur marine diesel oil (MDO) instead of heavy fuel oil (HFO) is shown to reduce PM and SOx emissions significantly (Shen and Li, 2020), thus the sulphur cap is considered to be an important step to achieve emissions reduction targets of the industry (Shen, et al., 2020). However, Sofiev et al. (2018) predicted that even if low sulphur regulations were in place, ship emissions would still be responsible for approximately 6.4 million childhood asthma cases and approximately 250000 deaths per year (Sofiev, et al., 2018). There have been also studies to develop spatial modelling frameworks to understand the shipping traffic-based emission behaviour for habitat of the certain areas (Wang, et al., 2007; Hadipour, et al., 2021).

In addition to the negative impact of ship-borne air pollution on human health, there are also external costs such as loss of yield and material damage in agricultural products. Considering the health spending and the burden placed on the social security system, it is thought that ship emissions will have an even more significant annual cost. This external cost calculation concept is explained in detail in Jugović et al (2018) (Jugovic, et al., 2018). For a comprehensive review of the literature on quantification and monetization of adverse impacts from human emissions, the reader can refer to Tichavska et al (2017) (Tichavska, et al., 2017).

Increasing external costs with ship sizes and maritime trade make ship emissions at ports a major concern for local and national authorities. Consequently, over the last twenty years, international bodies have been steadily increasing their efforts to decarbonise the industry. Kotrikla et al. (2019) argue that the European Union lacks a comprehensive legal framework regarding pollution caused by ships, yet IMO conventions and national laws of the member states are there to play a complementary role (Kotrikla, 2019). In addition, ports are expected to play an important role in decarbonisation of maritime transport by promoting green technologies and the use of environmentally friendly fuels by ships, thereby promoting the reduction of CO2 emissions on the high seas (COGEA, 2017). Zhu et al. (2017) discussed the importance of encouraging shipping companies to invest in PM emission reduction technologies by introducing market-based measures such as preferential taxation and green credits to reduce pollution in ports and offshore (Zhu, et al., 2017).

However, while green incentive schemes implemented by terminals and port authorities can partially reduce ship-to-port emissions by promoting voluntary speed reduction (VSR) and low-sulphur fuels, some argue that it is possible to reduce emissions more radically by combining renewable energy with onshore power supply (OPS). Using OPS, also known as "cold ironing" (CI), a docked ship can turn off auxiliary engines and use electricity from an onshore source to power its lighting, cargo handling, and other electronic equipment and machinery. Recent research shows that providing even a part of the energy demand of the ship with renewable sources during the hotelling at the quay phase can significantly reduce the emissions from berthing ships (Kotrikla et al, 2017; Rolan et al, 2019).

Moreover, Spengler and Tovar (2021) suggest that even without integration of renewable energy sources into the grid, onshore electricity provided by oil-fired power plants could significantly reduce external costs associated with in-port emissions (Spengler, 2021). By combining the global and local externalities of ship emissions, Spengler and Tovar (2021) calculate the potential gains of cold ironing in Spanish ports, which means a reduction in annual external costs of up to tens of millions of euros for certain port cities (Spengler, 2021). On the other hand, power supply to ships on land requires a complex electrical interface described in Coppola et al (2016) (Coppola, et al., 2016). Zis (2019) argued that the main obstacle to the rapid increase in CI availability was the lack of sufficient ports with the necessary

Toros University FEASS Journal of Social Sciences 2021, 9(16)

technological infrastructure and the rarity of refurbished ships that could be connected to a grid on land (Zis, 2019). The same article discusses that factors such as extensions of the geographic scope of low sulphur regulations may force ship operators to invest in universal solutions such as scrubbers rather than invest in CI improvement. It depends on the energy mix as suggested in Zis et al. (2016), cold ironing also has a disadvantage in terms of transmission and energy conversion losses, which can lead to underestimation if not included in emission calculations (Zis, et al., 2016).

A not-so-sophisticated but effective technology being deployed to cap emissions in port areas is the Automatic Mooring Systems (AMS). AMS do not only promise reduction in emissions but they also promise a productivity increase by decreasing the time spent on mooring/unmooring operations. AMS are machines consisted of vacuum pads placed on remote-controlled robotic arms which can stretch out to a ship's hull and stabilize it for port operations. While mooring a vessel by using traditional rope systems take minutes, it only takes seconds with the AMS. The purpose of this technology is to reduce the time a vessel spends manoeuvring by the quays, thus the amount of fuel burnt by marine engines. This simple principal of the AMS makes it a safer and more feasible investment which can be realised in many commercial ports giving service to various types of vessel. In a case study focusing on a certain Ro-Ro/Pax port, Díaz-Ruiz-Navamuel et al (2018) compared the traditional mooring method and the AMS in terms of emissions by using an estimation model combining the EPA and the ENTEC methods. According to the calculations of Díaz-Ruiz-Navamuel et al (2018), using AMS technology reduce emissions during mooring operations by 96.67% (Díaz-Ruiz-Navamuel, et al., 2018).

3. ANALYSIS

In this study, data on the duration of the ships hotelling at the quay and the amount of ship emissions at the quay were analysed with statistical comparative analysis. It has been assumed that one generator of a ship is running at the maximum continuous rating. Normally fuel consumption for every different brand and type of engines are different but for approximation for consumption of similar kind of high speed diesel engines Turkish Maritime Administration's set value of 134 g/kW-h has been used (IMAMB CoS., 2019). Thus, ships' hotelling time at quays and the total yearly emission amounts of them for the years 2019 and 2020 were estimated and compared with graphs. For this study, bar graphs in SPSS program were used (IBM. In Figure 1, there is comparison of ships' hotelling times for 2019 and 2020 years. According to this, it is seen that, the longer time of hotelling belongs to S11 in 2019 and S04 in 2020.

In Figure 2, there is total emission rates at the quay for 2019 and 2020 years. According to the 2019 version (updated in October 2020) of European Environment Agency's air pollutant emission inventory guidebook, the coefficients of PM, NO_x, and non-methane volatile organic compounds (NMVOC) for auxiliary high speed marine diesel engines are 3.5, 47.6, 1.7 kg/tonnes fuel, respectively (EMEP/EEA., 2019). Therefore, in 2019, the total emission rates of PM, NO_x, and NMVOC at the quay are 17.18, 233.70, and 8.35 metric tonnes respectively. In 2020, the total emission rates of PM, NO_x, and NMVOC at the quay are 19.03, 258.81, and 9.24 metric tonnes respectively. In accordance with the results, the more emissions have occurred at the quay in 2020 than in 2019.

It can be understood from the figures that how many days the ships made a hotelling at the Ro-Ro quays separately in 2019 and 2020. Some ships have never came to the quay for 2019 or 2020. For this reason, the graph information of some ships which belongs to 2019 or 2020 has one column.

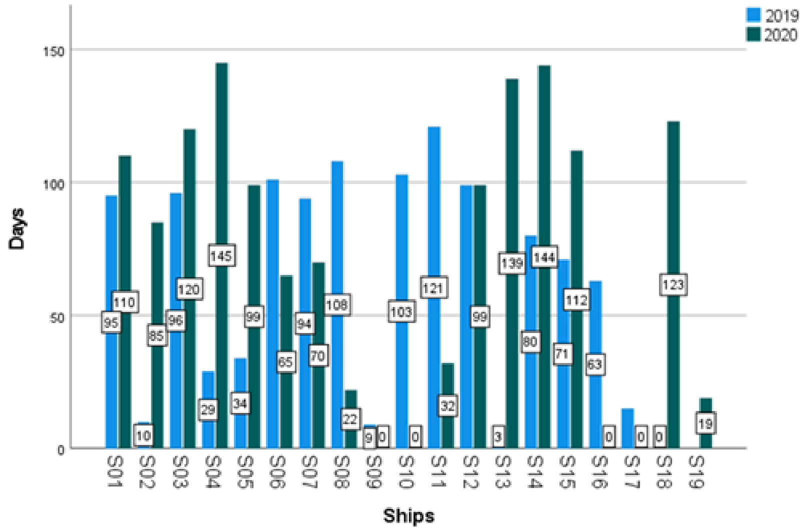

Figure 1. *Hotelling times at port for ships in 2019 and 2020*

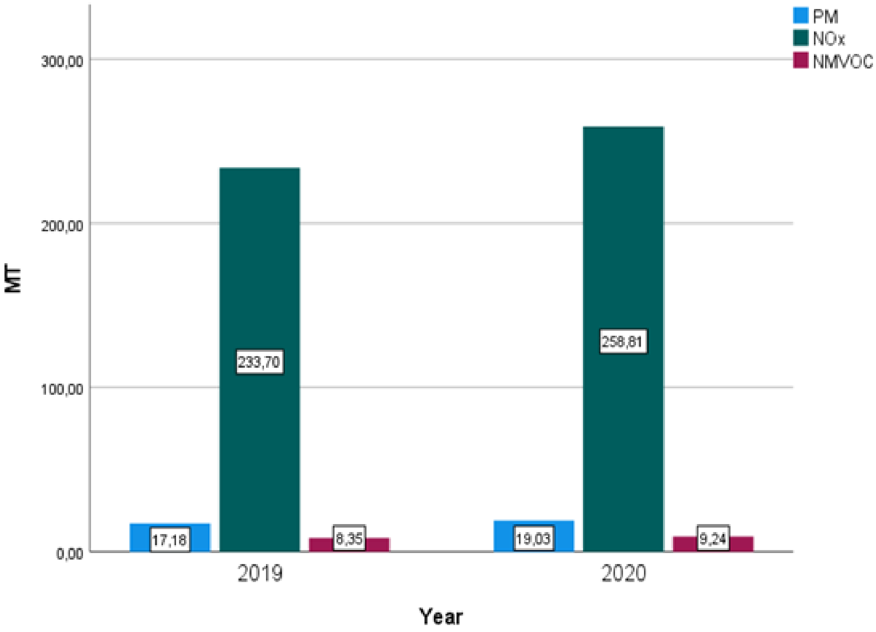

Figure 2. *Total emission rates at the port in 2019 and 2020*

4. CONCLUSION

Reducing greenhouse gas emissions is key to avoiding the most devastating effects of climate change. It is well accepted that ships are responsible for about 1 billion tons of GHG emissions. This fact alone underlines the important role of IMO and local maritime authorities in fighting climate change and pollution.

Due to the lack of a comprehensive historical database on shipping emissions, it is unable to determine which ship types have been accounting for the bigger parts of shipping emissions and thus have more responsibility in air and marine pollution. However, with environmental disasters claiming hundreds of lives, human beings are at point where every effort to fight climate change counts.

In this study, the emission data of ships at the quay of a Ro-Ro port in Tuzla for two consequent years, 2019 and 2020 were compared. Total emission rates by year are shown in Figure 2. In 2019, the total emission rates of PM, NOx, and NMVOC at the quay are 17,18, 233,70, and 8,35 metric tonnes respectively. In 2020, the total emission rates of PM, NOx, and NMVOC at the quay are 19,03, 258,81, and 9,24 metric tonnes respectively. It is seen that the values have increased in general terms. It was observed that the most significant increase was in NOx emissions.

According to calculations made, it can be said that there is no decrease in the emissions caused by the burning of hydrocarbon fuels in the generators of the ships approaching at the Ro-Ro ports in 2020 in Tuzla region, but an increase compared to the previous year, 2019.

In Karl et al. (2019), the Community Multiscale Air Quality Modeling System (CMAQ) model and the System for Integrated Modelling of Atmospheric Composition (SILAM) model were compared and used by comparing to EMEP model. It has been seen that CMAQ and EMEP models give similar results and different results than SILAM model. Additionally, it has been observed that three different models give different results, particularly in PM emissions. (Karl, et al., 2019). Calculations of emissions, particularly PM emission calculations, can also be performed with the CMAQ and SILAM models, in addition to the EMEP model, which is a model that is continually undergoing development.

In conclusion, it is seen that the COVID-19 pandemic did not affect Ro-Ro transportation in Tuzla Port. Therefore, higher quantities of in port emissions occurred at the Tuzla Port from Ro-Ro ships' generators in 2020 than in 2019. Although it is clear that the logistics networks were damaged during the COVID-19 pandemic, the increase in the total need for goods with the increasing population may have caused this situation. The temperature of the planet we live on is increasing day by day. Even the smallest increase in temperature on earth can have a significant impact on the outcome. As more heat is retained in the atmosphere, seawater temperatures will increase along with it (Galashev, 2011). The use of new technologies such as cold ironing to reduce the GHG released into the atmosphere by the ships at the quay may help to reduce the problem to some extent. With more detailed and more precise studies to be carried out in the future, the ecological effects created or to be caused by emissions and the harms to nature they may cause to environment and human health should be revealed more precisely and appropriate environmental policies can be developed.

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ARAŞTIRMA MAKALESİ/ **RESEARCH ARTICLE**

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Experienced Problems with Online Shopping: The Case of Turkey

Online Alışverişte Yaşanılan Sorunlar: Türkiye Örneği

Şeyda ÜNVER[1] **Ömer ALKAN [2]**

ABSTRACT

This study's objective is to investigate the sociodemographic and economic elements that are important in cases when people experience problems with their online purchases. A microdata set from the 2021 Information and Communication Technology Usage Survey in Households conducted by the Turkish Statistical Institute is used in the study. The factors connected to the problem individuals have with online purchases have been determined using binary logistic regression analysis. In the data set included in the analysis in this study, 52.4% of the men reported that they had encountered problems with their purchases made on the website or mobile application in the last three months. According to the study, 51.9% of individuals in the eastern region reported having difficulty with transactions made through a website or mobile application. As a result of the research, it has been discovered that education level, income level, age, gender, profession, family size, financial transactions conducted over the Internet, and regional characteristics are all linked to experiencing problems with online shopping.

Keywords: Online shopping, binary logistic regression, Turkey.

Öz

Bu çalışmanın amacı, bireylerin internet üzerinden yaptıkları satın alma işlemlerinde sorun yaşama durumlarında etkili olan sosyo-demografik ve ekonomik faktörlerin araştırılmasıdır. Çalışmada, TÜİK tarafından 2021 yılında yapılan Hanehalkı Bilişim Teknolojileri Kullanım Araştırmasından elde edilen mikro veri seti kullanılmıştır. Bireylerin internet üzerinden yaptıkları satın alma işlemlerinde sorun yaşama durumları ile ilişkili faktörlerin belirlenmesi için binary logistic regresyon analizi kullanılmıştır. Bu çalışmada analize dahil edilen veri setinde erkeklerin %52,4'ü son üç ay içinde web sitesi veya mobil uygulama üzerinden yaptıkları satın alma işlemlerinde sorunlar ile karşılaştıklarını bildirmiştir. Çalışmada doğu bölgesinde yaşayan bireylerin %51,9'unun da web sitesi veya mobil uygulama üzerinden yaptıkları satın alma işlemlerinde sorunlar ile karşılaştıklarını bildirdikleri tespit edilmiştir. Çalışmanın sonucunda eğitim durumu, gelir düzeyi, yaş, cinsiyet, meslek, hanehalkı büyüklüğü, internet üzerinden gerçekleştirilen finansal işlemler ve bölge değişkenlerinin online alışverişte sorun yaşama durumuyla ilişkili olduğu tespit edilmiştir.

Anahtar Kelimeler: Online alışveriş, binary lojistik regresyon, Türkiye.

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1. INTRODUCTION

The Internet plays a vital role in our lives in that it allows people to easily access our world and opens international borders. E-commerce is now widely accepted as a way of purchasing goods and services. Online shopping is the dominant alternative to traditional retail shopping (Çera et al., 2020). The basic concepts of online shopping have been developed in the Western World, and most of the relevant studies are centered in the US/EU or the Far East (Usunier et al., 2005). Due to social and economic variations, the findings of these studies might not be applicable to other regions of the world, and there hasn't been much comparative research on information and communication technology (ICT) in developing nations (Akman & Rehan, 2014). Turkey is a developing country with a relatively young and high population and is located between the individualistic and collectivistic cultures of Western and Far Eastern countries respectively (Chirkov et al., 2003). With all these characteristics, Turkey is an important and interesting example of developing countries and markets with high potential.

Turkey began using the internet in 1993. In 1996, the internet started to be used in homes and changed people's usage purposes day by day (Erceğ &Kılıç, 2018). With the rapid development of internet usage and communication technologies in the world, a new economic order has spread. Parallel to this, physical boundaries between buyers and sellers have disappeared, the breadth of markets where they interact has expanded, and sellers have elevated their commercial activities to web-based platforms by accepting clients from all over the world (Lightner, 2003).

Extensive research has been conducted by academics to learn about consumer behavior on online shopping platforms. Consumer-oriented and technology-oriented studies have tried to provide information about consumer behavior from various perspectives. Consumer-oriented studies have examined consumer shopping behavior in terms of consumer demographics (Alaam et al., 2008), cultural factors (Ko et al., 2004), psychological factors (Lin, 2007; Lian & Lin, 2008), and perceived risk factors (Almousa, 2011). In a study conducted on undergraduate and graduate students in Taiwan, it was stated that consumers' trust in online retailers affects not only their attitudes towards online shopping but also their online shopping intentions (Phung, Yen & Hsiao, 2009). Technology-oriented studies have evaluated consumer behavior in terms of technical features of online stores, such as privacy and design, ease of navigation and information content (Ranganathan & Ganapathy, 2002). Research has found that online consumers' privacy and security concerns are the main factors that significantly affect their intention to shop online (Lian & Lin, 2008).

Online shopping has various advantages, such as time saving, wide product options, ease of shopping, 24/7 shopping, saving the trouble of waiting in shopping lines, special internet discounts, but it also has various risks (Ağaç, Sevinir, & Yılmaz, 2018). Cheng, Liu, & Wu (2013), present these risks in five dimensions: financial risks, performance risks, social risks, time risks and privacy risks. Research shows that perceived benefits have a positive effect on consumers' attitudes towards online shopping, while perceived risks have a negative effect. (Hsu & Bayarsaikhan, 2012). In a study conducted in Turkey, it was determined that the most important risk dimension perceived by consumers in online clothing shopping is product risk (Alkibay & Demirgunes, 2016). The product risks mentioned in the research are; problems in sizing, lack of opportunity to try and examine the product, lack of opportunity to touch and see the product live. In another study, product performance risks were grouped as visual (design, fabric, color, detail), tactile (touch, feel, weight) and trial (fit, comfort, appearance on the body). The results of the study showed that online consumers perceive visual, tactile and trial product risks related to product performance based on evaluating product attributes through visual product experience. The study also found a positive relationship between visual and tactile risks and between tactile and trial risks (Yu, Lee, & Damhorst, 2012). In a study conducted in Ankara, the attitudes of university student internet users towards online shopping were investigated. It was found that financial problems, product quality problems, refund problems, product delivery problems, security problems and privacy problems were effective factors in online shopping concerns (Huseynov & Yıldırım, 2016).

The characteristics that influence people's online shopping behaviour have been identified in research recently undertaken in Turkey (Ünver & Alkan, 2021; Alkan & Ünver, 2021; Akman & Mishra, 2010; Akman & Rehan, 2014; Huseynov & Yıldırım, 2016). It is seen that the online shopping activities of individuals take place in several different ways and for various purposes (Potosky, 2007). Because online shopping improves opportunities in many areas, it is important to assess the extent of factors affecting online shopping and the underlying causes (Ono & Zavodny, 2007). It was found that demographic characteristics of individuals affect their actions before they commit any certain behavior (Zhang, 2005). Therefore, the differences in various aspects of experienced problems in online shopping among demographic groups have become an interesting area of research (Yang & Tung, 2007). It is important that both e-commerce providers and online shoppers understand the factors associated with individuals having problems with online shopping (Ünver &Alkan, 2021). In this study, binary logistic regression analysis was carried out to investigate the effect of selected demographic factors on individuals' online shopping problems.

This study investigates the factors related to the problems that the participants have had in the past three months when using the website or mobile application to shop. In this study, the research questions that are emphasized on the situation of individuals living in Turkey experiencing problems with online shopping are as follows: "What are the sociodemographic and economic characteristics of individuals?" and "Is there a relationship between the demographic and economic characteristics of individuals and their problems in online shopping?".

The aim of this study is to look into the sociodemographic and economic elements that are important in cases when people experience problems with their online purchases. The study used a microdata set from the 2021 Information and Communication Technology Usage Survey in Households conducted by the Turkish Statistical Institute. The factors connected to the problem individuals have with online purchases have been determined using binary logistic regression analysis. The remainder of this study is organized as follows. In Chapter 2, the data, variables and analysis method used in the study are mentioned. In Chapter 3, the results obtained from the research are explained in detail. In Chapter 4, the results obtained from the study are discussed and its relation with the literature is mentioned.

2. MATERIAL AND METHOD

2.1. Data

In this study, the Information and Communication Technology Usage Survey on Households performed by the Turkish Statistical Institute in 2021 was used as a microdata set. The Information and Communication Technology Usage Survey in Households, which has been carried out since 2004, aims to collect information about information and communication technologies owned by households and individuals and their uses. The sampling method employed in the study was stratified 2-stage cluster sampling (Alkan & Ünver, 2020; Alkan & Ünver, 2022).

Data from 9,438 participants in the Information and Communication Technology Usage Survey in Households in 2021 who were 15 years of age or older were used in this study.

2.2. Outcome Variables

The dependent variable of the study is the problems encountered in the purchases made by individuals through the website or mobile application in the last three months. Participants were asked about the problems encountered in their purchases made through the website or mobile application in the last three months as of the survey period:

1. Difficulty of use or inadequate operation of the website (1-Yes, 2-No)
2. Difficulties finding information on warranty conditions or other legal rights (1-Yes, 2-No)
3. Slower delivery than stated (1-Yes, 2-No)
4. Higher final costs than stated (1-Yes, 2-No)
5. Delivery of incorrect or damaged goods/services (1-Yes, 2-No)
6. Problems related to fraud (1-Yes, 2-No)
7. Difficulty or unsatisfactory response to complaints and redress (1-Yes, 2-No)
8. Not selling goods and services to the country from websites originating abroad (1-Yes, 2-No)
9. Other (1-Yes, 2-No)

questions were asked. Participants were coded as "1" if they encountered at least one of these problems, and as "0" if they didn't.

2.3. Independent variables

The independent variables to be included in this study are the variables that are available in the Information and Communication Technology Usage Survey in Households and the variables that stand out as a result of the literature research. The independent variables of the study are age (16-24, 25-34, 35-44, 45-54, 55+), gender, education level (uneducated/primary school, secondary school, high school, university), occupation (unemployed individuals, managers, professionals, technicians and associate professionals, clerical support workers, service/sales workers, skilled agricultural/ forestry/ fishery workers, craft/related trades workers, plant-machine operators/assemblers, elementary occupations). Financial transactions carried out over the internet; participants are asked about financial transactions made for private purposes through a website or mobile application:

1- Purchase of insurance policies or renewal of existing ones (Insurance policies purchased as a package with other services are also included) (1-Yes, 2-No)

2- Obtaining loans from banks or other financial institutions (1-Yes, 2-No)

3- Buying and selling stocks, bonds, funds and other investment instruments (1-Yes, 2-No)

Participants were coded as "1" if they had made at least one of these financial transactions, and as "0" if they had not made any of them. Income level (1st income level (lowest), 2nd income level, 3rd income level and 4th income level (highest)), number of individuals in the household (1-3, 4-5, 6 and above), and region (west, central, east).

Turkey is divided into 12 regions at Level 1 under the Nomenclature of Territorial Units for Statistics (NUTS). In this study, these regions are grouped as western, central and eastern regions (Ünver & Alkan, 2021). These regions and the provinces in these regions are shown in detail in Table 1.

Table 1. *Nomenclature of Territorial Units for Statistics- Level 1*

Region	Code	Level 1	Provinces
Western Region	TR1	İstanbul	İstanbul
	TR2	West Marmara	Tekirdağ, Edirne, Kırklareli, Balıkesir, Çanakkale
	TR3	Aegean	İzmir, Aydın, Denizli, Muğla, Manisa, Afyonkarahisar, Kütahya, Uşak
	TR4	East Marmara	Bursa, Eskişehir, Bilecik, Kocaeli, Sakarya, Düzce, Bolu, Yalova
Central Region	TR5	West Anatolia	Ankara, Konya, Karaman
	TR6	Mediterranean	Antalya, Isparta, Burdur, Adana, Mersin, Hatay, Kahramanmaraş, Osmaniye
	TR7	Central Anatolia	Kırıkkale, Aksaray, Niğde, Nevşehir, Kırşehir, Kayseri, Sivas, Yozgat

	TR8	West Black Sea	Zonguldak, Karabük, Bartın, Kastamonu, Çankırı, Sinop, Samsun, Tokat, Çorum, Amasya
Eastern Region	TR9	East Black Sea	Trabzon, Ordu, Giresun, Rize, Artvin, Gümüşhane
	TRA	Northeast Anatolia	Erzurum, Erzincan, Bayburt, Ağrı, Kars, Iğdır, Ardahan
	TRB	Centraleast Anatolia	Malatya, Elâzığ, Bingöl, Tunceli, Van, Muş, Bitlis, Hakkâri
	TRC	Southeast Anatolia	Gaziantep, Adıyaman, Kilis, Şanlıurfa, Diyarbakır, Mardin, Batman, Şırnak, Siirt

In order to observe the impacts of the categories of all variables to be included in binary logistic regression, ordinal and nominal variables were identified as dummy variables (Alkan & Ünver, 2022; Alkan et al., 2020).

2.4. Statistical Analysis

One of the main areas of statistical inference is the testing of statistical hypotheses. SPSS 20 and Stata 15 programs were used to analyze the data. Firstly, of all, frequencies and percentages of the individuals participating in the study were obtained for demographic, economic, and personal factors. In this study, binary logistic regression method was used to investigate the relationship between demographic and economic factors and individuals' experience problems with online shopping.

Binary logistic regression is a statistical analysis method used to examine the causal relationship between the dependent variable and the independent variable(s) when the dependent variable is a binary variable (Alkan & Ünver, 2020).

3. RESULTS

3.1. Characteristics of participants

The frequencies and percentages of the variables utilized in the study are shown in Table 2. According to Table 2, 34.1% of the individuals are between the ages of 25-34. When the education level variable is analyzed, it is seen that 48.4% of the individuals participating in the study are university graduates, while 5.8% are primary school graduates. In addition, 47.6% of the participants were male, while 52.4% were female. Table 2 shows that 51.9% of the individuals participated in the study from the western region. It is also seen that 40.2% of the individuals who participated in the study were not employed.

In the study, it was tested whether there was multicollinearity among the independent variables to be included in the binary logistic regression model. Variance inflation factor (VIF) values of 5 and above are considered to cause moderate multicollinearity, while values of 10 and above are considered to cause high multicollinearity (Ünver & Alkan, 2020; Alkan, Özar, & Ünver, 2021; Alkan, Oktay, & Genç, 2015). There are no variables in this study that induce multicollinearity between the variables.

Table 2. *Findings Related to the Factors Associated with Experiencing Problems with Online Shopping*

Variables		**n**	**%**	**VIF**
Age	16-24	849	26.9	ref.
	25-34	1,077	34.1	1.82
	35-44	769	24.4	1.81
	45-54	334	10.6	1.49
	55+	129	4.1	1.22
Education level	Uneducated/ Primary School	183	5.8	ref.
	Secondary School	398	12.6	2.74
	High School	1,047	33.2	4.07
	University	1,530	48.4	4.84
Gender	Male	1,654	52.4	ref.
	Female	1,504	47.6	1.23
	No	2,311	73.2	ref.

Financial transaction	Yes	847	26.8	1.16
Income level	1st income level (lowest)	705	22.3	ref.
	2nd income level	882	27.9	1.58
	3rd income level	767	24.3	1.63
	4th income level	804	25.5	1.85
Region	West	1,640	51.9	1.86
	Middle	1,012	32	1.8
	East	506	16	ref.
Number of individuals in the household	1-3	1,505	47.7	3.59
	4-5	1,404	44.5	3.4
	6 and above	249	7.9	ref.
Occupation	Managers	181	5.7	1.29
	Professionals	625	19.8	1.79
	Technicians and associate professionals	228	7.2	1.23
	Clerical support workers	181	5.7	1.19
	Service/sales workers	308	9.8	1.25
	Skilled agricultural/ forestry/ fishery workers	14	0.4	1.03
	Craft/related trades workers	132	4.2	1.19
	Plant-machine operators/ assemblers	119	3.8	1.16
	Elementary occupations	101	3.2	1.11
	Unemployed individuals	1,269	40.2	ref.

3.2. Model Estimation

A binary logistic regression model was used to determine the sociodemographic and economic factors associated with the individuals in the study experiencing problems with online shopping. The estimated model results are provided in Table 3. When Table 3 is analyzed; it is seen that age, gender, education level, occupation, financial transaction, and number of people in the household variables are significant in the estimated model.

***Table 3**. Estimated Model and Marginal Effects of Factors Associated with Experiencing Problems with Online Shopping*

Variables		**β**	**S.E**	**M.E**	**S.E**
Age (reference category:16-24)					
	25-34	-0.014	0.069	-0.009	0.044
	35-44	-0.094	0.076	-0.061	0.049
	45-54	-0.24	0.093	-0.159[b]	0.063
	55+	-0.368	0.134	-0.251[a]	0.094
Education level (reference category: uneducated/primary school)					
	Secondary School	0.062	0.119	0.043	0.084
	High School	0.19	0.108	0.13[c]	0.075
	University	0.35	0.112	0.234[a]	0.077
Gender (reference category: male)					
	Female	0.092	0.053	0.06[c]	0.035
Income level (reference category: 1st income level (lowest)					
	2nd income level	0.092	0.067	0.061	0.045
	3rd income level	0.101	0.072	0.067	0.048
	4th income level	0.187	0.077	0.123[b]	0.051
Region (reference category: East)					
	West	0.463	0.068	0.314	0.048
	Middle	0.25	0.071	0.176	0.051
Financial transaction (reference category: no)					
	Yes	0.439	0.061	0.276[a]	0.037
Occupation (reference category: unemployed individuals)					
Manager		-0.115	0.12	-0.076	0.08
Professionals		-0.016	0.084	-0.01	0.054
Technicians and associate professionals		0.034	0.108	0.022	0.069
Clerical support workers		-0.154	0.113	-0.102	0.076
Service/sales workers		-0.088	0.09	-0.058	0.06

Skilled agricultural/forestry/fishery workers	-0.682	0.323	-0.487[b]	0.25
Craft/related trades workers	-0.272	0.125	-0.183[b]	0.087
Plant-machine operators/assemblers	-0.211	0.131	-0.141	0.09
Elementary occupations	-0.189	0.137	-0.126	0.093
Number of individuals in the household (reference category: 6 and above)				
1-3	0.177	0.093	0.116[c]	0.062
4-5	0.03	0.09	0.02	0.061

[a]p < .01; [b]p < .05; [c]p < .10

According to the binary logistic regression model provided in Table 3, an individual between the ages of 45-54 is 16% less likely to experience problems with online shopping than the reference group. According to the study, an individual with a university degree is 23.4% more likely to experience problems with online shopping than the reference group. Individuals with 1-3 people in the household are 11.6% more likely to experience problems with online shopping compared to the reference group. Men are 0.6% more likely to experience problems with online shopping than women. An individual at the 4th income level is 12.3% more likely to experience problems with online shopping compared to the reference group. An individual working as a skilled agricultural/forestry/fishery worker is 48.7% less likely to have problems with online shopping than the reference group.

4. DISCUSSION AND CONCLUSIONS

Online shopping has grown to be one of the largest megatrends in the global economy thanks to the Internet's quick development. In this study, the data of 9,438 individuals who participated in the Household Information Technology Usage Survey conducted by the Turkish Statistical Institute in 2021 were used. In this study, a binary logistic regression method was used to investigate the relationship between demographic and economic factors and individuals' experiencing problems with online shopping. According to the results of the analysis, age, gender, education level, occupation, financial transaction, and the number of people in the household variables are significant.

In the study, it was concluded that as the age of individuals increases, the likelihood of experiencing problems with online shopping decreases. In some studies, it has been concluded that the probability of online shopping decreases as the age of individuals increases (Bhatnagar, & Ghose, 2004; Alqahtani, Goodwin, & de Vries, 2018; Beneke, Scheffer, & Du, 2010; Alkan & Unver, 2021). Therefore, the findings in this study could be associated with this situation. In addition, it was concluded that as the educational level of individuals increases, the likelihood of experiencing problems with online shopping increases. In some studies, it has been concluded that the likelihood of online shopping increases as the educational level of individuals increases (Akman & Rehan, 2014; Farag et al., 2006). Therefore, the findings in this study could be associated with this situation. In addition, as the income levels of individuals increase, the likelihood of experiencing problems with online shopping increases. In some studies, it has been determined that the probability of online shopping increases as the income level of individuals increases (Akman & Mishra, 2010; Smith et al. (2008). Higher income customers seek higher quality service interactions (Ganesan-Lim, Russell-Bennett, & Dagger, 2008).

In the data set included in this study's analysis, it was determined that men have more problems in online shopping than women. Also, it was determined that men are more likely to experience problems with online shopping than women. In some studies, it has been determined that men are more likely to shop online than women (Zhang, 2005; Potosky, 2007). Therefore, the findings in this study could be associated with this situation. The study concluded that the probability of experiencing problems with online shopping decreases as household size increases. In addition, according to the study, an individual who makes financial transactions for private purposes through a website or mobile application is more likely to experience problems with online shopping than an individual who does not make financial transactions for private purposes through a website or mobile application.

The share of Turkey in e-commerce is increasing every passing day and provides significant profits to the country's economy by raising the commerce volume and potential in both national and international markets. Despite the increasing number of e-commerce users observed in the public and private sectors, legal and sectoral regulations, it is seen that e-commerce’s potential cannot be fully evaluated, and it lags behind developed countries. The first step to be taken for this purpose is the development of technological infrastructure. It is considered that the study will fill the related gap in the literature since it has been carried out on a large sample and some demographic factors that are not generally included in the studies conducted in this regard have been included in the analysis.

This study has a few limitations, as almost any study would have. First of all, it should be noted that the data in this study is secondary data and the variables required for statistical analysis consist of variables that are available in the data set. Second, some variable effects such as household internet access, duration of internet use, ownership of electronic devices for online shopping by household members, and online shopping attitudes of parents, siblings, other individuals in the household or friends in the neighborhood could not be included in the analysis since they were not included in the data set. Moreover, since the data is cross-sectional, a definite causal relationship cannot be inferred between experiencing problems with online shopping and related socioeconomic factors. Another limitation is that the direct or indirect effects of the factors among themselves cannot be observed since no modeling is used in the analysis process. Due to these factors, the data obtained in this data collection method may be biased.

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Sürdürülebilir Ulaşım İle Lojistik Merkez Yer Seçimi

Logistics Center Location Selection with Sustainable Transportation

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Öz

Dünya ticaretinde rekabetin hızla artması ile daha sistemli ve hızlı taşımacılığa ihtiyaç duyulmaktadır. Yük taşımacılığında kilit rol oynayan lojistik merkezler, hızlı ve sistemli taşımacılığa cevap verebilmenin yanında sera gazı emisyon değerini azaltabilmekte, trafik tıkanıklığı ve çevre kirliliğini önleyerek çevreye daha duyarlı sürdürülebilir ulaşım sağlayabilmektedir. Bu çalışma ile yük taşımacılığında sürdürülebilir ulaşımı desteklemek amacıyla ulaşım modları arasında daha az sera gazı emisyon değeri olan demir yolu ve deniz yolu ulaşım modlarının ülkemizdeki lojistik merkezlerde daha aktif rol oynaması amaçlanmıştır. Bu bağlamda sürdürülebilir lojistiği sağlayarak lojistik merkez yer seçiminde optimum konumu bulmak için ülkemizde bulunan 51 adet demir yolu yük istasyonu ve 71 adet liman başkanlığının konumları Coğrafi Bilgi Sistemlerine aktarılarak alternatif iller elde edilmiştir. Lojistik alanında uzman kişilerin görüşleri ve literatür taraması doğrultusunda "Çevreye Duyarlılık", "Güvenilirlik" ve "Riskler" kriterleri belirlenmiştir. Her il için ilgili kurumlardan alınan verilere göre AHP tekniği yardımıyla alternatif iller sıralanarak lojistik merkez yer seçimi için en uygun konum bulunmuştur.

Anahtar Kelimeler: Sürdürülebilir Ulaşım, Sera Gazı, Lojistik Merkez, CBS, AHP

Abstract

With the rapid increase in competition in world trade, there is a need for more systematic and faster transportation. Logistics centers, which play a key role in freight transportation, can respond to fast and systematic transportation, as well as reduce greenhouse gas emissions, prevent traffic congestion and environmental pollution, and provide more environmentally friendly sustainable transportation. With this study, it is aimed to play a more active role in the logistics centers in our country, with the rail and sea transportation modes, which have less greenhouse gas emission value among the transportation modes, in order to support sustainable transportation in freight transportation. In this context, in order to find the optimum location in the logistics center location selection by providing sustainable logistics, the locations of 51 railway freight stations and 71 port authorities in our country were transferred to Geographic Information Systems and alternative provinces were obtained. In line with the opinions of experts in the field of logistics and literature review, "Environmental Sensitivity", "Reliability" and "Risks" criteria were determined. According to data obtained from the relevant institutions for each province, alternative provinces were ranked with the help of AHP technique and the most suitable location for logistics center location selection was found.

Keywords: Sustainable Transportation, Greenhouse Gas, Logistic Center, GIS, AHP

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1. GİRİŞ

Sürdürülebilir ulaşım sosyal, çevresel ve iklimsel etkiler bakımından sürdürülebilir olan ulaşımı ifade etmekte olup taşımacılık için kullanılan araçları içermektedir. Ulaştırma sistemlerine ait altyapı ve enerji kaynaklarını kapsayan sürdürülebilir ulaşım ile kısa vadede yakıt verimliliği, uzun vadede ise ulaşımın fosil temelli enerji kaynaklarından uzaklaşması hedeflenmektedir. Ulaşımın sürdürülebilirliği ulaşım sisteminin çevresel ve iklim etkileri ile değerlendirilmektedir (Vikipedi, 2022). Ulaşım ile doğrudan ilgili olan lojistik (Kalaycı, 2017) ise insanların ihtiyaçları olan ürünleri doğru yerde, doğru zamanda, doğru miktarda ve doğru şekilde karşılamak üzere her türlü servis hizmetinin ve bilgi akışının başlangıç noktasından son noktaya kadar etkili ve verimli bir biçimde planlanması, taşınması, depolanması ve kontrol altında tutulması olarak tanımlanmaktadır (Emrullah, 2020). Lojistik performans ülkelere rekabet açısından avantaj sağlayabilmekte, uluslararası ticareti arttırarak yeni pazarlara doğru genişlemeye izin vermekte ve işletmeleri teşvik etmektedir. Ulaşım, lojistik ve ticaretle ilgili altyapının verimsiz sistemleri bir ülkenin uluslararası ölçekte rekabet etme potansiyelini ciddi şekilde engellemektedir (Göçer, vd. 2022). Ulaşım altyapısı, ülkelerin ekonomik kalkınmasını etkilemekte olup etkin ve yüksek kalitede dizayn edilmiş bir ulaşım sistemi ile ekonomik büyüme sağlanacaktır (Choudhary, vd. 2007). Ulaşım altyapısının ekolojiye de etkisi bulunmakta olup Dünya Bankası tarafından yayınlanan rapora göre çevresel etkiler incelendiğinde ulaşımdan kaynaklanan karbon emisyonlarının gelişmekte olan ülkelerde gelişmiş ülkelere göre üç kat daha hızlı arttığı öngörülmektedir. Bu sebeple karbon emisyonlarının artışına bağlı sera gazlarının artması sürdürülebilir ulaşıma olan ilgiyi artırmıştır (Demirtürk, 2021). Sera gazı emisyon miktarı lojistik merkezler açısından değerlendirildiğinde lojistik merkezlerin sera gazı emisyonunu azalttığı bilinmektedir. Dündar (2021) yaptığı çalışmada lojistik merkezlerin sera gazına etkisini araştırmıştır. Yapılan bu çalışmaya göre lojistik merkezin olduğu illerde toplam sera gazı emisyon miktarı %65,69 iken lojistik merkez olmayan illerde sera gazı emisyon miktarı %78,43 olarak bulunmuştur. Bu oranlar ile lojistik merkezlerin de sera gazı emisyon miktarını azalttığı anlaşılmaktadır. Sera gazları arasında en fazla üretilen karbondioksit gazının (Erdoğan, 2020) sektörlere ve ulaştırma sistemlerine göre oranları sırasıyla Tablo 1 ve Tablo 2'de gösterilmektedir. Bu veriler TÜİK verileri dikkate alınarak hazırlanmıştır. 2015-2019 yılları arasında sektörlere ait karbondioksit oranları Tablo 1'de gösterilmektedir. 1995-2019 yılları arasında sektörlere ait karbondioksit oranları ise EK-1'de yer almaktadır (TÜİK, 2022).

Tablo 1. *Sektörlere Göre Karbondioksit Oranları*

Sektörler	**2015 (%)**	**2016 (%)**	**2017 (%)**	**2018 (%)**	**2019 (%)**
Tarım, ormancılık ve balıkçılık	3,39	3,33	3,36	3,36	3,75
Madencilik ve taş ocakçılığı	0,25	0,23	0,22	0,21	0,23
İmalat	40,46	40,23	39,22	38,92	37,49
Elektrik, gaz, buhar ve klima temini	44,26	44,44	45,64	46,51	46,83
Su temini; kanalizasyon, atık yönetimi ve iyileştirme faaliyetleri	0,11	0,12	0,11	0,11	0,11
Yapı	1,90	1,90	1,88	1,81	1,91
Taşımacılık ve depolama	9,62	9,75	9,58	9,08	9,68

Kaynak: TÜİK

Tablo 1'e göre tüm yıllarda ilk üç sırada sırasıyla elektrik, gaz, buhar ve klima temini, imalat ve taşımacılık ve depolama sektörleri yer almaktadır. Tablo 2'de 2010-2020 yılları arasında ulaştırma sistemlerine göre sera gazı oranları verilmektedir.

Tablo 2. *Ulaştırma Sistemlerine Göre Sera Gazı Oranı*

Yıllar	Hava Yolu (%)	Kara Yolu (%)	Demir Yolu (%)	Deniz Yolu (%)	Diğer (%)
2010	6,23	88,15	1,03	3,74	0,85
2011	6,99	86,42	1,02	4,79	0,78
2012	5,95	90,08	0,72	2,64	0,61
2013	5,47	91,32	0,67	1,72	0,82
2014	5,58	91,02	0,70	1,88	0,81
2015	5,58	91,43	0,58	1,53	0,87
2016	5,27	92,35	0,42	1,19	0,77
2017	4,58	92,77	0,45	1,16	1,04
2018	4,41	93,18	0,48	1,15	0,79
2019	4,32	93,00	0,45	1,52	0,72
2020	2,71	94,89	0,37	1,62	0,41

Kaynak: TÜİK

Tablo 2'ye göre tüm yıllarda kara yolunun sera gazı oranı en yüksektir. En düşük sera gazı oranına ise demir yolu taşımacılığı sahiptir. Kara yolu taşımacılığının karbondioksit oranının diğer ulaşım sistemlerine göre daha yüksek olması, bu ulaşım sisteminin daha yaygın kullanılması ve bu ulaşımda kullanılan araçların fosil yakıt kullanması ile ilgilidir. Bu durum sonucunda ise çevre ve insan sağlığını tehdit eden küresel ısınma ve iklim değişikliği gibi sorunlar meydana gelmektedir (Emrullah, 2020). Dünya genelinde taşımacılık sektöründe kullanılan petrol oranının %60 olması ve buna bağlı oluşan sera gazı çevreyle uyumlu taşımacılığın gerekliliğini ortaya çıkarmıştır (Mücevher, 2021). Bu çalışma ile yük taşımacılığında daha çevreci ulaştırma sistemi olan demir yolu ve deniz yolu taşımacılığın etkinliğini artırarak lojistik sektörüne ait sera gazı emisyon oranlarını azaltmak amaçlanmıştır. Bu kapsamda lojistik merkez yer seçimi için demir yolu ve deniz yolu bağlantısı olan iller Coğrafi Bilgi Sistemleri (CBS) ile seçilmiştir. Literatür taraması ve uzmanların bilgi ve deneyimlerinden faydalanılarak sürdürülebilir ulaşım amacıyla "Çevreye Duyarlılık", "Güvenilirlik" ve "Riskler" olarak belirlenen kriterlerin birbirine göre üstünlükleri, Türkiye'de üniversitelerin endüstri mühendisliği, inşaat mühendisliği, lojistik ve şehir ve bölge planlama bölümlerinde görev yapmakta olan akademisyenler, LODER üyeleri ve lojistik merkez yapımını üstlenen TCDD'nin ilgili biriminde çalışanlardan oluşan lojistik alanında uzman 9 kişinin görüşleri doğrultusunda belirlenmiştir. Alternatif iller, kriterlere ve bu kriterlere ait illerin ilgili kurumlardan alınan verilerine göre AHP tekniği yardımıyla sıralanarak lojistik merkez yer seçimi için en uygun konum bulunmuştur. Bu sayede sürdürülebilir ulaşım ile gelecek nesillere daha çevreci ulaşım sağlanacaktır.

2.YÖNTEM

Sürdürülebilir ulaşımı destekleyecek lojistik merkez yer seçim kriterlerini belirlemek üzere ilgili çalışmalar incelenmiştir. Bu çalışmada AHP yöntemi kullanıldığından literatür AHP yöntemi kullanılan çalışmalar ile sınırlandırılmıştır. Alternatif illerin belirlenmesinde Coğrafi Bilgi Sistemi yazılımından faydalanılmıştır.

2.1. Analitik Hiyerarşi Proses

Analitik Hiyerarşi Proses (AHP), genel bir ölçüm teorisi olup kriter ve alt kriterlerin ikili karşılaştırılmasına dayanarak birbirlerine göre üstünlüklerini belirleyen bir tekniktir. AHP yönteminde ilk olarak hiyerarşi oluşturulup, hiyerarşide amaç ortaya konarak kriterler, alt kriterler ve alternatifler belirlenmektedir. Tablo 3'te gösterilen önem skalasına göre her kriterin kendi arasında ikili karşılaştırılmasıyla, kriterlerin birbirlerine göre durumları bulunmaktadır. Daha sonra her bir kriterin bütün içerisindeki özvektör değeri hesaplanır ve tutarlılık oranı kontrol edilmektedir (Saaty, 1987).

Tablo 3. *Önem Skalası*

Önem Derecesi	Açıklama
1	Eşit derecede önemli
3	Orta derecede önemli
5	Kuvvetli derecede önemli
7	Çok kuvvetli derecede önemli
9	Aşırı derecede önemli
2,4,6,8	Ara değerler

2.2. Lojistik Merkez Yer Seçimi için Kriter Belirleme

Bu çalışmada lojistik merkez ile ilgili birçok çalışma incelenmiştir. Zheng vd. (2009), lojistik ağı için yaptıkları çalışmada belirledikleri ana ve alt kriterlerin önem ağırlıklarını AHP yöntemi ile bulmuşlardır. Dış koordinasyon, altyapı ve lojistik hizmet, ekonomik fayda, sürdürülebilirlik ve ilgili politikalar olarak beş ana kriter oluşturmuşlardır. Yang ve Meng (2016), yaptıkları çalışmada lojistik merkez konumunda en uygun yer için sosyal, ekonomi, teknik ve çevresel fayda olmak üzere dört kriter belirlemiştir. Bu kriterleri AHP tekniği ile sıralamıştır. Görçün (2018), yaptığı çalışmada hız, erişim, ücret, çevreye duyarlılık, güvenlik, hizmet sıklığı, aktarma olanakları, dakiklik ve konfor kriterlerini incelemiş ve AHP ile sıralamıştır. Grine vd. (2018), çalışmasında erişilebilirlik, politika, ekonomi, sosyal, teknolojik, çevresel ve yasal kriterlerini incelemiş ve AHP tekniğine göre sıralamıştır. Alberto (2000), yaptığı çalışmada çevresel yönler, maliyet, yaşam kalitesi, yerel teşvikler, müşterilere sağlanan zaman güvenilirliği, müşteri talebine yanıt esnekliği ve müşterilerle entegrasyon kriterlerini incelemiştir. Bu çalışmada 'Çevreye Duyarlılık', 'Güvenilirlik' ve 'Riskler' kriterleri ülkemizde sürdürülebilir ulaşımı güçlendirmek için lojistik merkez yer seçiminde belirlenmiştir. Kriterler, bu kriterlerin çalışmada değerlendirilmesi ve alındığı ilgili kurumlar aşağıda açıklanmıştır.

- Çevreye Duyarlılık: İllerde mevcut olan ulaşım sistemi ağı ve bu ulaşım sistemlerinin sera gazı emisyon değerleri ile bağlantı kurulması ile tanımlanmaktadır. TÜİK'ten alınan veriler doğrultusunda her bir alternatif il için, değerlendirilen alternatif ilin ihracat ve ithalat yaptığı ülkenin başkenti ile arasındaki mesafe (km), ihracat ve ithalat yaptığı yük miktarı ve bu yükün taşınması esnasında kullanılan ulaşım türüne göre sera gazı emisyon değeri parametreleri dikkate alınmıştır.

- Güvenilirlik: Kurulması planlanan lojistik merkezin gelecekte daha etkin kullanılmasının öngörülebilmesi amacıyla 2017 yılına ait illerin 'Sosyo-Ekonomik Gelişmişlik Sıralaması' kullanılmaktadır. Bu veri Devlet Planlama Teşkilatı'ndan alınmıştır.
- Riskler: İllere ait ortalama sıcaklık olarak belirlenmiştir. İklim bilgileri Çevre, Şehircilik ve İklim Değişikliği Bakanlığı'na bağlı Meteoroloji Müdürlüğü'nden alınmıştır.

2.3. Lojistik Merkez Yer Seçimi İçin Alternatif İl Belirleme

Modern lojistiğin önemli bir parçası olan demir yolu (Jianhua, 2001) ile tedarik zincirinin temel bileşeni ve uluslararası ticarette ve dağıtımda büyük role sahip olan liman (Notteboom, 2006) bağlantısı, ekonomik ve rekabetçi koşulların sağlanmasında stratejik bir unsurdur (Leal ve Pérez, 2012). Demir yolu bağlantısı sadece liman hinterlandının genişlemesini sağlamayıp ayrıca liman için yeni katma değerli yük ve hizmetlerin artmasına olanak sağlamaktadır. Bu durumda demir yolu, liman rekabet gücü için çok önemli olup erişebilirliği artırarak daha etkili ve güvenilir hizmet sunmakta veya insanlar üzerine daha az etkiye sahip limanların mekânsal gelişimini teşvik etmektedir (Leal ve Pérez, 2012). Demir yolu ve deniz yolu taşımacılıklarının birbirleri ile bağlantı kurması, rekabeti arttırarak ticareti geliştirmesinin yanında düşük sera gazı emisyonları ile ekolojinin korunmasına katkı sağlayacağı için bu çalışmada demir yolu ve deniz yolu (iç su yolu dahil) bağlantılı iller CBS ile lojistik merkez yer seçimi için belirlenmiştir. CBS, lojistik alanındaki birçok çalışmada kullanılmakta olup Alragheb'in yaptığı çalışmada CBS'nin lojistik merkezlerin hızlı ve objektif bir şekilde planlanması için uygun konumlar ürettiği tespit edilmiştir (Alragheb, 2021). Korkmaz çalışmasında lojistik alanında araç takibi, yönlendirmesi ve rotalama amaçlarıyla CBS'nin kullanımının ülkemizde gelişime açık olduğunu belirtmiştir (Korkmaz, 2004). İlişkileri, dokuları ve mekânsal dağılımları daha iyi analiz etmek, gözlemlemek ve anlamak için kullanılan bir bilgisayar sistemi olan Coğrafi Bilgi Sistemleri (Alragheb, 2021) bu çalışmada farklı ulaşım ağı sistemlerinin entegrasyonunun yapılabilmesi, ağ yapılarının birbiri ile entegre edilmesi (Özyağcı ve Oral, 2012) amacıyla kullanılmıştır. Bunun için Türkiye'de bulunan 51 adet demir yolu yük istasyonu ve 71 adet liman başkanlığının konumları Coğrafi Bilgi Sistemlerine aktarılarak hem demir yolu yük istasyonu hem de liman başkanlığı bulunan iller, lojistik merkez yer seçimi için alternatif il olarak belirlenmiştir.

3. BULGULAR

Çalışmanın bu kısmında lojistik alanında uzman kişilerin görüşleri dikkate alınarak kriterlerin önem ağırlıkları ve alternatif illerin kurumlardan alınan ilgili verileri doğrultusunda sürdürülebilir ulaşım için lojistik merkezi yer seçimi sonuçları AHP yöntemi ile elde edilmiştir.

3.1. Lojistik Merkez İçin Kriterlerin Önem Ağırlıkları

Tablo 4'te AHP yöntemine göre kriterlerin önem ağırlıkları gösterilmektedir.

Tablo 4. *Kriterlerin Önem Ağırlıkları*

Kriterler	Kriter Sıralaması
Çevreye Duyarlılık	0,661198524
Güvenilirlik	0,271775783
Riskler	0,067025694

3.2. Lojistik Merkez İçin Alternatif İller

Demir yolu yük istasyonu ve liman başkanlığı bulunan illerden her iki bağlantıya da sahip iller Şekil 1'de sarı renk ile gösterilmektedir.

Şekil 1*. Demir Yolu Yük İstasyonu ve Liman Başkanlıkları Bağlantılı İller*

Şekil 1'e göre ülkemizde demir yolu yük istasyonu ve liman başkanlıkları bulunan iller, Adana, Balıkesir, Bitlis, Bursa, Edirne, Elâzığ, Hatay, İstanbul, İzmir, Kırklareli, Kocaeli, Mersin, Sakarya, Samsun, Tekirdağ ve Zonguldak olmak üzere CBS'den elde edilmiştir. Bu illerin belirlenen kriterlere göre gerekli verileri ilgili kurumlardan alınmıştır ve bu iller, elde edilen veriler doğrultusunda AHP tekniği ile Super Decision programı kullanılarak sıralanmıştır. Bu sıralama ise Tablo 5.'te gösterilmektedir.

_Tablo 5.__Lojistik Merkez Yer Seçimi İçin Alternatif İllerin Sıralaması_

Sıra	İller	Önem Ağırlığı	Sıra	İller	Önem Ağırlığı
1	İstanbul	0,19697	9	Adana	0,04689
2	Kocaeli	0,101185	10	Samsun	0,045145
3	İzmir	0,08135	11	Sakarya	0,039677
4	Hatay	0,081086	12	Balıkesir	0,037654
5	Bursa	0,076515	13	Kırklareli	0,035999
6	Mersin	0,069665	14	Edirne	0,030346
7	Tekirdağ	0,062983	15	Elâzığ	0,019546
8	Zonguldak	0,06247	16	Bitlis	0,012521

4. TARTIŞMA VE SONUÇ

Ülkemizin bulunduğu stratejik konum ile uluslararası ticarette büyük potansiyele sahiptir. Türkiye'nin bölgede lojistik üs olması gerekli ulaşım yatırımları, doğru plan ve projeler ile ilgilidir. Dış ticarette büyük öneme sahip lojistik hizmetlerde yaşanabilecek bir günlük gecikme ticaret hacmini %1 oranında azaltmakta olup tarım sektöründe ihracat oranında ise %7 oranı kadar azaltmaya sebep olabilmektedir (Emrullah, 2020). Bu sebeple lojistik sektörünün bir bütün olarak sistemli çalışması gerekmektedir. Bu çalışmada hem sera gazı emisyon değeri bakımından kara yoluna göre daha çevreci hem de uluslararası ticarette büyük paya sahip olan deniz yolu ve demir yolu ulaşımları kullanılarak belirlenen kriterler doğrultusunda lojistik merkez için yer seçimi yapılmıştır. Sürdürülebilir ulaşım için demir yolu ve deniz yolu bağlantılı alternatif iller, CBS ile bulunup lojistik merkez yer seçimi için belirlenen kriterler doğrultusunda AHP yardımı ile sıralanmıştır. Bu sıralamaya göre lojistik merkez için en uygun ilk 5 il; İstanbul, Kocaeli, İzmir, Hatay ve Bursa olarak bulunmuştur. Bu iller arasında İstanbul Halkalı'da 2013 yılında ve Kocaeli Köseköy'de 2010 yılında lojistik merkezler işletime açılmıştır. Ayrıca İstanbul Avrupa Yakası'nda proje aşamasında lojistik merkez mevcuttur. Diğer illerde herhangi bir işletime açılmış veya yapım aşamasında lojistik merkez projesi mevcut değildir (TCDD, 2020). Bu durumda bu çalışmaya göre demir yolu ve deniz yolunun daha aktif kullanılabileceği bir lojistik merkez için ilk olarak İzmir, Hatay ve Bursa illerinden birinin tercih edilmesi ile sürdürülebilir ulaşım ve buna bağlı Türkiye'nin sera gazı emisyonu azaltım politikaları desteklenecektir. Bu politikalara göre kara yolu taşımacılığının payını azaltmak, deniz yolu ve demir yolu taşımacılığı payını artırmak, kentsel alanlarda sürdürülebilir ulaşım yaklaşımlarını uygulamak hedeflenmiştir. Ulusal İklim Değişikliği Eylem Planı (2011-2023), demiryollarının yük payını %15'e çıkarmak, deniz yollarının kabotaj yük taşımacılığındaki payını %10'a yükseltmek, 2023 itibariyle kara yolu yük taşımacılığındaki payı %60'ın altına düşürmek, şehirlerde sürdürülebilir ulaştırma planlamasının uygulanması için 2023 sonuna kadar gerekli mevzuat, kurumsal yapı ve rehberlik belgelerinin geliştirilmesi sera gazı emisyonunu azaltacak birkaç hedef ve politikayı içermektedir (ÇSB, 2018). Bu çalışma ile kurulması önerilen lojistik merkez sayesinde ulaşımda sera gazını azaltan sürdürülebilir ulaşım politikaları desteklenerek ülke ekonomisine katkı sağlanacaktır.

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EK-1

Aşağıdaki tabloda 1995-2019 yılları arasında sektörlere ait karbondioksit oranı verilmektedir. Tarım, ormancılık ve balıkçılık 1, madencilik ve taş ocakçılığı 2, imalat 3, elektrik, gaz, buhar ve klima temini 4, su temini; kanalizasyon, atık yönetimi ve iyileştirme faaliyetleri 5, yapı 6 ve taşımacılık ve depolama 7 rakamı ile gösterilmektedir.

Yıllar	**Sektörler**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
1995	5,93	0,54	46,88	34,78	0,24	3,01	8,63
1996	5,62	0,66	47,83	33,58	0,28	3,87	8,16
1997	5,39	0,74	47,21	34,47	0,31	4,44	7,45
1998	5,26	0,73	45,49	36,79	0,30	4,46	6,98
1999	5,57	0,57	42,29	40,79	0,24	3,34	7,19
2000	5,12	0,70	42,19	40,66	0,28	4,26	6,78
2001	5,16	0,46	40,04	44,22	0,20	2,59	7,33
2002	5,07	0,67	43,63	39,64	0,27	3,99	6,74
2003	4,86	0,80	45,28	37,16	0,32	4,92	6,66
2004	5,12	0,67	45,15	36,76	0,27	4,03	8,01
2005	4,75	0,60	42,64	40,94	0,24	3,59	7,23
2006	4,70	0,69	42,47	40,44	0,27	4,18	7,25
2007	4,58	0,71	39,29	43,23	0,28	4,31	7,59
2008	5,86	0,39	35,33	47,10	0,15	2,69	8,50
2009	5,76	0,41	34,74	47,59	0,15	2,84	8,50
2010	5,63	0,39	38,97	44,67	0,14	2,69	7,50
2011	6,01	0,27	38,64	45,62	0,11	1,92	7,43
2012	1,42	0,34	41,70	45,05	0,13	2,42	8,94
2013	1,31	0,38	42,98	45,08	0,15	2,65	7,45
2014	1,47	0,27	40,33	46,06	0,12	2,07	9,67
2015	3,39	0,25	40,46	44,26	0,11	1,90	9,62
2016	3,33	0,23	40,23	44,44	0,12	1,90	9,75
2017	3,36	0,22	39,22	45,64	0,11	1,88	9,58
2018	3,36	0,21	38,92	46,51	0,11	1,81	9,08
2019	3,75	0,23	37,49	46,83	0,11	1,91	9,68

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ARAŞTIRMA MAKALESİ/ **RESEARCH ARTICLE**

Greenhouse Gas Emission And Their Trend Prediction Using AIS and Trade Data

AIS ve Ticaret Verileri Kullanılarak Sera Gazı Emisyonu ve Eğilim Tahmini

Thuta Kyaw WIN[1] **Daisuke WATANABE**[2] **Shigeki TORIUMI**[3]

ABSTRACT

Due to decarbonization and greenhouse gas (GHG) emission reduction attempts nowadays, liquefied natural gas (LNG) has become widely used as an alternative marine fuel. As Japan is the top global LNG importer and one of the largest crude oil importers, this study focuses on LNG and tanker shipping and their emissions in Japan, and import volumes. In this study, the emission estimation model is constructed based on the Holtrop-Mennen power prediction method. Using automatic identification system (AIS) data, fuel consumption and GHG emissions are estimated. Next, long term GHG emission is predicted using the Japan trade statistics. Combining the vessel movement data and trade statistics, GHG emission in Japan is projected to decline over years for tankers, and to remain stable for LNG carriers. The results could be considered in formulating environmental and trade policy. It is hoped the study will provide useful insights for zero emission projects and implementations in Japan.

Keywords: Automatic identification system, ship emission, greenhouse gases, LNG, Japan.

ÖZ

Günümüzde karbonsuzlaştırma ve sera gazı (GHG) emisyonlarını azaltma girişimleri nedeniyle sıvılaştırılmış doğal gaz (LNG) alternatif bir denizcilik yakıtı olarak yaygın bir şekilde kullanılmaya başlanmıştır. Japonya en büyük küresel LNG ithalatçısı ve en büyük ham petrol ithalatçılarından biri olduğundan, bu çalışma LNG ve tanker taşımacılığı ile bunların Japonya'daki emisyonlarına ve ithalat hacimlerine odaklanmaktadır. Bu çalışmada, emisyon tahmin modeli Holtrop-Mennen güç tahmin yöntemine dayalı olarak oluşturulmuştur. Otomatik tanımlama sistemi (AIS) verileri kullanılarak yakıt tüketimi ve sera gazı emisyonları tahmin edilmiştir. Daha sonra, Japonya ticaret istatistikleri kullanılarak uzun vadeli sera gazı emisyonu tahmin edilmiştir. Gemi hareket verileri ve ticaret istatistikleri birleştirildiğinde, Japonya'daki sera gazı emisyonunun tankerler için yıllar içinde azalacağı ve LNG taşıyıcıları için sabit kalacağı öngörülmektedir. Sonuçlar çevre ve ticaret politikalarının oluşturulmasında dikkate alınabilir. Çalışmanın Japonya'daki sıfır emisyon projeleri ve uygulamaları için faydalı bilgiler sağlayacağı umulmaktadır.

Anahtar Kelimeler: Otomatik tanımlama sistemi, gemi emisyonu, sera gazları, LNG, Japonya.

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1. INTRODUCTION

Transportation including all modes as well as passenger and freight is the second largest CO2 emitter, which accounts for 24% of the world CO2 emissions (International Energy Agency [IEA], 2017). International shipping accounts for 2.89% of the global CO2 emissions in 2018 (International Maritime Organization [IMO], 2021). While shipping is the most efficient and eco-friendly modes of transport in terms of emissions per cargo carried and distance travelled, carbon and greenhouse gas (GHG) emissions are also expected to rise from international shipping (Benamara et al, 2019).

In 2018, IMO adopted the initial strategy on GHG emission reduction from ships. The strategy set the target to reduce the current GHG emissions by at least 40% by 2030, 50% by 2050, and to phase out GHG by the end of the 21st century. UNCTAD (2021) assessed that the global shipping fleet has become more energy efficient although GHG emissions continue to increase (United Nations Conference on Trade and Development).

To achieve the 2050 target and beyond, one of the pathways to GHG reduction will be the use of alternative fuels. Among them, liquefied natural gas (LNG) fuel is one of the options. The (MLIT) assumed that LNG fuels will continue to be the trend to emission pathways (MLIT, 2020) although LNG is not as effective as other alternatives such as hydrogen and ammonia. The IMO report (2020) showed that the LNG market sector will continue to grow. Therefore, this study primarily focuses on LNG shipping and their emissions.

A report by IGU showed that Japan is the top LNG importer, importing 74.43 MT which accounts for 21% of the global LNG market (International Gas Union [IGU], 2021). LNG trade in the Asian market is projected to increase (IEA, 2019). As LNG is already practically applied as alternative marine fuels and as energy use, LNG import to Japan is expected to increase. In addition to LNG, Japan is one of the largest crude oil importing countries. Therefore, it is important to note and keep track of the import volumes and vessels in Japan waters and their GHG emissions. Hence, the Japan coastal region is chosen as a study domain.

In this study, the authors would like to focus on emission status and the relation to crue oil and LNG trade in the Japan coastal region. We hope that the study will offer new insights and considerations in terms of environmental regulations and marine traffic policies to protect the local environment and society.

2. Background on Automatic Identification System (AIS)

Ships of over 300 gross tonnage engaged in international voyages and cargo vessels of over 500 gross tonnage not engaged in international voyages are required to equip Class A AIS by IMO (2002). The purpose of AIS is to enhance safety of life at sea, safety and efficiency of navigation, and protection of the marine environment. Initially intended as a collision avoidance system for vessel identification, target tracking, and information exchange for situational awareness, it is designed for ships to automatically transmit vessel information to ships in vicinity and reporting to maritime authorities.

Nowadays, AIS data provide valuable resources to authorities, academia and industry. AIS data are extensively applied in the following fields: maritime surveillance, environmental sustainability, energy efficiency, speed optimization, route planning and predictive analysis in ship performance and trajectory prediction. Munim et. al. (2020) noted that AIS data applied to investigate a wide range of research topics will contribute to big data and AI research domain in the maritime industry.

In terms of emission study using AIS data, Yao et al (2016) studied ship emission inventories from terrestrial AIS in the Yangtze River estuary. Li et al (2016) investigated uncertainties in ship emission inventory in the Pearl River Delta region. Kim et al (2021) estimated the global LNG fleet emission inventory spatially. Woo and Im (2021) studied the gas emission inventory in Busan by bottom-up approach. Wang et al (2021) conducted the prediction on CO2 emissions by long short-term memory (LSTM). In this study, ship emission estimation will be calculated based on the Holtrop-Mennen power prediction model by using satellite AIS data.

As AIS data are movement data and do not contain cargo information, studies using AIS data focus on emission estimations from marine traffic. However, trade volumes can be estimated from AIS data. Yan et al (2020) analyzed the global marine oil trade based on AIS data. Applying AIS data, the study analyzed the traffic route, trade volume and trade network. Van der Loeff et al (2018) discussed the approach for commodity volume estimation from AIS data by linking cargo composition data, vessel journeys and specifications and vessel emissions from a bottom-up methodology. Trimmer and Godar (2019) suggested a study approach to carbon emissions and air pollution to commodity shipment and allocated emissions to commodities.

3. DATA AND STUDY AREA

3.1. Brief Data Description

The AIS data used in this study were provided by exactEarth. The data are collected via satellites by the company so the data can be obtained throughout the oceans regardless of the vessel position and the weather conditions.The reported data consist of maritime mobile service identity number (MMSI), IMO number, vessel name, callsign, vessel type, vessel type cargo, vessel class, length, width, flag country, destination, estimated time of arrival (ETA), draught, longitude, latitude, speed over ground (SOG) in knots, course over ground (COG), rate of turn (ROT), heading, navigation status, timestamp of the last position and static AIS message, date and time of the last position and static AIS message, main vessel type and sub vessel type. The data were provided in the comma-separated values (csv) format. Each data point is reported in Greenwich Mean Time (GMT).

The data were collected worldwide for 6 months from 2016-01-01 UTC to 2016-06-30 UTC (Universal Time Coordinated). However, not all vessel types and ships were covered by exactEarth satellites as the obtained dataset includes only the following types: oil and chemical tankers, gas tankers, other tankers, tugboats, general cargo ships, offshore vessels, specialized cargo ships, bulk carriers, ro-ro cargo ships, passenger ships, container ships, and others. This dataset extensively focuses on tankers accounting for 98.6%, under which crude oil tankers, oil product tankers, chemical tankers and LNG carriers are sub-categorized.

The trade data used in this study were obtained from the mineral resources and petroleum products statistics report of the Ministry of Economy, Trade and Industry of Japan (METI). The report provides crude oil, petroleum and LNG import and export statistics on a monthly basis and by area and country. In addition to imports and exports, the report consists of the product stock changes, processing and inventory, product value and their trade terms. In this study, monthly import volumes were extracted from import and export section of each products, and they were matched to the vessel types in the AIS data.

3.2. Study Area

In this study, the Japan coastal area is chosen as the main study domain since the authors are mainly interested in estimating GHG emissions in Japan. The United Nations Convention on the Law of the Sea (UNCLOS) Part 2 of "Territorial Sea and Contiguous Zone", in Section 2 "Limits of the Territorial Sea", Article 3 "Breadth of the territorial sea", states that every state has the right to establish the breadth of its territorial sea up to a limit not exceeding 12 nautical miles, measured from baselines determined in accordance with this Convention. Therefore, 12 nautical mile buffers are created along the Japan coastlines and AIS data for 6 months in the buffer zone are selected for analysis.

4. CALCULATING GHG EMISSIONS

4.2. Data Preparation

Before calculation is proceeded, AIS data need to be verified and made reliable. Bereta et al (2021) pointed out technical issues could exist in AIS data: absence of ship identification, human error inputs, reporting frequency, sensor malfunction, and timestamping. Therefore, data processing is mandatory. First, missing ship information in AIS data are either rejected or verified through public vessel tracking services. Then, unusual high speeds are checked, and the vessel positions are confirmed not to be over land. For the next step, transmission timestamp and their intervals are checked as they are not uniform. The data gap was addressed by Goldsworthy (2016) in the spatial-temporal distribution of the ship emission prediction problem. Finally, data are made sure to achieve voyage by voyage emission calculation so that calculations of each vessel voyage do not overlap other voyages. As this study intends to focus on tanker vessel types, only such vessels are filtered in the final dataset. The number of vessels used in the study after buffering is described in the following table.

Table 1. *Number of vessels in the dataset*

Vessel type	Number of vessels (before processing)	Number of vessels (after processing)
Oil and chemical tanker	6974	195
Gas tanker	1318	150
Tug	29	
Other tanker	28	1
General cargo ship	23	
Offshore vessel	16	
Specialized cargo ship	5	
Bulk carrier	24	
Ro-Ro cargo ship	11	
Passenger ship	4	
Container ship	5	
Others	2	
Total	8439	346

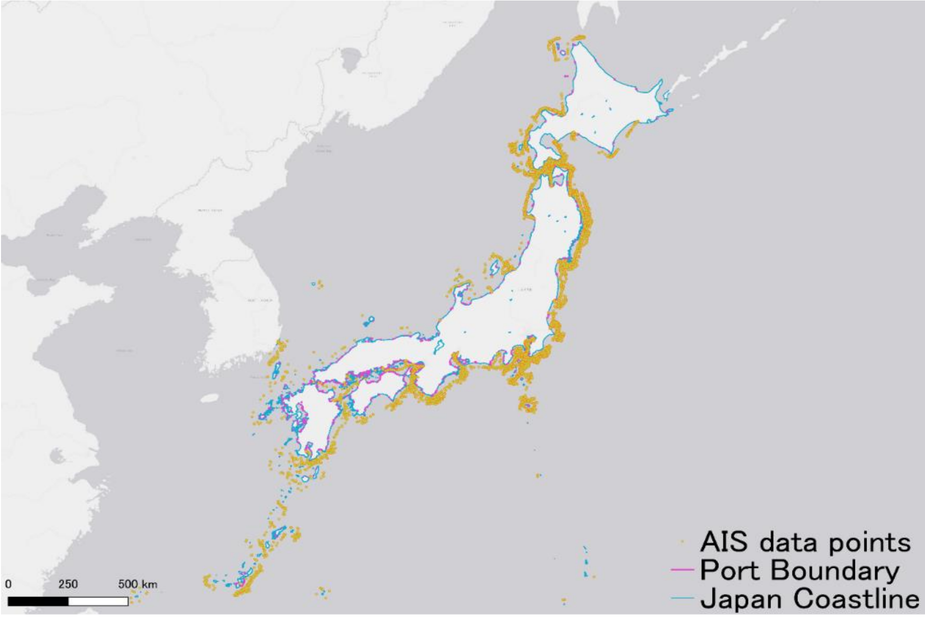

***Fig 1**. Study domain and AIS data points*

4.3. Vessel Emission Estimation Model

Once data processing is completed, the vessel emission estimation model will be calculated using ship dimensions, ship resistance, predicted power and assumed parameters. The model is based on International Towing Tank Conference (ITTC) recommended procedures and the approximate power prediction method (Holtrop and Mennen, 1982). The Holtrop-Mennen method is the numerical prediction of propulsive power at the design stage of a ship based on ship dimensions. Holtrop (1984) again re-analyzed resistance and propulsion data, calculated using dimensions and other parameters. The vessel emission estimation method is summarized in Figure 2.

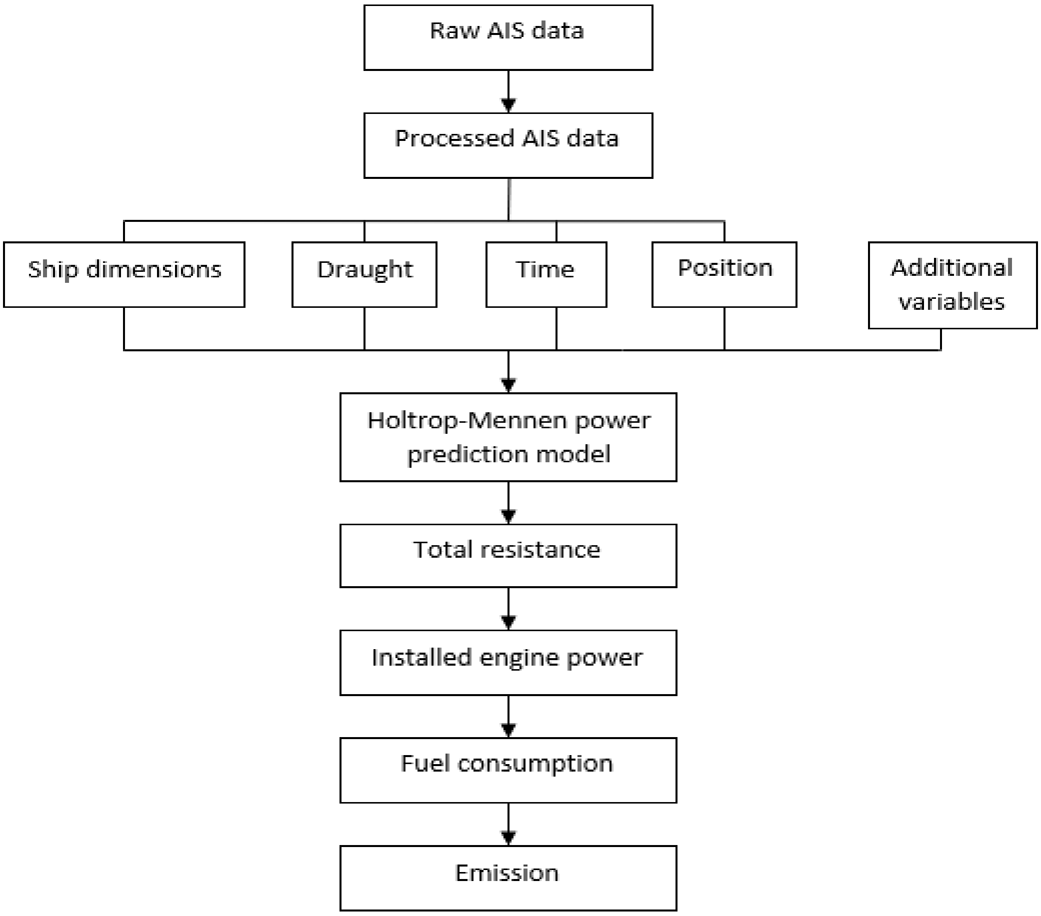

***Fig 2**. Flowchart of vessel emission estimation model*

As AIS data contain length, breadth, and draught, necessary length calculations are carried out first. MAN Diesel & Turbo (2011) assumed average conversions to length of the waterline (LWL) and length between perpendiculars (LPP) from length overall (LOA) which are lengths recorded in AIS data.

$$LPP = LWL * 0.97 = LOA * (0.97)^2 \quad (1)$$

The displacement (▽) of each vessel can be derived from the following formula.

$$\nabla = C_B * LPP * breadth * draught \quad (2)$$

Approximate block coefficients (CB) of tanker vessels by MAN Diesel & Turbo (2011) range from 0.80-0.85 with average speed of 12-16 knots.

ITTC recommends calculating total resistance of a ship as

$$R_T = 0.5 * C_T * \rho * S * V^2 \quad (3)$$

Where RT represents total resistance, CT for total resistance coefficient, ρ for seawater density, S for wetted surface, V for ship speed.

MAN Diesel & Turbo (2011) assumed residual resistance coefficient to be neglected in the calculations so the equation can be rewritten as

$$C_T = C_F + C_A + C_{AA} + C_R \cong C_F + C_A + C_{AA} \quad (4)$$

Where CF = frictional resistance coefficient, CA = incremental resistance coefficient, CAA = air resistance coefficient, CR = residual resistance coefficient.

An approximate wetted surface estimation is given as follows (Kristensen and Lützen, 2013). Wetted surface calculation can be different depending on ship type as there are different formulations suited to each type of vessel.

$$S = 1.025 * \left(\frac{\nabla}{\text{draught}} + 1.7 * LPP * draught \right) \tag{5}$$

CF can be calculated as follows.

$$C_F = \frac{0.075}{(logR_n - 2)^2} \tag{6}$$

CF and CA can be derived from the following equations.

$$C_A = \frac{0.5 * log(\nabla) - 0.1 * \left(log(\nabla)\right)^2}{1000} \tag{7}$$

Harvald (1983) advised the resistance value will be too low for large ships with displacement more than 160000 T if the above equation is used. In such cases, it is advised to apply the following formula.

$$C_A = Maximum\left(-0.1; \left(0.5 * log(\nabla) - 0.1 * \left(log(\nabla)\right)^2\right)/1000\right) \tag{8}$$

CAA is assumed as follows

***Table 2**. Air resistance coefficients*

Ship Types	CAA
Small, Handysize, Handymax tankers	0.00007
Panamax, Aframax, Suezmax tankers	0.00005
VLCC	0.00004

Source: Kristensen and Lützen (2013)

Reynolds number can be calculated in the following equation, where ν stands for kinematic viscosity of seawater. Kinematic viscosity of seawater can be derived from a study on thermophysical properties of seawater by Nayar et al (2016).

$$R_n = \frac{V * LWL}{\nu} \tag{9}$$

Once total resistance is known, power can be predicted in the below equation (Kristensen and Lützen, 2013). This required power is calculated with vessel's total resistance, sailing at the speed V at calm sea conditions.

$$P = R_T * V * \left(1 + \frac{sea\ allowance}{100}\right) \tag{10}$$

Harvald (1983) suggested sea allowance in power prediction. Sea margin (m), also known as sea allowance, refers to allowances on installed power for roughness, fouling and weather. Depending on ship sizes and hull forms, sea allowance will be different. Small ships will have higher sea allowance while slender hulls will have less service allowance. The suggested sea allowances dependent on shipping routes suggested by Harvald (1983) are taken as approximate parameters in the calculation.

Table 3. *Sea allowance of major shipping routes*

Routes	Sea allowance
North Atlantic, route, westbound	25 – 35 %
North Atlantic, eastbound	20 – 25 %
Europe – Australia	20 – 25 %
Europe - Eastern Asia	20 – 25 %
The Pacific routes	20 – 30 %

Source: Kristensen and Lützen (2013)

Considering resistance, ship speed, sea margin, transmission power (ηD) and quasi-propulsion coefficient (ηT), the installed engine power can be calculated using the following equation (Molland et al, 2011).

$$P_E = \frac{R_T * V}{\eta_D * \eta_T} + m \tag{11}$$

Once estimated power is known, fuel consumption of each vessel can be calculated. Specific fuel oil consumption (SFOC) depends on each ship type as well as marine engines installed onboard. MAN Diesel & Turbo (2011) calculated SFOC for various types of vessels. In this study, only LNG carriers and tankers will be used.

***Table 4**. SFOC by ship type*

Ship type	SFOC in g/kWh
LNG carrier	215
Tanker	210

Source: MAN Diesel & Turbo (2011)

In determining SFOC, engine age also plays a key role. SFOC baselines are proposed for slow/medium/high speed marine diesel engines as shown in the below table.

Table 5. *SFOC by engine age and type*

Engine age	SSD	MSD	HSD
Before 1983	205	215	225
1984-2000	185	195	205
Post 2001	175	185	195

Source: IMO GHG Study Report (2021)

Fuel consumption is given by the following equation, where SFOC is in g/kWh and time difference in hours (ΔT)

$$Fuel\ consumption\ (FC) = P_E * SFOC * \Delta T \tag{12}$$

Vessel emission value can be derived from emission factors of each pollutant.

$$Emission = Emission\ factor * FC \tag{13}$$

Depending on fuel types, the emission factor of the pollutant will vary and their values were introduced in IMO GHG Reports (2014 and 2021).

Table 6. *Emission factors*

Pollutant	Emission Factor (g/g fuel)
Carbon dioxide (CO2)	3.114
Nitrogen oxides (NOX)	0.0903
Sulphur oxides (SOX)	0.025
Particulate matter (PM)	0.00728
Carbon monoxide (CO)	0.00277
Methane (CH4)	0.00006
Nitrous oxide (N2O)	0.00015
Non-methane volatile organic compounds (NMVOC)	0.00308

Source: IMO GHG Reports (2014).

5. RESULTS

5.2. Fuel Consumption and GHG Emissions

Based on the AIS data and the power prediction method, fuel consumption and GHG emissions in the Japan coastal waters for the first six months of 2016 can be calculated. Fuel consumption is calculated to be 150,041.02 tons.

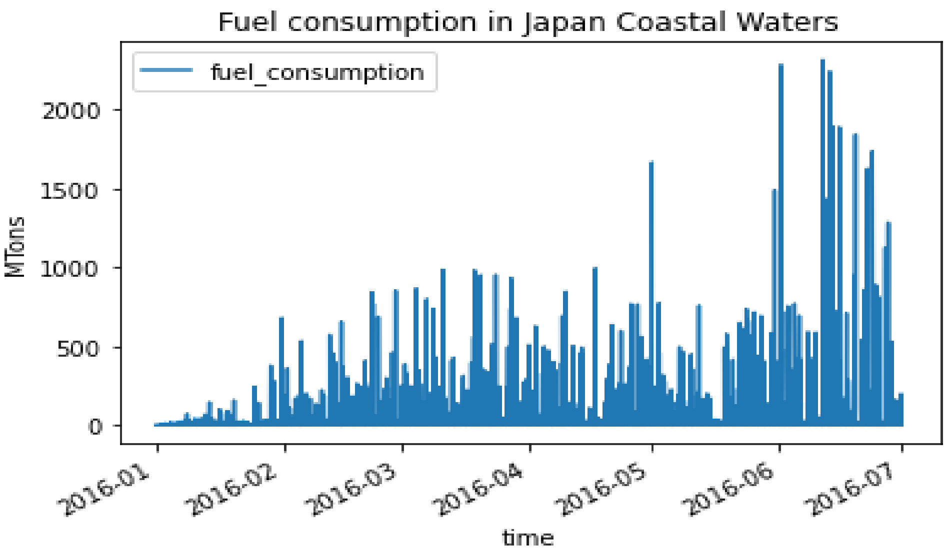

Fig 3. *Daily fuel consumption in Japan coastal waters*

Using the emission factors of each pollutant, the emission inventory can be estimated. The calculated results are shown in the following table and their daily amounts in the below figure. In the emission inventory, CO2 pollutes the most, 96% of the total emission.

Table 7. *Emission inventory for 6 months*

Emission Pollutant	Amount (metric tons)
CO2	467,227.76
NOx	13,548.70
SOx	3,751.02
PM	1,092.29
CO	415.61
CH4	9.00
N2O	22.50
NMVOC	462.12

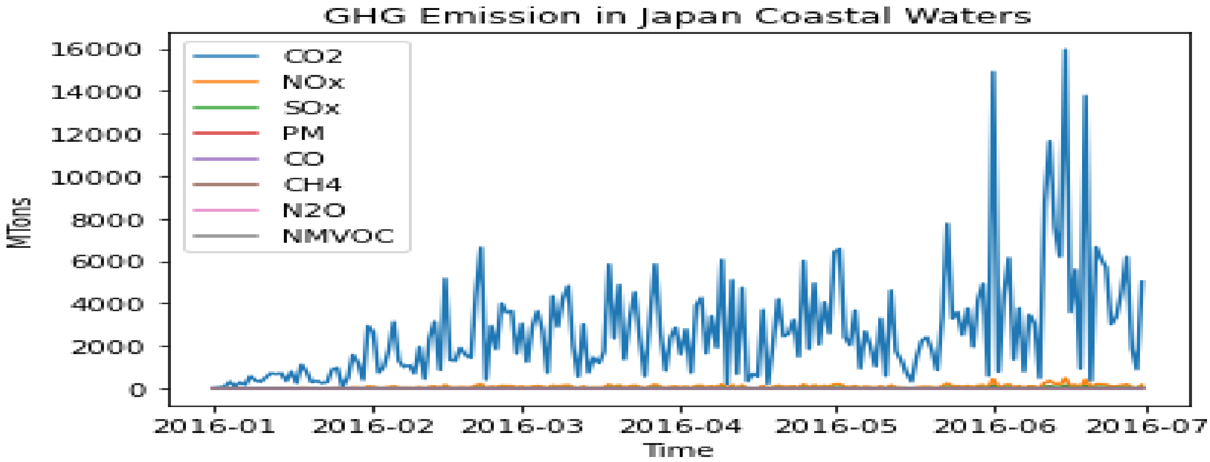

Fig 4. *Daily emissions in Japan coastal waters*

5.3. Long Term GHG Emission Prediction

The Ministry of Economy, Trade and Industry of Japan (METI) compiles the trade statistics of monthly LNG, crude oil and fuel products import amount. The mode of transport to import energy sources such as fuel, oil and LNG is via tanker ships. In addition, 32 LNG receiving terminals (19% of the global share) are in Japan (IGU, 2021). Therefore, energy import volumes and ship emission volumes are important factors to consider for long term prediction. The prediction can be applied in policy making for energy resource import and environmental protection.

Referring to the 2016 METI statistics from January to June, total LNG import is 38,543,894 tons and the average is 6,423,982 tons a month. For fuel and oil products, the import volume is 15,184,603 kiloliters (kl), averaging 2,530,767 kl per month.

Table 8. *Monthly imports and emissions (2016 January to 2016 Jun)*

Import		Emission							
Oil & fuel	LNG	CO2	NOx	SOx	PM	CO	CH4	N2O	NMVOC
kl	MTon	MTon							
3419728	6571013	17469.38	506.5784	140.2487	40.84043	15.53956	0.336597	0.841492	17.27864
2595435	7022133	62450.04	1810.931	501.3651	145.9975	55.55125	1.203276	3.008191	61.76818
2324958	7830571	83793.52	2429.851	672.7161	195.8949	74.53695	1.614519	4.036297	82.87863
2474860	6113092	76471.08	2217.514	613.9296	178.7763	68.0234	1.473431	3.683578	75.63613
2430470	5337500	79509.95	2305.635	638.3265	185.8807	70.72658	1.531984	3.829959	78.64183
1939152	5669585	147533.8	4278.196	1184.44	344.9088	131.2359	2.842655	7.106637	145.923

Referring to Table 8 and Figure 3, import volumes tend to decrease in June 2016 whereas emission volumes tend to be higher than previous months. Ship emissions tend to increase steadily from January 2016 and remain mostly stable from March to May 2016.

Using the METI statistics, vessel GHG emission results and vessel arrivals in Japan, long term GHG emission is predicted. The trend shows that energy resources are imported in high quantities in the beginning and ending of each year and start decreasing around March every year. However, LNG imports drop sharply from March 2020 to 4224784 tons in May 2020 while the average per month is 6276284.667 tons. This is illustrated in Figure 5.

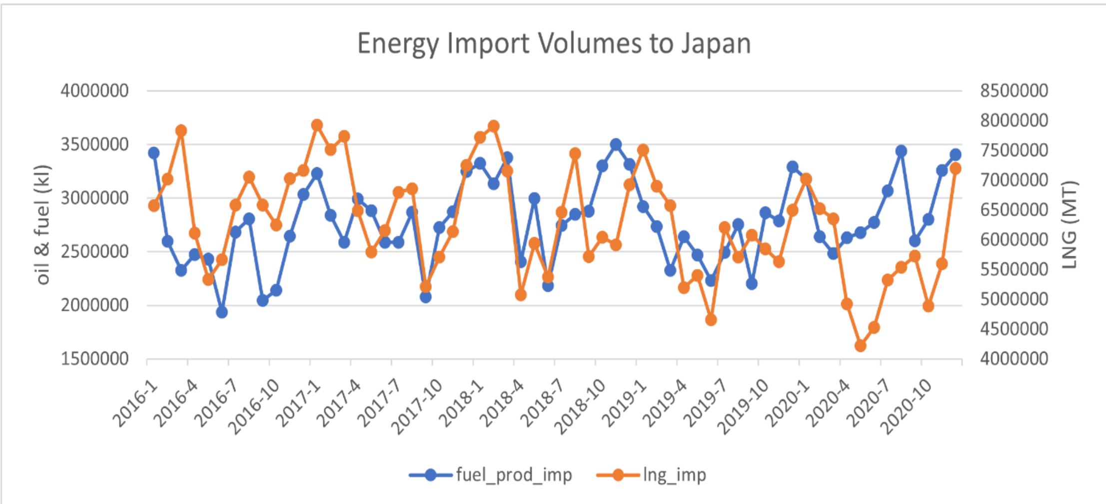

Fig 5. *Energy import to Japan (2016 ~ 2020).*
Source: *METI.*

In addition to trade statistics from the Japan METI agency, UN Comtrade database is also used. The database aggregates global trade statistics annually and monthly by product and trading partner. Among the UN Comtrade databases, the AIS-based database is applied in this study. It estimates the global seaborne trade in real time by collecting AIS data. The data is updated on a weekly basis. The trade data derived from AIS data include the number of port calls, metric tons of cargo, deadweight tonnage by specifying the reporting country, vessel type, trade flows: import or export, and the period.

In order to predict GHG emissions from LNG carriers and tankers in Japan coastal waters, fuel consumption is estimated first by the following variables: fuel oil and products import volumes, LNG import volumes, port calls, and deadweight tonnage from the dataset. The number of port calls and deadweight tonnage derived from the Comtrade database and those derived from the exactEarth AIS dataset are compiled and checked on the differing values. Port calls refer to the number of times a vessel calls at a port to carry out cargo loading and discharging operations. Deadweight tonnage refers to a vessel's weight carrying capacity, not including the empty weight of the ship. Then emission factors are applied to predict the total emission volumes for each type of vessel separately as in the equation (13).

$$Fuel\ consumption\ LNG = \alpha_1 * LNG\ import + \alpha_2 * port\ call + \alpha_3 * deadweight \quad (14)$$

$$Fuel\ consumption\ tanker = \beta_1 * \text{oil import} + \beta_2 * \text{port call} + \beta_3 * \text{deadweight} \quad (15)$$

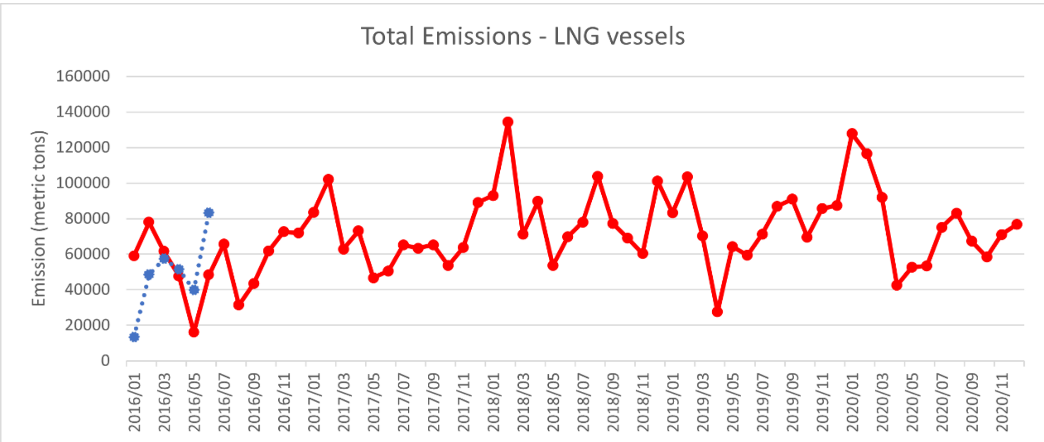

Fig 6. *Projected emissions from LNG carriers*

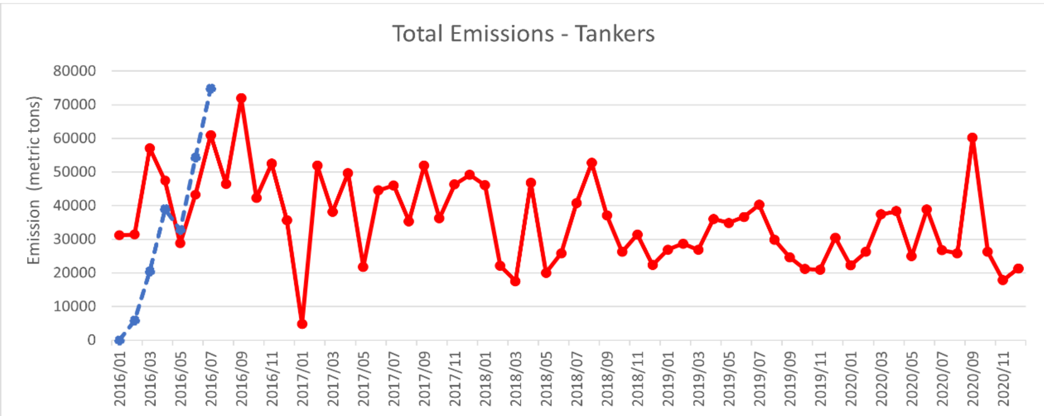

Fig 7. *Projected emissions from tankers*

In Figures 6 and 7, the blue line represents the estimated emissions from the AIS data for six months while the red line represents projected emissions based on the METI trade statistics and UN Comtrade database. In this study, estimations were made to compare emission volumes for 6 months and long term predictions based on the trend of 6 months were carried out. The 6-month comparison result discovered that high differences occur in the first month of study, where emissions estimated from trade data were 4 times higher for tankers and 3 times higher for LNG carriers than emissions calculated from AIS data; emissions from AIS data were found to gradually increase in the remaining 5 months of comparison. During January 2016 to June 2016, total emissions estimated from the trade were found to be higher than from AIS data (24% for tankers and 28% for LNG carriers). Similar trends were discovered in both AIS and trade data. In the long term perediction, although the import trend and the volumes remain relatively stable from 2016 to 2020, overall GHG emissions tend to gradually decline from 2016. The decline is mostly found in tankers as the vessels increase in size and utilize more space since the deadweight gets larger and fewer port calls are made. However, LNG carriers' emissions remain almost the same and projected to increase.

6. CONCLUSION

In this study, two main objectives are focused: GHG emission estimations from tankers and LNG carriers and trade statistics. Emission from 8 air pollutants (CO2, NOx, SOx, PM, CO, CH4, N2O and NMVOC) is calculated for the first half of 2016.

Based on ITTC procedures and the Holtrop-Mennen numerical power prediction method, vessel emission estimation model estimates the GHG emissions of LNG and tanker ships in Japan coastal waters from the AIS data. As tracking data do not cover all ships, calculated emissions will not cover the actual emissions. In the dataset, engine types and their information are not available. Therefore, calculations are done with value assumption. If more information is available, better accuracy in fuel consumption and emissions can be estimated. With the calculation results from the current AIS data, it is assumed that emissions are particularly higher after the peak season, particularly during the third quarter of each year. This can be due to the higher vessel movements once energy resources are imported. Therefore, air pollution impacts on the local environment and urban and port areas should be investigated. It can help the government and stakeholders identify environmental and health issues to improve the local society.

Next, the long term GHG emission is predicted based on the trade data. The prediction results show the gradual decrease in GHG over years. However, this prediction is based on the available six-month vessel movement data. In addition, prediction in this study is based only on statistics from two sources: Japan METI and UN Comtrade. Further study should be focused to develop a better emission forecast model using more trade data. In this study, emission estimation from trade data is studied based on vessel port calling activity and cargo weight carried. From this study, vessel emissions can be estimated if the country's trade volumes are known. The authors recognize that the prediction model can be improved and re-evaluated provided that more historical AIS data are available. Further research should be conducted on more accurate data-driven approaches to estimate ship emissions from each trade and commodity so that environmental friendly trade policy can be further researched and implemented to benefit the local society.

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Sustainable Supply Chains for Bioeconomy: A Survey on Projects and Literature on Agro-Biomass

Biyoekonomi İçin Sürdürülebilir Tedarik Zincirleri: Tarımsal Biyokütle ile İlgili Projeler ve Literatür Üzerine Bir Araştırma

Tümay YAVUZ[1] **Atiye TÜMENBATUR**[2]

Abstract

Bioeconomy, which is based on the replacement of materials and energy production based on fossil resources with biomaterials and/or biofuels or energy generation from biomass resources, has an important place in the circular economy. Sustainable supply chains are essential to meet bioeconomy's full potential. This study aimed to provide a theoretical framework to make use of the untapped biomass potential in Turkey. Study focused on the literature fit for purpose for the further studies to be executed for building a holistic approach on developing biomass and bioenergy projects, alternative concepts and business models utilizing agro-biomass resources and developing a conceptual framework for sustainable supply chains for a circular bioeconomy. Research clearly shows that many projects are executed within the scope of bioeconomy in Europe, mostly with a collaborative sense, and are supported by funding mechanisms in line with EU policies. In Turkey, more regulatory policies should be developed, awareness should be raised, and application-oriented innovation projects should be developed, involving all sector stakeholders.

Keywords: Circular Economy, Bioeconomy, Bioenergy, Biomass Supply Chains, Agricultural Residues.

Öz

Fosil kaynaklara dayalı malzemelerin biyomateryaller ile, enerji üretiminin ise biyoyakıtlarla veya biyokütle kaynaklarından direkt enerji üretilmesi ile ikame edilmesine dayanan biyoekonomi, döngüsel ekonomide önemli bir yere sahiptir. Biyoekonominin potansiyelinden tam olarak faydalanabilmek için sürdürülebilir tedarik zincirleri gereklidir. Bu çalışma, Türkiye'deki kullanılmayan biyokütle potansiyelinden yararlanabilmek için teorik bir çerçeve sunmayı amaçlamıştır. Biyokütle ve biyoenerji projeleri, alternatif konseptler ve tarımsal biyokütle kaynaklarından yararlanan iş modelleri geliştirmeye yönelik bütünsel bir yaklaşımla yürütülecek gelecekteki çalışmalar için amaca uygun literatüre odaklanılmış ve döngüsel bir biyoekonomi için gerekli olan sürdürülebilir tedarik zincirleri için kavramsal bir çerçevenin geliştirilmesi hedeflenmiştir. Araştırmalar, Avrupa'da biyoekonomi kapsamındaki pek çok projenin, çoğunlukla işbirlikçi bir anlayışla yürütüldüğünü ve AB politikaları doğrultusunda finansman mekanizmalarıyla desteklendiğini açıkça göstermektedir. Türkiye'de de benzer şekilde daha fazla düzenleyici politika geliştirilmeli, farkındalık artırılmalı ve tüm sektör paydaşlarını içeren uygulamaya yönelik inovasyon projeleri geliştirilmelidir.

Anahtar Kelimeler: Döngüsel Ekonomi, Biyoekonomi, Biyoenerji, Biyokütle Tedarik Zincirleri, Tarımsal Kalıntılar**.**

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1. INTRODUCTION

Issues such as tackling climate change, the supply chains broken by the pandemic, the paradigm shift from globalization to localization, and the ability to supply cheap and clean energy resources considering supply security and geopolitical developments, leave their mark on our day globally. In order to overcome these challenges and achieve sustainable development goals, it is essential to switch from the linear economy model in the past, which can be summarized as take-make-consume-dispose, to a circular economy model that uses resources in a more efficient and environmentally friendly way. This requires a redesign of value chains and fundamental changes in business models and policies.

Bioeconomy, which is based on the replacement of materials and energy production based on fossil resources with biomaterials and/or biofuels or energy generation from biomass resources, has an important place in the circular economy. For effective bioeconomy deployment, supply chains must first be structured and optimized.

This study aims to provide a theoretical framework to make use of the untapped biomass potential in Turkey and pave the way for a sustainable bio-based economy and has been limited to biomass resources based on agricultural residues and agro-industry waste streams for being able to conceptualize an agro-biomass business in Turkey.

In the first section, a survey on EU funded projects for the utilization of agricultural residues as bio commodities or biofuels to substitute fossil-based materials or fuels has been conducted. Second section includes a survey on literature for designing sustainable biomass supply chains which is essential for biomaterial utilization and/or energy generation from agricultural biomass and a stepping stone for the successful application of the projects for a successful bioeconomy.

1.1. Background & Overview

Currently two global transformations are leading the way to sustainable development. First is the transition from linear economy to circular economy, second is the energy transformation promoting decarbonization, digitalization, distributed energy generation and energy efficiency. The question now is "how to convert the resources to more efficient and sustainable products and services" rather than "what sources we should use?".

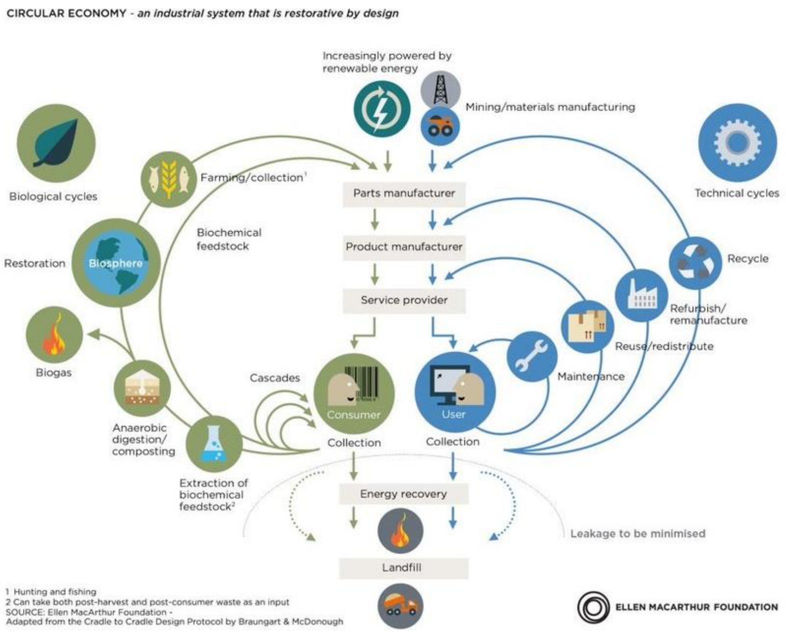

***Figure 1**. The Butterfly Diagram Visualizing the Circular Economy*

The circular economy has become evident as a practical alternative to the existing linear (take-make-waste) status quo which is unsustainable and one of the global challenges of 21st century. Circular economy tends to keep resources functioning at their highest potential by means of not consuming them but recovering in a continuous and long lasting loop. The value of the resources are preserved through cycles of reusing, repairing, remanufacturing or recycling. It is a regenerative system where the needs of the public are met within the natural means (Van Kruchten et al., 2020).

Ellen Macarthur Foundation is an international charity, which was launched in 2010 and is pioneering in accelerating the transition to the circular economy. They point out that eliminating waste and pollution, circulating products and materials at their highest value and regenerating nature are the three principles which are guiding the transition to circular economy (Ellen Macarthur Foundation, 2013).

An illustration of material flows in circular economy including the two main cycles – the technical cycle and the biological cycle is presented in Figure 1, which is called as the circular economy system diagram and also known as the butterfly diagram (Ellen Macarthur Foundation, 2022).

Figure 2*. 17 UN Sustainable Development Goals*

Currently, either for academic or for industrial purposes, individual or corporate goals should be aligned with that of United Nations' 17 Sustainable Development Goals (SDGs) which are briefly illustrated in the chart provided in Figure 2. UN conceive the SGDs as "the blueprint to achieve a better and more sustainable future for all, which address the global challenges" (United Nations, 2022).

What is the relation between circular economy and sustainability? and how circular economy can help us in achieving the sustainable development goals? are the two questions which come to mind. We can simply answer them that circularity contributes to a more sustainable world, but not all sustainability initiatives contribute to circularity.

There are several studies which briefly explain how circularity is incorporated in the Sustainable Development Goals of the United Nations. One of the recent studies is on the relevance of circular economy practices to the SDGs, which provides an extensive matching exercise and an assessment of the contribution of circular economy practices to SDG goals. According to the study, circular economy practices which directly contribute to achieving SDG goals with the strongest relationships and creating synergies are stated as SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG12 (Responsible Consumption and Production) and SDG 15 (Life on Land) (Schroeder et al., 2019).

1.2. Terms & Definitions

Biomass, Bioenergy and Bioeconomy

In the Directive 2009/28/EC of the European Union, biomass is considered as one of the renewable energy sources; it is defined as "biodegradable products, wastes and residues of biological origin and biodegradable products belonging to agriculture, forestry and related industries (such as fisheries, aquaculture) and biodegradable parts of industrial and municipal wastes" (European Commission, 2009). Biomass energy is generated by valorization of biomass sources through various conversion technologies and processes and serve three main areas; electricity, heat, and biofuel production, which is mainly used for transportation.

Bioeconomy or biobased economy is a new model for industry and the economy. According to the definition of the German Bioeconomy Council (Bioökonomierat), bioeconomy is "the knowledge-based production and use of biological resources to provide products, processes, and services in all economic sectors within the frame of a sustainable economic system" (German Bioeconomy Council, 2022). It involves using renewable biological resources sustainably to produce food, energy, and industrial goods. It also exploits the untapped potential stored within millions of tons of biological waste and residual materials. The transition from a fossil fuel-based to a biobased economy is expected to reduce our dependency on fossil fuels and achieve more sustainability as well as contribute to climate and environmental protection. The 2018 EU Bioeconomy Strategy defines the bioeconomy as, "those parts of the economy that use renewable biological resources from land and sea – such as crops, forests, fish, animals and micro-organisms – to produce food, materials and energy" and strongly emphasizes that the European bioeconomy needs to have sustainability and circularity at its heart for success (European Commission, 2018).

According to a study in Universitat Autònoma de Barcelona, "circular economy is the 'what' – the result to be achieved (the desirable outcome capable of decoupling the use of resources from natural resources), whereas bioeconomy is the 'how' (what type of biophysical processes should be enhanced to achieve the expected result)". The study also indicates that the principles of a sustainable bioeconomy and the principles of a circular economy should be in harmony for proper implementation (Giampietro, M., 2019).

Developing a stronger bioeconomy will help the EU in accelerating progress towards a circular and low-carbon economy. It will also help modernizing and strengthening the EU industrial base, creating new value chains and greener, more cost-effective industrial processes, while protecting biodiversity and the environment" (European Commission, 2018).

Circular bioeconomy has enormous potential for creating millions of green jobs, especially in rural areas, creating mitigation and carbon neutrality, reducing atmospheric emissions and our dependence on fossil resources. It also helps ecosystem and biodiversity restoration, aligned with the SDGs, recover part of the degraded ecosystems. More information about the EU's bioeconomy strategy and action plan can be seen in Bioeconomy: The European Way to Use Our Natural Resources, Action Plan 2018 (European Commission, 2019).

Biomass Value Chain

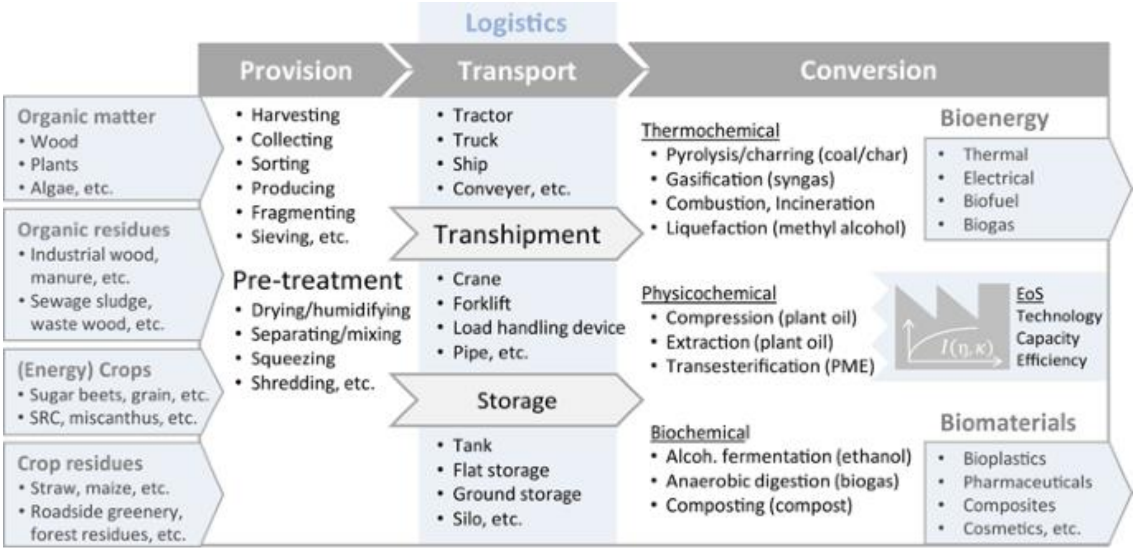

Figure 3. *Biomass Value Chain (Rudi et al., 2017)*

Bioeconomy aims at using sustainable renewable biomass resources for the production of bioenergy and various pathways exist for bioenergy generation, as illustrated in Figure 3. A general biomass value chain (BVC), also referred to as biomass supply chain (BSC) in literature, is characterized by the valorization of biomass feedstock, such as organic, wood, and crop material or residues, as well as of municipal organic wastes and manure for the production of bioenergy and innovative bio-based materials. The flow diagram given in Figure 3 illustrates the paths and interactions where biomass resources are subject to several provision and transport means and then are processed with different conversion technologies yielding various bio-products for different end-uses.

It is critical to decide which technology to apply prior to designing the biomass value chain (BVC) depending on the various biomass pathways and conversion options. The technoeconomic assessment of biomass valorization pathways is difficult and has to be supported by optimization models considering the complexity and interdependencies, such as economies of scale. Diverse BVC optimization models exist for the techno-economic assessment of biomass pathways and the selection of biomass feedstocks and technologies, which considers not only technology and capacity planning but also the trade-off between transportation costs and technology investment (Rudi et al., 2017).

Agro-biomass (Agricultural Biomass)

Biomass is derived from organic material such as trees, plants, and agricultural and urban waste. Biogas, biodiesel, and bioethanol are the three main categories of bioenergy provided by agriculture, and each has experienced dynamic growth in recent years.

In addition, short rotation coppice provides solid biomass, while agriculture also provides by-products and residues (such as straw) used for bioheat and biopower. Furthermore, dedicated energy crops like perennial grasses and short rotation forestry and coppice provide non-food cellulosic and ligno-cellulosic biomass.

Biomass grasses, short rotation forestry and short rotation coppice have high energy yields – about three times those of traditional energy crops. They imply lower environmental pressure and can be irrigated with wastewater (European Commission, 2022).

***Table 1.** Agro-biomass Resources (Bioenergy Europe, 2022)*

Agricultural Residues	Large potential, 1 ton of an agricultural product yields 1 ton of agricultural residues Herbaceous: Straw, maize residues Woody: agricultural prunings, orchard plantation removals		
Agro-industrial	No harvesting required, often low moisture / good calorific value, very comptetive fuel sources Olive stones / olive cake, nut shells, sunflower husk, peach kernels, cotton ginning residues and others		
Perennial Energy Crops	Higher yields, cultivation on abondoned, marginal or contaminated land, eco-system services, etc. Herbaceous: Mischantus, switchgrass Woody / Short Rotation Coppice: poplar, willow, etc.		

With around 20% of the bioenergy feedstock coming from agriculture, both dedicated energy crops and agricultural residues can be utilized to produce heat, electricity and biofuels. Agricultural biomass represents an important and sustainable energy source although its potential remains largely untapped. Scarce mobilisation of residues is at the basis of their underutilisation. Several studies point in the direction of an increased role for agricultural biomass to achieve Europe's long-term decarbonisation objectives.

The challenges that may be encountered while developing new business models based on agricultural residues and the potential solutions to overcome these difficulties and the social and environmental benefits that can be obtained from such business models are presented in Table 2 and Table 3.

***Table 2.** Benefits from Agro-biomass (Bioenergy Europe, 2022)*

Socio-Economic Benefits
Income/activity diversification for farmers
Local job creation and socio-economic development
Self-sufficiency (reduced reliance on imported fossil fuels)
Environmental Benefits
Reduction of air emissions from avoidance of open field burning of residues
Reduction of GHG emissions from substitution of fossil fuels
For lignocellulosic crops: phytoremediation, improvement of soil quality, carbon sequestration, water quality and biodiversity

***Table 3**. Challenges in Agro-biomass Business (Bioenergy Europe, 2022)*

Challenges	**Potential Solutions**
Higher CAPEX investment requirements compared to fossil fuel options	Adopt agro-biomass heating in end-users with higher demand Subsidize CAPEX through suitable policy instruments
Dispersed resource, harvesting costs, low density	Development of local supply chains with appropriate technical implements
Challenging chemical fuel properties (e.g. ash, nitrogen, alkalis, etc.)	Use of appropriate, modern combustion technologies
Inhomogeneous material & low density	Use of appropriate feeding systems Homogenization through pelletization

Low priority of residue management for farmers	Introduction of suitable policy instruments (e.g. incentives for treatment, stricter fines for field burning)
Low priority / lack of awareness for policy makers, etc.	Knowledge transfer, dissemination, promotion of success cases

2. METHODOLOGY

This study aimed to focus not only the research papers on this subject, but also the research projects which provide a working environment and forms a base for many individual and collaborative papers and publications. The scope of this study is limited to agricultural residues and agro- industry residues, co-products and waste streams in terms of biomass sources.

A systematic literature study has not been conducted. Instead, focused on the literature fit for purpose for the further studies to be executed by the authors for:

- Building a holistic approach on developing biomass energy projects utilizing agro-biomass resources,
- Understanding alternative concepts and business models in biomass and developing a conceptual framework for sustainable supply chains for circular biomass and bioenergy projects.

A selection of exemplary projects and articles on the design of sustainable supply chains in order to form an infrastructure for new biomass energy projects or for studies on obtaining biomaterials from biomass wastes within the framework of circular economy principles in Turkey have been examined with the motivation of raising awareness in Turkey about the studies in this field.

In certain cases, project-based studies come to the prominence instead of individual studies in order to produce solutions to the major problems and needs of the European Union when research requires a more global perspective. Such collaborative research projects, particularly supported by EU funds (e.g., Horizon and similar programs) have prevailed over the past decades and researchers are required to work across disciplines, institutions and borders. Researchers can maximize outputs, answer bigger and more complex scientific questions and expand their research by combining expertise and resources. Collaborative research projects have more significant outcomes (i.e., economically viable) than independent research work and provide more opportunities to researchers from non-academic sources. (Springer Nature, 2022).

Generating outputs that have an impact on policy, practice, industry, or the general public can increase chances of getting funded. In addition, some funding bodies now give priority to international and industry-academia collaborations. For example, the EU Commission's Horizon 2020 program, which offered nearly 80 billion Euros of funding between 2014 and 2020 for research projects tackling societal challenges, prioritized collaborative projects.

Working collaboratively can help researchers meet potential future employers, mentors, and collaborators, expanding their network. Collaborations are opportunities to learn new skills, make new friends, gain a new perspective, and join stimulating discussions and with experts in researchers' own field or complementary fields.

From this point of view, in the first part of the study, projects supported by the Horizon program or similar funding mechanisms throughout the EU were reviewed. The projects in subject are mostly on agro-biomass. A few projects on other biomass resources, which present inspiring implementations of logistics and supply chain models like integrated biomass logistics centers and trade centers have also been surveyed. Besides, a special emphasis has been given to projects solely on developing supply chain and logistics optimization models and toolsets and setting up unique business models.

In the second and last part of this study, individual academic studies and academic publications/articles derived from the projects discussed in the first part are surveyed and a summary of literature review has been compiled with this respect, focusing on supply chain design for agricultural residues.

2.1. Review of Projects on Agro-biomass

The Circular Bio-based Europe Joint Undertaking (CBE JU) is a €2 billion partnership between the European Union and the Bio-based Industries Consortium (BIC) that funds projects advancing competitive circular bio-based industries in Europe. CBE JU is operating under the rules of Horizon Europe, the EU's research and innovation program, for the 2021-2031 period (Circular Bio-based Europe Joint Undertaking, 2022).

The Bio-based Industries (BBI) is dedicated to realizing the European bioeconomy potential, turning biological residues and wastes into greener everyday products through innovative technologies and biorefineries, which are at the heart of the bioeconomy. The BBI is about bridging key sectors, creating new value chains and producing a range of innovative bio-based products to ultimately form a new bio-based community and economy (Bio-based Industries Consortium (BIC), 2022).

BBI aims at a sustainable and competitive bio-based industry providing jobs and growth that contribute to a circular bio-society, involving primary sectors as strategic partners in bio-based value chains. BBI stimulates investment & create new, local value chains by connecting European regions and the bio-based industry and aims to establish climate-neutral operations and replace fossil-based products to mitigate climate change.

Common objectives of the BBI funded projects and expected impacts are summarized as follows:

- Building new value chains based on the development of sustainable biomass collection and supply systems with increased productivity and improved utilization of biomass feedstock (incl. co- and by-products).
- Unlocking the utilization and valorization of waste and lignocellulosic biomass.
- Bringing existing value chains to new levels, through optimized uses of feedstock and industrial side-streams while offering innovative added value products to the market, thus creating a market pull and reinforcing the competitiveness of EU agriculture and forest-based industries.
- Bringing technology to maturity through research and innovation, by upgrading and building demonstration and flagship biorefineries that will process the biomass into a range of innovative bio-based products.

Projects solely on developing supply chain and logistics optimization models and setting up unique business models in biomass are summarized in Table 4.

Project landscape as per the biomass type, project focus and the target regions are briefly presented in Table 5 which is derived from a presentation on "Lessons Learned from Earlier Projects" from Market Uptake Support for Intermediate Bioenergy Carriers (MUSIC) Project (Voset al., 2020). More information can be accessed through Bio-Based Industries Joint Undertaking website at Projects section (Bio-based Industries Consortium (BIC), 2022). Summary of the projects, objectives, expected impacts, project achievements, targeted value chains and markets and a list of consortium partners can be accessed through that portal.

Project deliverables including dissemination, communication and exploitation reports, scientific publications, roadmaps, handbooks, best practice guidelines, benchmarks, case studies, training materials, technical reports and feasibility reports can be accessed on each project's specific web site.

Table 4. *A Summary of Optimization & Business Models on Agro-biomass with Exceptional Logistics & Supply Chain Features*

S2Biom	The main objective is to support the sustainable delivery of non-food biomass feedstock at local, regional and pan European level through developing strategies, and roadmaps that are supported by a computerized toolset with updated harmonized datasets at local, regional, national and pan European level for EU28, Western Balkans, Moldova, Turkey, and Ukraine (S2Biom Project, 2016).
euro pruning	EuroPruning aimed to optimise biomass from pruning logistics chain to make it cost-effective and to ensure quality adequacy to final consumer needs. EuroPruning developed new machinery for harvesting and treating prunings from the field, investigated solutions for cost-effective storage options, and developed a decision-support tool for improving logistics from farm to final user (EuroPruning Project, 2016).
SecureChain sustainable biomass energy	A renewable energy project supported by the European Union's research and innovation programme. The main goal is to promote sustainable bioenergy chains in the rural area, which fulfil high environmental standards and are economically viable for small and medium-sized enterprises (SME) (Kies, U., Reumerman P. et al., 2018).
sucellog	SUCELLOG aims to widespread the participation of the agrarian sector in the sustainable supply of solid biofuels in Europe. The focus is on the implementation of agro-industry logistic centres in the agro-industry as a complement to their usual activity evidencing the large synergy existing between the agro- economy and the bioeconomy (Sucellog Project, 2017).
AGRO in LOG INTEGRATED BIOMASS LOGISTICS CENTRES FOR THE AGRO-INDUSTRY	The main goal is the demonstration of Integrated Biomass Logistic Centres (IBLC) for food and non-food products, evaluating their technical, environmental and economic feasibility. The project is based on three agro-industries that are willing to deploy new business lines in their facilities to open new markets in bio-commodities (energy, transport and manufacturing purposes) and intermediate bio-products (transport and biochemicals) (AgroInLog Project, 2022).
NREL Transforming ENERGY (IBSAL)	The Integrated Biomass Supply & Logistics (IBSAL) model is a dynamic (time dependent) model of operations that involve collection, harvest, storage, preprocessing, and transportation of feedstock for use at a biorefinery. The model calculates itemized costs, energy input, and carbon emissions. It estimates resource requirements and operational characteristics of the entire supply infrastructure (The National Renewable Energy Laboratory (NREL), 2022)

Table 5. *A Summary of Projects on Agro-biomass in EU (Vos et al., 2020) & (Bio-based Industries Consortium (BIC), 2022)*

	Biomass Type				Project Focus					Target Countries			
Project Name	Forest Biomass	Agro-biomass	Landscape Biomass	Marginal Lands/Energy Crops	Biomass Mapping	Mobilisation of Biomass	Value Chain Development	Logistics Develeopment	Logistics& Trade Centers	South EU	North EU	Central EU	East EU
AgroBioHeat		x		x			x			x			
AgroInLoG		x							x	x	x		
BioBoost	x	x	x		x	x		x		x	x	x	x
BiomasSud +		x			x					x			
Bio4A				x			x			x			
TradeCenter II	x								x				x
BioPlat-EU				x			x			x	x	x	x
BioRes	x								x				x
EuroPruning		x				x		x		x		x	
Enabling	x	x	x	x		x	x		x	x	x	x	x
ForBio				x	x		x			x		x	x
GreenGain			x		x	x	x			x		x	
Infres	x				x			x			x	x	
Logist'EC				x		x	x	x		x		x	
S2BIOM	x	x	x	x	x			x		x	x	x	x
SecureChain	x						x			x		x	
SimWood	x					x				x	x	x	x
SucelLog		x							x	x		x	
uP_running		x	x		x	x	x			x		x	

2.2. Biomass Supply Chain Design & Decision Variables

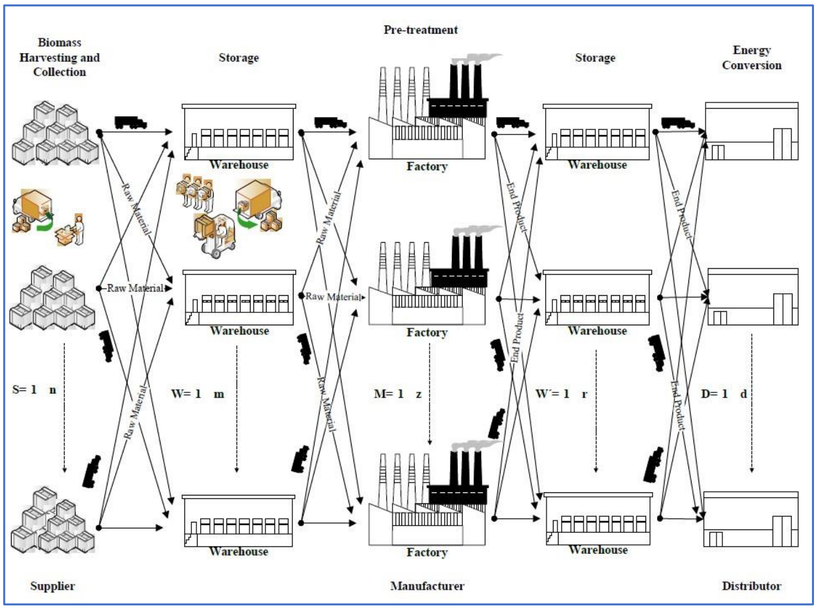

Figure 4. *Biomass Supply Chain Network (Zahraee, S.M., Shiwakoti, N., Stasinopoulos, P., 2020)*

Biomass supply chain management and optimization studies apply to network design problem within conversion, storage and transportation, scheduling problem within harvesting & collection, storage and transportation, facility location problem within pretreatment, storage and conversion, vehicle routing problem within harvesting, collection and transportation and lastly technology selection problem within pretreatment and conversion (Sun et al., 2020). Performance evaluation and optimization models are the two main approaches used in network modeling in biomass supply chain design. These models are classified into three sub-models in each; models based on cost calculations, GIS-based models and simulation models in performance evaluation whereas deterministic, stochastic and multi-objective models in optimization (Ba et al., 2016).

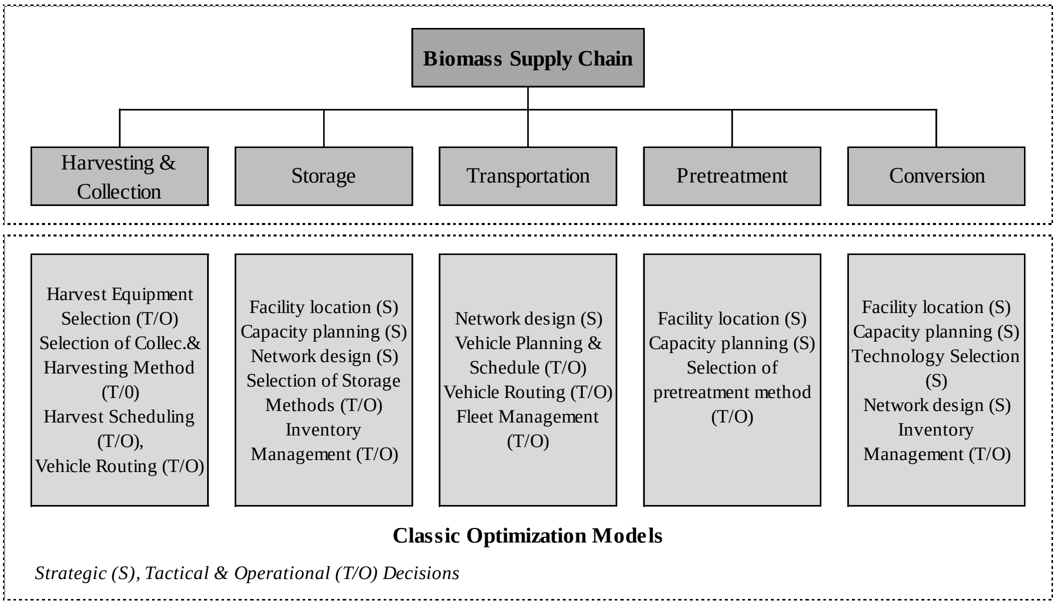

Figure 5. *Strategic, Tactical & Operational Decisions in BVC Design*

Strategic, tactical, and operational decisions are made based on different decision variables while designing a biomass value chain. It is seen that most of the research has focused on strategic and tactical decisions (Ba et al., 2016).

Strategic decisions comprise decisions valid for long-term periods which require substantial financial investment. While developing bioenergy projects, such decisions cover the selection of biomass types, the size and location of pretreatment plants and conversion equipment, the transportation modes, and making long-term supply contracts. Tactical decisions include medium-term decisions which are applied for a multi-period time span, over a few months. Examples in biomass supply chains cover the harvesting amount in each period for each farm/land, the number of vehicles required (fleet size), and the safety stock levels. Finally, operational decisions are made for a short-term, usually over a few days. They are derived from splitting tactical decisions into detailed operations. The timing of harvesting operations in a given day and the assignment of detailed vehicle routes are typical examples in biomass supply chains (Zahraee et al., 2020).

Unlike fossil resources, biomass is spatially distributed and its valorization is restricted by low-energy densities and high water contents. Long-distance transportation is not cost-effective, as a result of which small- or medium-scale conversion facilities are required. Large scale facilities, on the other hand, benefit from economies of scale and lower specific investments. For this reason, a trade-off between transportation and investment-related cost exists, which affects the structure of the biomass value chain (Rudi. et al., 2017).

In the second and last part of this study, individual academic studies and academic publications/articles derived from the projects discussed in the first part are surveyed and a summary of literature review has been compiled with this respect, focusing on supply chain design for agricultural residues.

Table 6 presents a summary of literature on selected topics focusing on supply chain design for agricultural residues and agro-industry waste streams. The scope of the literature reviewed is comprehensive to provide the readers a wide perspective on developing sustainable supply chains on agro-biomass including literature and market reviews, field and case studies, research reports by institutions, techno-economic assessments, conceptual framework and business models, GIS-based models, simulation models and optimization models.

***Table 6**. Literature Review Summary for Selected Topics in Agro-biomass*

No	Authors & Date	Problem	Methodology	Summary
1	Balaman Ş.Y., 2014	A Fuzzy Goal Programming Based Decision Support System for Design and Management of Biomass to Energy Supply Chains	Design-oriented research, mathematical modeling	A fuzzy goal programming-based decision support system for bioenergy supply chain planning with a holistic view and simultaneous provision of economic and environmental objectives and service level targets for a comprehensive SCT, and for addressing the uncertainties in the target values of parameters and decision makers.
2	Athanasios, A.R. et al., 2009	Logistics issues of biomass: The storage problem and the multi-biomass supply chain	Analysis, case study	Applying a case study of three commonly used biomass storage methods to achieve concrete comparative results and develop an innovative model to reduce storage space requirement by combining multiple biomass supply chains
3	Tatsiopoulos, I. & Tolis, A., 2003	Economic aspects of the cotton-stalk biomass logistics and comparison of supply chain methods	Optimization, simulation	This paper describes a model, which simulates the cotton biomass supply chain. This study examines the feasibility and the problems that arise while trying to organize an integrated logistics network and optimize its transportation economy. Also, economic aspects of other logistics procedures like collection and warehousing are analyzed.
4	Devrim, M.Y., Van Duren, I. et al., 2016	Design of sustainable second-generation biomass supply chains	Analytical model, case study	Comparison of the economic and environmental impacts of supply chain applications in 4 different scenarios for the evaluation of second-generation biomass resources for energy production in centralized, decentralized and mobile energy conversion facilities.
5	Lautala, P., Hilliard, M. et al., 2015	Opportunities and Challenges in the Design and Analysis of Biomass Supply Chains	Conceptual framework, simulation, literature review	Concept study including integrated supply systems for sustainable biomass trade and alternative models for investigating the factors affecting the biomass supply chain.
6	Khwaja, C. et al., 2015	Triggering the creation of biomass logistic centres by the agro-industry	Case study, application	It is within the scope of the SUCELLOG project to expand the agricultural sector's participation in sustainable biomass supply. The project is to be used as biomass logistics centers where agricultural and agricultural industry wastes and residues are processed and handled during the idle periods of the agro-industrial establishments, which are complementary to their usual activities. Identification of companies that are suitable for this project.
7	Sambra, A. & Sørensen, C., 2008	Optimized Harvest and Logistics for Biomass Supply Chain	Benchmark, Case study	Research within the scope of the BioREF (sustainable, reliable and economical production of fuel from energy crops in bio-refineries) project. Optimization of harvesting and logistics for the transport of oilseed crops and suitable agricultural residues to production facilities & reverse logistics of process residues for agricultural use in the biomass feedstock infrastructure.
8	Aalto, M., Korpinen, O. et al., 2017	Dynamic Simulation of Bioenergy Facility Locations with Large Geographical Datasets – A Case Study in European Region	Simulation, GIS, Geographical Data Analysis	A low-cost method for the logistics of agricultural residues that considers time and location-dependent variations in biomass supply
9	Annevelink, B., Gogh, B., et al., 2017	Conceptual Description of an Integrated Biomass Logistics Centre (IBLC)	Conceptual framework	Application of integrated biomass logistics centers in agro-industrial organizations. Determining the features and characteristics of these centers, evaluating their technical, environmental and economic feasibility. Comparison of competitive advantage of agro-industry organizations according to biomass supply business models to be established from scratch (Agro-in-log is the successor to the Sucelllog project)

10	Lucile, G., Marion, D., Hélène P., 2022	Biomass Supply Chains Development in Rural Areas: How to Take Public Stakeholders' Needs and Expectations into Account?	Case study, survey & interviews, decision making support	Increasing regional integration while developing biomass supply chains in rural areas. Determining the needs and expectations of public stakeholders, presenting suggestions for regional integration accordingly, being involved in the decision-making process, determining the economic, environmental and social criteria considered in regional projects in this process.
11	Kougioumtzis, M.A., Karampinis, E. et al., 2018	Assessment of biomass resources for an integrated biomass logistics center (IBLC) operating in the olive oil sector	Field study, analytical study, case study	The use of olive pomace plants operating in the olive oil sector as IBLC, which processes olive tree pruning residues as a biomass raw material after the main post-processing, apart from their normal operations. The results of this study will also be a guide for other facilities operating in the sector.
12	Annevelink, B., Garcia Galindo, D., et al., 2017	A logistics case study with "LocaGIStics" software for the Aragon (Spain) Region	Case study, supply chain design,	LOCAGISTICS is support software specially developed for regional distribution chains. From the plans of energy and biomass producers; Better designs can be developed by considering logistics concepts such as transportation, preprocessing, storage, and energy conversion criteria.
13	Menéndez, J. A., Fernández-Tresguerres, L. et al., 2018	Report on the availability of Biomass Sources in Spain: vineyards and olive groves	Research report	Prepared for EU ERANETMED2-72-246 project. This project aims to directly use biomass waste from vineyards and olive groves for electricity generation.
14	Vourdoubas, J., 2017	Power generation possibilities from olive tree pruning residues, olive industry by-products and other wastes in Crete, Greece	Literature review, technical and economic assessment	Investigation of current use and future prospects of olive tree pruning residues, olive industry by-products and waste for energy generation in Crete. Calculation of energy production potential based on olive tree biomass estimation in Crete. Evaluation of the experiences in olive oil producing countries together with the technologies used or tried so far.
15	Pantaleo, A., Carone, M., Pellerano, A., 2012	Olive Residues to Energy Chains in the Apulia Region Part I: Biomass Potentials and Costs	Field study, analytical study, techno-economic assessment	The residue, waste and by-product sector in the olive growing value chain is reviewed. The energy potential of pruning waste and pomace is estimated and collection costs are evaluated with different supply chain scenarios.
16	Iakovou, E., Karagiannidis, A. et al., 2010	Waste biomass-to-energy supply chain management: A critical synthesis	Literature review, decision making support	A critical synthesis of the literature applicable to all stakeholders involved in the design and management of biomass supply chains is presented. General system components and the different aspects that distinguish them from traditional supply chains are discussed. The results of all relevant literature are classified. The decision-making process for biomass supply chain design is examined and these are mapped at the relevant strategic, tactical and operational levels of the hierarchy and research is classified.
17	Manzanares, P., Ruiz, E. et al., 2017	Residual biomass potential in olive tree cultivation and olive oil industry in Spain: valorization proposal in a biorefinery context	Business model proposal	Olive crop and olive oil industry generates several residues, i.e., olive tree pruning biomass (OTPB), extracted olive pomace (EOP) and olive leaves (OL) that could be used to produce high-added value products in an integrated biorefinery. OTPB is generated in the field as a result of pruning operation to remove old branches; EOP is the main residue of the pomace olive oil extracting industry after extraction with hexane of residual oil contained in olive pomace; and OL comes from the olive cleaning process carried out at olive mills, where small branches and leaves are separated by density. In this work, an analysis of the potential of OTPB, EOP and OL residues was addressed by estimating the production volumes at national level and the spatial distribution of these residues using geographic information system software.

18	Voivontas, D., Assimacopoulos, D., Koukios, E., 2001	Assessment of biomass potential for power production: a GIS based method	GIS based decision-making analysis.	A method is presented, which estimates the potential for power production from agriculture residues. A GIS decision support system (DSS) has been developed, which implements the method and provides the tools to identify the geographic distribution of the economically exploited biomass potential.
19	Sun, O., Fan, N., 2020	A Review on Optimization Methods for Biomass Supply Chain: Models and Algorithms, Sustainable Issues, and Challenges and Opportunities	Literature review, bibliometric analysis	Due to special characteristics of biomass, this particular kind of supply chain is different from the classic supply chains in different ways. The optimization methods, including mathematical programming and heuristic algorithms are widely used in the domain of biomass supply chain management in both tactical and practical manners Literatures are classified by different components throughout the entire supply chain: harvesting and collection, storage, transportation, pretreatment, and conversion. A bibliometric analysis is also performed in this review to obtain comprehensive understanding of this area.
20	Sharma, B., Ingalls, R. et al., 2013	Biomass supply chain design and analysis: Basis, overview, modeling, challenges, and future	Literature review,	Efficient supply chain management of lignocellulosic biomass is crucial for the success of second-generation biofuels. This paper systematically describes energy needs, energy targets, biofuel feedstocks, conversion processes, and finally provides a comprehensive review of Biomass Supply Chain (BSC) design and modeling. Specifically, the paper presents a detailed review of mathematical programming models developed for BSC and identifies key challenges and potential future work.
21	Rudi, A., Müller, AK., Fröhling, M. et al., 2017	Biomass Value Chain Design: A Case Study of the Upper Rhine Region	Techno-economic Assessment, Mathematical modeling, Decision-making support	A case study application of a biomass value chain design for the tri-national Upper Rhine Region is presented. A mathematical model is formulated, which uses existing potentials in order to optimize the biomass value chain in terms of multiple feedstocks, technologies, and outputs. The resulting insights provide for a techno-economic assessment of biomass value chains and the identification of potential biomass pathways.
22	Heinimö, J. & Junginger, M., 2009	Production and trading of biomass for energy – An overview of the global status	Market review	The aim of this paper is to summarize trade volumes for various biomasses used for energy and to review the challenges related to measurement of internationally traded volumes of biofuels.
23	Wu, J. & Wang, L., 2012	Economic Analysis Model for Biopower Plants Based on Biomass Logistics Networks and Its Application in Heilongjiang Province, China	Optimization, mathematical modelling, Economic feasibility	A mathematical model was developed to assess the economic feasibility of a biomass-based power plant in the Northeast of China. The objective of this model is to maximizes the net present value (NPV) of a biopower plant over its economic life, which subjects to the constraints of biomass availability, plant investment and operation & maintenance costs, plant capacity, transportation logistics, raw material and product pricing, financing, and business taxes.
24	Perpiñá Castillo, C., Alfonso, D. et al., 2009	Methodology based on Geographic Information Systems for biomass logistics and transport optimisation	GIS, Mapping, Facility Location Selection	The aim of this study is to contribute by outlining a procedure for achieving an optimal use of agricultural and forest residue biomass. In this regard, it develops and applies a methodology focused on logistics and transport strategies that can be used to locate a network of bioenergy plants around the region. This methodology was developed using a Geographic Information Systems and it provides information on the spatial distribution of biomass residues.
25	Frombo, F., Minciardi, R. et al., 2009	A decision support system for planning biomass-based energy production	Optimization, GIS, Decision Support System	Environmental decision support systems (EDSS) are recognized as valuable tools for environmental planning and management. In this paper, a geographic information system (GIS)-based EDSS for the optimal planning of forest biomass use for energy production is presented. A

				user-friendly interface allows the creation of Scenarios and the running of the developed decision and environmental models.
26	Ruiz, J., Juárez, M.C. et al., 2013	Biomass logistics: Financial & environmental costs. Case study: 2 MW electrical power plants	Techno-economic analysis	This paper examines the following points concerned with the logistics of biomass: optimum biomass transport distances to plants, transport costs, CO2 emissions relative to CO2 avoided and the surface areas required to grow or collect biomass. Particular emphasis is placed on the logistics of biomass-fired electric power plants rated at 2 MW electrical, a size that enables electric power distribution to be decentralized.
27	Alakangas, E., Wiik, C. & Vesterinen, P., 2008	Efficient trading of biomass fuels and analysis of fuel supply chains and business models for market actors by networking	Market review	Analysing the current and future biomass fuel market trends and biomass fuel prices. Additionally, collected feedback on the suitability of CEN 335 solid biofuel standard for trading of biofuels. Estimation on techno-economic potential of the biomass was given until 2010 based on the existing studies and experts' opinions.
28	Morales-Rincon, L., Martínez, A. et al., 2015	Gis-Based Methodology for Optimum Location of Biomass Extraction Plants and Power Plants Using Both Logistic Criteria and Agricultural Suitability Criteria	GIS based facility location	A GIS-based methodology to identify the optimal locations for biomass extraction plants and biomass power plants is presented. Both agricultural land suitability criteria and logistic criteria were considered to select the optimal locations. Agricultural land suitability criteria were included as several independent variables of edaphic and climate conditions.
29	Ravula, P., Grisso, R. & Cundiff, J., 2008	Cotton logistics as a model for a biomass transportation system	Discrete event simulation, Optimization	Various systems capable of harvesting, storing and transporting biomass efficiently, at a low cost, need to be designed. The transportation system of a cotton gin, which shares several key components with a biomass transportation system, was simulated using a discrete event simulation procedure, to determine the operating parameters under various management practices.

3. FINDINGS & DISCUSSION

Currently two global transformations are leading the way to sustainable development. First is the transition from linear economy to circular economy, second is the energy transformation promoting decarbonization, digitalization, distributed energy generation and energy efficiency. The question now is "how to convert the resources to more efficient and sustainable products and services" rather than "what sources we should use?". Going circular and deploying bioeconomy will help us achieve sustainable development goals and tackle climate change.

Despite the fact that energy generation from biomass has a very old history in Europe, many R&D, innovation, technology development and application projects are carried out to evaluate biomass primarily as biomaterials, in accordance with the principles of circular economy, and it is tried to increase the usage areas of biomaterials.

Although it is widely used in the European Union countries, it can be said that biomass energy is still an overlooked giant in the field of renewable energy. Many projects within the scope of bioeconomy are supported by policies and funding mechanisms. Renewable energy investments are expected to increase throughout the European Union as a result of the geopolitical risks that have reached the highest level with the Russia-Ukraine war and the supply security threats brought about by the dependence on Russian natural gas and oil. In this framework, the sector stakeholders demand the support and funds for energy production from biomass to be increased.

Studies in the European countries are generally carried out within the scope of large projects funded by the European Union, as part of the whole, in accordance with the organization and project goals and objectives. It is seen that there are fewer individual studies. The transition to a similar working culture in Turkey will be beneficial in closing our research gap on this subject.

4. CONCLUSION & IMPLICATIONS

Right policies and rigorous sustainability regulations is essential to meet bioeconomy's full potential. More regulatory policies should be developed in Turkey to foster a national strategy and standards taking both circular economy principles and energy transition into account. On the other hand, dissemination activities should be organized in order to raise awareness among the public.

Utilizing more biomass resources as biomaterials and/or biomass energy sources to replace fossil resources will facilitate transition to a circular economy and increase renewable share in the energy mix. Clear goals should be defined for an efficient bioeconomy. It seems that there is a need for an upper regulatory body that will coordinate the execution of the works within these targets and determine the necessary incentives.

Relevant legislation and incentives should support initiatives in R&D and application-oriented innovation projects, involving all sector stakeholders, especially universities and industrial organizations.

It is seen that Turkish research institutions rarely participate in European Union supported projects, but even these studies are not sufficiently announced and introduced to other sector stakeholders and relevant institutions and organizations in Turkey. More collaboration either nationwide or internationally is required for proper and efficient project execution and being able to achieve the targets.

Turkey is currently experiencing great economic difficulties. On top of that, we are experiencing great difficulties in access to agricultural products at reasonable prices on the consumer side and producers/farmers have cost issues. To overcome these problems, agricultural policies should be reorganized, and it is essential to develop a biomass economy based on agricultural residues, which will allow agricultural producers to reduce their costs and earn additional income. In this way, rural development will be possible with both additional income and new job opportunities.

Technical and economical characteristics of biomass energy projects require multidisciplinary and interdisciplinary studies. Biomass resource assessment, biomass supply chain design and management, and logistics optimization activities need to be carried out properly in order to execute efficient projects in energy generation from biomass.

Considering country conditions, current academic studies and projects for energy production from biomass, the projects and literature examined in this study will shed light on our future research and possible thesis study on the supply chain design and logistics optimization required for the use of olive pruning residues and olive oil industry residues (olive cake, pomace) in biofuel or power plant energy production. Currently, there is not such an application in Turkey.

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