Fırat Üniversitesi Müh. Bil. Dergisi
36(2), 965-978, 2024

Araştırma Makalesi
https://doi.org/10.35234/fumbd.1468659

A Modeling Approach for Cargo Transportation Considering Energy Saving

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(Geliş/Received:17/04/2024; Kabul/Accepted: 27/09/2024)

Abstract: This study presents a cargo transportation system management model that enables users to carry out the cargo process efficiently and economically. Cargo transportation is an important part of the transportation systems network. The advantages of cargo transportation are to ensure the safe delivery of products, save time and reduce costs. This study addresses the solution to the problems of high carbon dioxide emissions, and late and expensive deliveries caused by large distribution networks, by taking into account the density and logistics strategies of the cargo companies. The proposed cargo management system focuses on delivering cargo to destinations along the route that users are currently traveling on. This system is built around three main components: optimized route planning by an A* algorithm, a system model controllable through mobile and web interfaces, and nodes designated as drop-off and pick-up points for cargo. The A* algorithm runs with a reward matrix that also takes direction into account to calculate the optimal route. Users carry out the cargo management and tracking processes on mobile and web interfaces. Automatic nodes, which are the model prototype of the study, represent the cargo vending machines where users deliver/receive their cargo. Through this work, users can view and select cargo to carry while traveling between destinations and earn profits by acting as cargo carriers/drivers.

Key words: Cargo transportation system management model, A* algorithm, route planning, automatic node.

Kargo Taşımacılığında Enerji Tasarrufuna Dayalı Bir Modelleme Yaklaşımı

Öz: Bu çalışma, kullanıcıların kargo sürecini verimli ve ekonomik bir şekilde gerçekleştirmelerini imkan sağlayan bir kargo taşımacılığı sistemi yönetim modeli sunmaktadır. Kargo taşımacılığı, ulaşım sistemleri ağının önemli bir parçasıdır. Kargo taşımacılığının avantajları, ürünlerin güvenli bir şekilde teslim edilmesini sağlamak, zamandan tasarruf etmek ve maliyetleri azaltmaktır. Bu çalışma, kargo şirketlerinin yoğunluk ve lojistik stratejilerini dikkate alarak, büyük dağıtım ağlarının neden olduğu yüksek karbondioksit emisyonları, geç ve pahalı teslimatlar sorunlarına çözüm getirmektedir. Önerilen kargo yönetim sistemi, kullanıcıların şu anda seyahat ettiği rota üzerindeki varış noktalarına kargo teslim etmeye odaklanmaktadır. Bu sistem üç ana bileşen etrafında oluşturulmuştur: A* algoritması tarafından optimize edilmiş rota planlaması, mobil ve web arayüzleri aracılığıyla kontrol edilebilen bir sistem modeli ve kargo için bırakma ve alma noktaları olarak belirlenmiş düğümlerdir. A* algoritması, optimum rotayı hesaplamak için yönü de hesaba katan bir ödül matrisi ile çalışır. Kullanıcılar, kargo yönetimi ve izleme süreçlerini mobil ve web arayüzleri üzerinden gerçekleştirmektedir. Çalışmanın model prototipi olan otomatik düğümler, kullanıcıların kargolarını teslim ettikleri/aldıkları kargo satış makinelerini temsil eder. Bu çalışma sayesinde kullanıcılar, varışlar arası seyahat ederken taşıyacakları kargoyu görüntüleyip seçebilecek ve kargo taşıyıcısı/sürücüsü olarak hareket ederek kazanç elde edebileceklerdir.

Anahtar kelimeler: Kargo yönetimi sistem modeli, A* algoritması, rota planlama, otomatik düğüm.

1. Introduction

Cargo transportation is an important development unit of the transportation and logistics sector. Cargo transportation aims to deliver goods or loads sent or carried by a transportation vehicle from one place to another safely and quickly. The processes of sending and receiving cargo have become a part of people's daily routine. People use cargo transportation as an interface to meet their needs. In this way, the transportation sector has become important in meeting the demands of customers. Transportation systems enable people to improve their quality of life on a global scale. It is also expected to provide environmental, social and economic benefits [1-4].

The transportation and logistics sector needs to use energy resources efficiently for sustainability. There is a direct relationship between transportation and energy. This relationship can be evaluated from a cost-benefit perspective. Transportation agents (passengers, cargo, information, etc.) need a proportional amount of energy. Energy consumption in the transportation sector accounts for more than 20% of world energy consumption [5-7]. Transportation activities can have harmful effects such as noise pollution, air pollution, traffic congestion, etc. It

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is heavily dependent on energy-intensive petroleum products, primarily gasoline and diesel. It causes greenhouse gas emissions and air pollution, which are the leading causes of global warming [8, 9].

The logistics sector is growing rapidly. Transportation systems need transformations that are compatible with time, cost, and environmental conditions [10, 11]. For this, it is necessary to use technology and digital platforms at a high level. In addition, it is very important to use artificial intelligence (AI) methods to keep up with the competition in the sector [12, 13]. Logistics companies can operate their management models more efficiently by using AI methods; for example, generating leads, maintaining customer and service relationships, and automating sales and marketing tasks [14-16]. AI-supported management models help logistics companies simplify complex structures, increase customer satisfaction, generate profits, and reduce environmental damage. In the logistics sector, computer-based computing is used to control and manage the flow of services throughout the supply chain [17, 18]. Shippers can optimize the transportation route between product locations and destinations. Many processes can be monitored using AI-powered data-driven analytics; for example, the safe delivery of shipments, anticipating potential problems, and preventing delays. AI offers significant advantages in route planning. For example, it can take into account many variables such as traffic density, weather conditions, and finding the shortest route. Unlike traditional route planning methods, it can optimize routes depending on the real-time conditions. In this way, delivery times of cargoes are reduced, and time and energy are saved.

This work aims to benefit users by proposing a cargo transportation management system considering time, energy and cost. With this system, users provide cargo transportation services and can earn green coin. Users carry out the cargo management and tracking processes on mobile and web interfaces. This work also presents a prototype model representing a cargo vending machine where users deliver/pick up their cargo. This study proposes a modern cargo transportation system. Users can observe transfer points with the suggested route planning algorithm. This system helps reduce environmental impacts by allowing routes that consume less fuel to be determined. It allows for more efficient use of routes and avoids unnecessary energy consumption. This both reduces costs and protects the environment. This study proposes a good infrastructure to increase competitiveness in the sector. It provides daily work opportunities to users, especially due to the increase in demand for the cargo sector with the spread of e-commerce. This model has a computer-based calculation method. Therefore, it is different from current cargo transportation systems. Another feature that distinguishes it from existing systems is that users can also be included in the system. In this way, the user earns green coin through the system as a cargo carrier.

In this model, the activities of the agents consist of the interaction between the cargo carrier and the user. The design and authorization of the nodes where users drop off and pick up their cargo provides the hardware infrastructure of this management model. This model uses an optimized A* algorithm for route planning. This algorithm minimizes unnecessary trips by utilizing existing traffic patterns, reducing both time and energy consumption. The system integrates mobile and web interfaces for real-time management and control, while also featuring automatic nodes as drop-off and pick-up points. Authorization at the drop off and pick up nodes of the cargo is carried out by the interaction of the cargo carrier and the user. By encouraging users to transport cargo along their pre-planned routes, the model promotes sustainable logistics operations.

As a contribution of this study; a) it encourages users to carry cargo along pre-planned routes, b) the model creates infrastructure for sustainable logistics operations, c) it is designed with a management system approach to reduce carbon dioxide emissions, d) the users of the system are also in the role of cargo carriers. If there is a user who is already going from one place to another, he can deliver cargo on his route. In this way, it both contributes to energy saving and earns green coin, e) it offers a scalable solution for future integration with green technologies such as electric vehicles.

The rest of this study is organized as follows: Section 2 offers a literature review of the technology-based transportation and logistics industry. The technology applied to this model and the developed methods are presented in Section 3. The parts of the cargo transportation system management model, the algorithm developed for the route planning, and the parameters of the model are explained in Section 4. Finally, the conclusions of this study are discussed in Section 5.

2. Literature Review

Studies suggest that computer-based computations combined with AI offer significant improvements to supply chain and logistics operations. Technology and high computational methods provide substantial benefits in logistics operations, including energy and cost savings, reduced workforce activities, increased security and quality of service, faster deliveries, optimized routes and customer satisfaction.

Transportation activities have negative impacts on the environment, such as noise and air pollution, traffic congestion, infrastructure erosion and carbon dioxide emissions, etc. [7]. The transportation sector has a significant impact on world energy consumption. Considering the environmental side effects of transportation activities, the methods to reduce energy consumption are needed to ensure sustainable growth of transportation sector [7, 19]. The increasing population in urban areas, directs the exploration of efficient ways of sustainable freight transportation. The intensive use of the existing infrastructure by transportation activities reveals the need to increase urban delivery points [20, 21]. Energy management methodologies, incentives the adoption of hybrid vehicles and models for delivery time are suggested for energy and cost savings in the sector [22-25]. The effect of pollutant emissions on the route planning of vehicles enables the design of new route models and the development of optimization algorithms [26].

As in other sectors, it becomes a necessity to take advantage of AI for operational competence in terms of productivity, efficiency and speed in the transportation sector. AI systems facilitate many processes, such as supply chain planning, automation, capacity planning, dataset analysis, etc. One of the most popular applications of AI techniques has been towards solving transportation network design problems. These problem classes include traveling salesman problem (TSP), vehicle routing and scheduling, minimum spanning tree, load aggregation, intermodal connection and road network problems [27, 28]. Other applications of AI in the transportation sector can be listed such as logistics planning, warehousing management system, software robots, autonomous robots, damage detection, self-driving vehicles, automating document processing, etc. [29].

Today, different measures are being investigated to solve the problem of a sustainable urban cargo transportation [13, 30]. Studies in the literature indicate that the load capacity is an important parameter in the inclusion of electric vehicles in the load carrying system [31, 32]. Electric and hybrid vehicles have shown potential to reduce fuel consumption and emissions, particularly when integrated into urban freight transport systems [33]. Heavy vehicles used in transportation both cause air pollution and adversely affect urban life [34]. This model offers a solution to reduce the vehicle traffic network of cargo companies.

Examining similar studies reveals that the program known as Amazon Flex allows Amazon to expand its distribution network, increase deliveries during high demand periods such as ”Black Friday” and speed up relevant delivery for customers [35]. Amazon Flex, where people have the chance to earn additional income in various countries such as United States of America, was established as a subsidiary of Amazon with its own package distribution system. It is an application that mediates customers to pick up products they purchased from online retailers, employs them as courier-mediators, and provides income for users. Uber Freight is a platform that connects truck drivers with companies that need cargo delivered. Similar to this model, it optimizes routes and cargo transportation based on real-time demand. While Uber Freight is more focused on professional truck drivers rather than everyday users, the core idea of optimizing routes and reducing inefficiencies in the logistics process aligns with this approach [36]. CargoX is a blockchain-based platform for smart bill of lading (B/L) management. It allows for more secure and efficient cargo transportation by automating documentation processes, ensuring faster and more transparent logistics. CargoX focuses on document management and security in logistics. Shiply is an online marketplace where people can list items they need to transport, and transport providers offer quotes [37]. The model encourages transport providers to take on additional deliveries along their existing routes, reducing the need for extra trips. This allows to users to act as cargo transporters along their own routes. Convoy is a digital freight network that uses technology to improve the efficiency of truckloads by optimizing the routes drivers take. Convoy employs machine learning to reduce empty miles (when trucks drive with no cargo) and to maximize route efficiency [38].These examples offer similar features to our proposed system for optimizing cargo transportation in terms of technology, user involvement, and environmental sustainability. There is a need to a management model to eliminate or minimize the adverse factors encountered during transportation activities. A transportation management model must consider many factors; energy and cost savings, customer supply demand, a sustainable supply chain, and an efficient transportation process. This proposed system proposes a management model to cover all these components.

3. Technique and Technologies

In this study, a RESTful API based Python Flask application was used to build a management system. Representational State Transfer (REST) is an architectural style that uses HTTP methods for communication between client and server. The RESTful API allows for easy communication between different components of the system. It enables the development of a flexible and modular architecture. In the proposed model, the RESTful API facilitates communication between different components like the mobile and web interfaces with the central server. Google Maps API was integrated into the system to provide a range of location-based services such as route planning and tracking of cargo shipments. The API allows cargo transporters to display maps, plot locations and create routes on the map. To create alternative routes for the model, an optimized A* algorithm was developed. This algorithm facilitates more efficient and cost-effective transportation planning by considering factors such as traffic, weather conditions, and road closures. To further improve the scalability and reliability of the system, the server application was packaged as a docker container and run it on an auto-scalable server using Kubernetes. This allows the system to automatically scale up or down as the number of users and cargo shipments increases or decreases, providing a more efficient and cost-effective solution. MYSQL, a relational database management system, was implemented as a Docker container. Docker is a containerization platform that allows packaging of the application and its dependencies into a single container, making it easier to deploy and run the system on different environments without compatibility issues. In this model, Docker is employed to package the server application, ensuring that the system is portable, secure, and easy to deploy on different infrastructures. By using the Docker, it is possible to have full control over the data and to ensure system security and reliability. The database can be easily scaled as needed to accommodate the growing number of users and cargo shipments.

In the mobile module of the system, the Android Studio platform was used to create android applications. This platform provides a comprehensive set of tools for developing, debugging and testing android applications. To ensure the security of user data, data encryption techniques were implemented. This means that the user data stored on the mobile device or on the server is encoded. It can only be accessed by authorized parties with the correct decryption key. This added security measure helps to protect the sensitive information of users and prevent any unauthorized access or breaches. A Raspberry Pi was used as the mechanism to control the nodes to simulate the system.

4. System Management Model

The system management model includes four main components; server, automatic node, web and mobile parts (Figure 1).

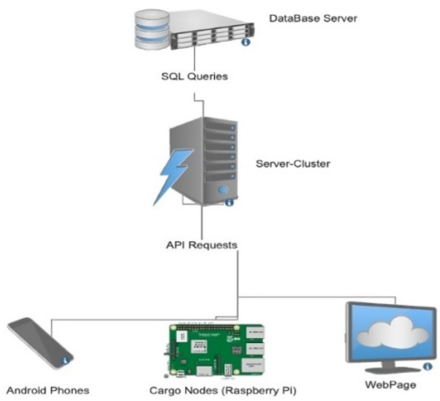

Figure 1. The prototype of system management model.

The server part is a central component of the system that constructs the communication network of all other components. The database management system stores the data which includes the information of the cargo's characteristics, cargo owner, cargo transporter (driver) who will carry the cargo, cargo recipient, latitude and longitude information of nodes and user information. User encompasses all roles: cargo sender, cargo receiver, and transporter. A single account can serve as a cargo sender, cargo receiver, and cargo transporter. Cargo transporters are users who take on the role of delivering cargo along their routes. There are no additional conditions or requirements to be a transporter. Users are incentivized through the system to transport cargo to designated nodesThe automatic node defines drop-off and pick-up points for the cargo shipments. The nodes communicate with the central API to access the necessary information about which cargo node box should be opened and closed at a specific time. This means that the correct cargo is delivered to the correct destination and at the right time.

Android, web and mobile parts send a request to the server by the RESTful API. Since all devices communicate through a single server, it will create a bottleneck at the port, thus the server is divided into three nodes. Server-node modules are shown in Figure 2. Requests to the server are distributed to three different nodes by the load balancer. Load balancing refers to distributing incoming network traffic across multiple servers to enhance the performance and reliability of the system. In this system, the load balancer is crucial to handling the high volume of user requests efficiently, particularly when multiple users are accessing the system simultaneously. In this way, having a load balance enhances the working performance of the application. For example, in cases of multiple user login and executing A* algorithm in map route calculation.

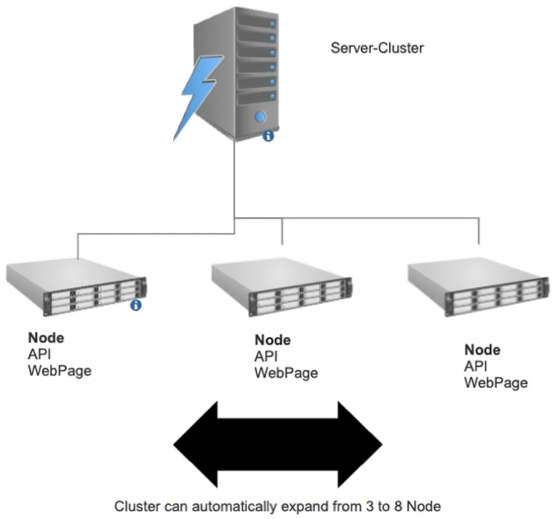

Figure 2. Auto scaling structure of the clusters.

In this model, there is an interaction between users and cargo transporters. New users can register through the mobile application, while existing users can log in. Loggedin users can add cargo and ensure that their cargo is shipped. Users can leave the cargo at the specified node after registering the cargo, this cargo is again taken by another user to the node where it needs to go, and finally, the recipient picks up the cargo from the node using the mobile application.

In the web application, users can register in the application or, if they are already registered, they can log in. Once logged in, they will have access to their active cargo information. They will be able to view details such as the origin, destination and status of the shipment. Additionally, users can view their balance and star rating within the application on their profile pages. This will give them an overview of the green coin they have earned from transporting cargo, and their reputation as a reliable and efficient transporter. Furthermore, users who will carry out cargo transportation will be able to reserve the cargoes they want to transport by the website with the developments to be made in the future. This will allow them to plan their cargo transportation schedule in advance and book cargo shipments according to their availability and preferences.

The mobile application works directly connected to the server with the API. Operations such as route calculation and shipping fee calculation are not performed in the mobile application, these operations are calculated on the server side by adding the current status to the equation and they communicate using the Restful API. During communication, if user information (login, registration, address, etc.) is to be transferred, this information is encrypted, and user passwords are kept encrypted in the database. The functions of the mobile application include creating a new user account, logging in with an existing account, and displaying the user's balance and star rate. The mobile application consists of two parts: the user module and cargo transporter module.

The user module performs the following functions:

- Adding new cargo to the system for transfer
- Ensuring the node control for leaving the cargo to be transferred to the cargo node (authorization to open and close the appropriate box of the node to be delivered)
- Having the node control authorization to track whether the cargo has been delivered and to pick up the cargo

The cargo transporter performs the following functions:

- Specifying the route to go and listing suitable cargoes
- Selecting the cargoes to be transported and getting node control authorization
- Tracking the nodes that need to be visited on the map

Automatic nodes are cargo vending machines where users deliver or pick up their cargo. They can be controlled by the mobile application. The node communicates with the server at certain intervals, and opens/closes the required box when an authorized person wants to access a box. If it notices a change in the status of the boxes through communication with the node server, it gives feedback on the LCD screen and performs the necessary operations using the servo library. The cargo node activity class diagram is shown in Figure 3.

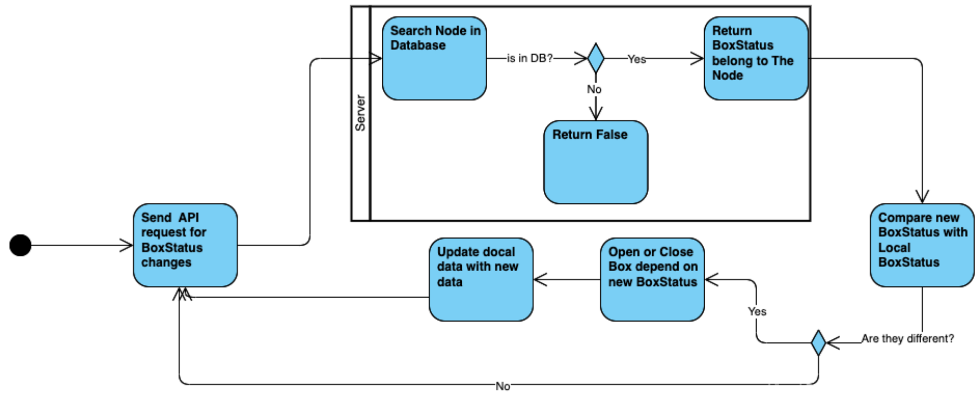

Figure 3. Authorization at the drop off and pick up nodes of the cargo.

4.1 Route Planing: Optimized A* Algorithm

The A* algorithm was optimized to filter for the extra mile and reduce workload. Even if the round trip distance between the nodes is the same, it is critical whether the driver is on the route or not. For this reason, a rewards matrix is created that also takes into account the direction, allowing for the calculation of the most appropriate route without the driver going in the opposite direction. The reward matrix is used to optimize route planning by evaluating the most profitable routes for the cargo transporters. It considers various factors such as distance and the value of the cargo. The matrix is dynamically generated before each route calculation to ensure that the optimal path is chosen for cargo transportation. The parameters of the A* algorithm are presented in Table 1.

Table 1. The parameters of the A* algorithm.

Parameters	Description
Source node	Initial point
Destinitation node	End point
Map	Calculates the optimum distance between two or more points given the coordinates
DB	Provides the connection with the database that holds the coordinates of the nodes and the cargo information. Gets a list of nodes and cargoes in the system before each route calculation
Base distance	The distance between source node and destination node, used as a benchmark when calculating alternative routes, stores data in kilometers
Nodes	Holds nodes to be used for route calculation
Rewards	Keeps the value of cargoes between nodes in matrix form
Gasoline price	Represents the current gasoline price
α	Gain parameter (used as a hyperparameter when calculating the income of the cargo, a bigger value of α increases the value of cargoes, allowing more distant nodes to be included in the route, a smaller value of α is the reverse

An example of reward matrix is shown in Table 2. The numbers in Table 2 represent the nodes, the numbers in column 1 indicate the starting point, the numbers in row 1 indicate the end point. For example, the value of cargo that will go from Node 2 to Node 3 is 22, and the value of cargo that will go from Node 3 to Node 2 is 55. As cargo values at nodes may change over time, this matrix is regenerated before the calculation. Reward matrix is created by following these steps:

- In the first step, nodes that extend the distance beyond the initially determined route by the user are pruned. This way, routes that the user technically cannot travel are not calculated, saving processing power.
- In the second step, the values of the cargos between the remaining nodes are calculated (the calculation formula can be found in the article). This calculation is basically created by subtracting the costs of the additional distance added to the route from the earned fee. At this point, the results can be normalized by adding an extra control variable. During the calculation, the nodes are visited sequentially, and the cargo values between all the nodes that remain after the pruning process are calculated.

- In the third step, the most efficient route is calculated using the A* algorithm and the reward matrix, and then presented to the user.

Table 2. An example of the reward matrix.

Node	1	2	3	4
1	-	20	50	-
2	-	-	22	90
3	30	55	-	-
4	-	20	36	-

The algorithm running process is described below.

- Base distance is calculated using the source node and destination node information provided by the user. Base distance refers to the benchmark distance between the source and destination nodes in the route planning process. It is used to filter out nodes that are too far away to be included in the optimal route, reducing unnecessary calculations.
- All up-to-date node information is pulled from the database.
- Nodes that are farther from the source node or destination node than the base distance are excluded from participating in the route calculation, thus preventing the algorithm from performing unnecessary calculations for nodes that are unreasonably far away to go.

An example of calculation model of the route planning is shown in Figure 4.

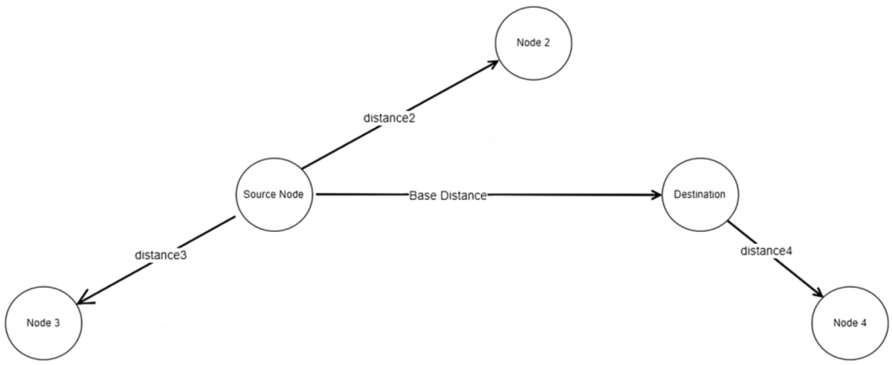

Figure 4. An example model of the cargo transportation between nodes from source point to destination point.

If the base distance is greater than distance 2 and distance 4 and if it is less than distance 3, node 3 is eliminated without being included in the reward matrix. It is navigated through the remaining nodes, and Equation 1 is applied during this navigation.

$$val = rewards(current\ nodes) - (|base\ distance - distance\ between\ current\ nodes|)\ x\ gasolinePrise\ x\ \alpha \quad (1)$$

If $val > 0$, it indicates that it will be profitable to go to the node and the node is added to the route list. After the navigation process is completed, the cargoes are retrieved from the database for the nodes in the route list. During this process, any cargo that can be found in intermediate nodes is checked. The result for the route and cargo calculated by A* algorithm is as shown Equation 2 and 3.

$$routes = [Source\ node; Node2; Node4; Destination\ node] \quad (2)$$

$$cargoes = [Source\ node\ toNode2;\ Source\ node\ toNode4;\ Source\ node\ toDestination\ node; Node2\ toNode4; Node2\ toDestination\ node; Node4\ toDestination\ node] \quad (3)$$

In this way, maximum efficiency is obtained for each node visited. This process can be optimized. The algorithm can be run recursively as intermediate nodes, Source and Destination. For example: Since Node 2 and Node 4 will be visited already, Node 2 and Node 4 can be given as Source and Destination Node and the algorithm can be run again. In this case, by changing the value, the number of nodes can be prevented from increasing too much in each recursion.

The definations in the algorithm for an example scenario are given below.

- User A (UA): Cargo Sender
- User B (UB): Cargo carrier
- User C (UC): Cargo Receiver
- Server (SV): Backend application designed to communicate with mobile applications via Rest API, implemented as a Docker container, scalable with Kubernetes
- Node A: Node where User A drops off the cargo
- Node B: Node where User B stops to pick up additional cargo
- Node C: Node where User C receives the cargo

The algorithm steps for an example scenario are shown in Table 3.

Table 3. The algorithm steps of the model for an example scenario.

UA Step 1: User A registers the cargo in the system. During the registration process, details such as dimensions, weight, type of cargo, and the delivery node are requested.
SV Step 2: The server calculates the value of the cargo based on the provided details and grants User A access to Node A.
UA Step 3: User A uses the mobile application to place the registered cargo into Node A.
SV Step 4: The cargo placed in Node A becomes visible to Cargo Carriers.
UB Step 5: User B selects the start (Node A) and end (Node C) points on the map via the mobile application.
SV Step 6: The server lists the cargos going from Node A to Node C and calculates the reward.
SV Step 7: The server calculates alternative routes for User B: - First, it filters based on the total distance the user will travel, which allows interaction with nodes close to and along the user's likely route. - Then, it creates a Reward Matrix using the distances between nodes and the values of the cargos within them. - The Reward Matrix is processed with the A* algorithm to generate the most profitable alternative route for User B (In this scenario, it determines that stopping at Node B to pick up cargo and delivering it to Node C is more profitable).
UB Step 8: User B selects the alternative route that includes Node B.
SV Step 9: The server grants User B authorization to pick up cargo from Node A and Node B.
UB Step 10: User B uses the mobile application authorization to pick up the first cargo from Node A.
UB Step 11: User B uses the mobile application authorization to pick up the second cargo from Node B.
SV Step 12: The server grants User B access to Node C to deliver the cargos.
UB Step 13: User B uses the mobile application authorization to deliver the cargos to Node C.
SV Step 14: The server sends notifications via the mobile application to the necessary users to collect their cargos and grants authorization for Node C.
SV Step 15: The server transfers the earned reward to User B.

In route planning, the extra distance to be traveled is used as a parameter rather than direction. If the additional distance is beneficial for the user, it is added to the route. For a node in the opposite direction, the extra distance will be traveled both to and from, which will decrease its value in the reward matrix. Therefore, it is unlikely that a route in the opposite direction will be presented to the user. However, an additional parameter can be used to further reduce the cargo value if the cargo is in the opposite direction.

Alternative routes specified for the cargo nodes between the source and destination nodes in the application shown in Figure 5 are also displayed to the user on the map.

The nodes indicated in the application in Figure 5 are the districts of Izmir in the Aegean region of Türkiye. The application runs with real data.

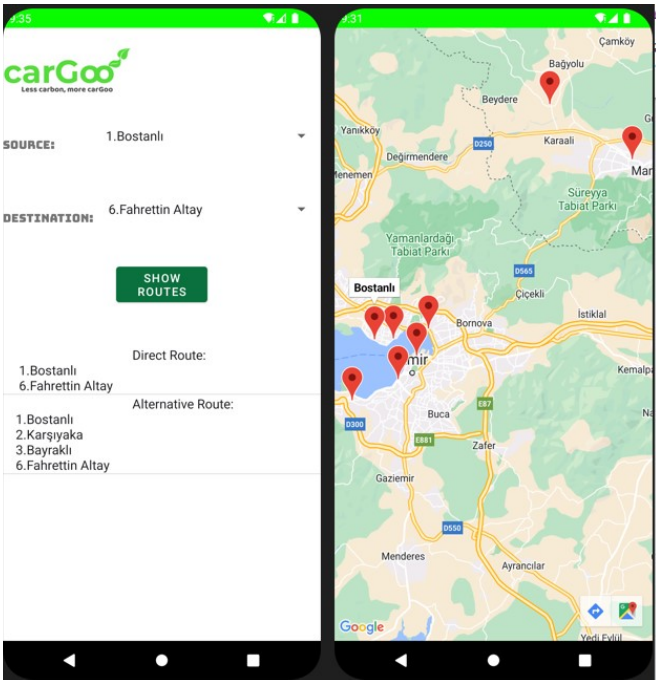

Figure 5. The route planning listed by the algorithm on the web application.

4.2 Characteristics of System

Three important interrelated agents are identified in the model. These agents and the system characteristics are given in Table 4.

Table 4. The parameters of the system model.

Agents	User/Cargo transporter	Cargo	Node
Agents' attributes	id national id mail password name lastname phone balance star	id type weight volume	id name latitude longtitude
Events	sign in/sign up to the system	reception/delivery	node box open/close
Activity	login submition of new cargo taking the cargo selection of the route map activity listing the cargo	transferring	access
System's state	the number of the user max. optimum route	the number of cargo map information	the number of the node

As indicated in Table 4, the diagram of the user activites are given below.

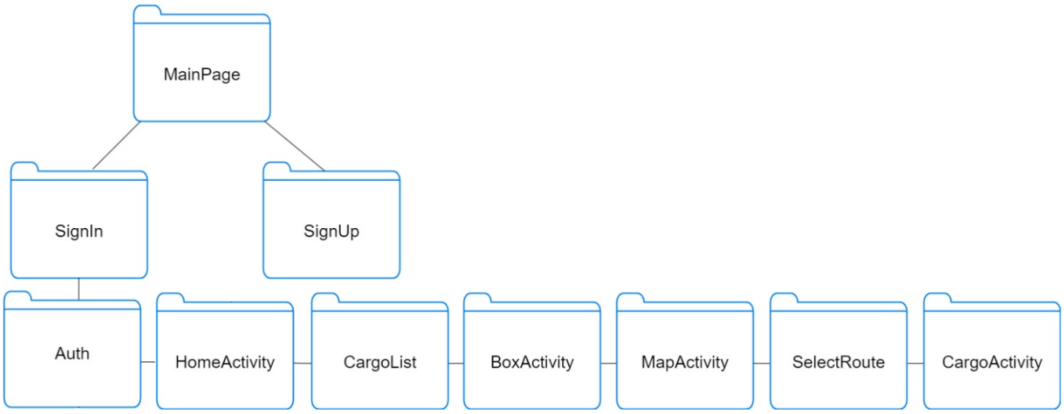

Figure 6. The diagram of user management model.

In Figure 6, the actions to be performed by the user are defined in the user class by entering the user properties into the system. After the user saves his one-time user information, he can log in or update the system with his user id and password. After the user enters the cargo information (receiver information, the cargo type, the cargo size, the cargo delivery-destination node, etc.) on the mobile application, the cargo is introduced to the system. When the user leaves the cargo to the node box, it enables the node box to be opened over the cargo registered in the system. After leaving the cargo in the box, the node cover is closed. Figure 7 shows the relationship between the cargo and the node in the cargo transfer process by API.

After the user delivers his cargo to the node box, the cargo will start to be listed in the driver section of the system. Another user (cargo transorter-driver) in the system can list the cargoes on the route to be taken from this driver section. The A* algorithm can show the user new routes over the cargo nodes between the source node and destination node. By using these routes, the user can earn from cargo transfer. The user's earnings in cargo transfer are represented by the star index. The star index is a performance evaluation metric for users acting as cargo transporters. It reflects the efficiency and reliability of the transporter, with higher star ratings indicating better performance in terms of timely and safe deliveries. For example, the delivery of the cargo before the time predicted by the A* algorithm increases the star index.

The user defined as the driver in the cargo transfer delivers the cargo on his route to the cargo node boxes at the destination. The cargo recipient can receive his cargo from the node box with his user id and node id in the system.

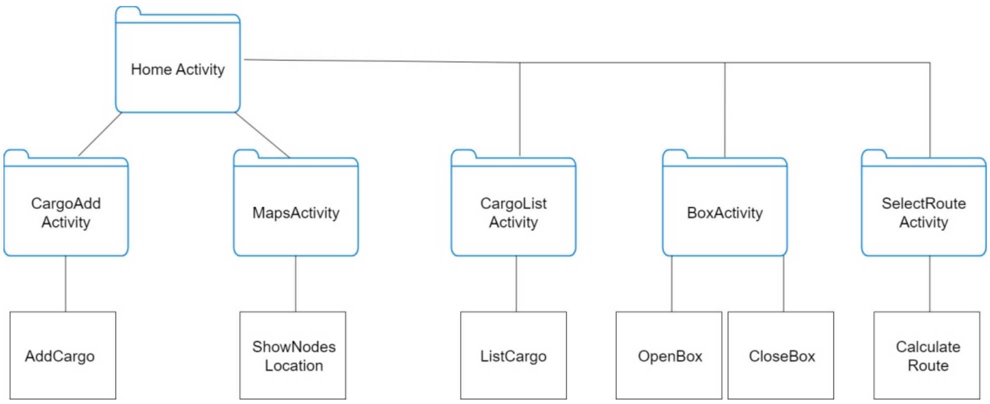

Figure 7. The diagram of cargo transferring management model.

All activities indicated in Figure 7 can be carried out easily by mobile. Mobile, web and node parts cannot access the database directly. The database management system works by sending a request to the server by API that runs this system.

Parameters of the mobile application are indicated in the table below.

Table 5. The description of cargo parameters on the mobile application.

Parameter	Description
Receiver mail	The user defines the e-mail address of the recipient side, cargo information is transmitted via this e-mail.
Cargo weight	The cargo weight information is defined
Cargo capacity	The physical volume information of the cargo.
Cargo type	The category of cargo (for example, electronics, food, toys, medicine, clothes, etc.)
Source node	The point of shipment
Destination node	The destination of the cargo
User index (star)	The confidence index of cargo transport users

After defining the user and the cargo information, the cargo delivery process begins. The cargo parameters on the mobile application are shown in the Figure 8a below. In Figure 8b, the cargoes submitted by the user are listed. This list includes cargo type, cargo size and volume, cargo delivery point, and cargo destination information. Figure 8c shows a user's operation panel. The user can add a new cargo, list the cargoes on his route, and start the cargo transportation (driver) operations through this panel. The user can earn the green coin from cargo transportation, and can increase the star index according to the transportation performance. The higher the star index of a user, the safer and faster transportation service it provides.

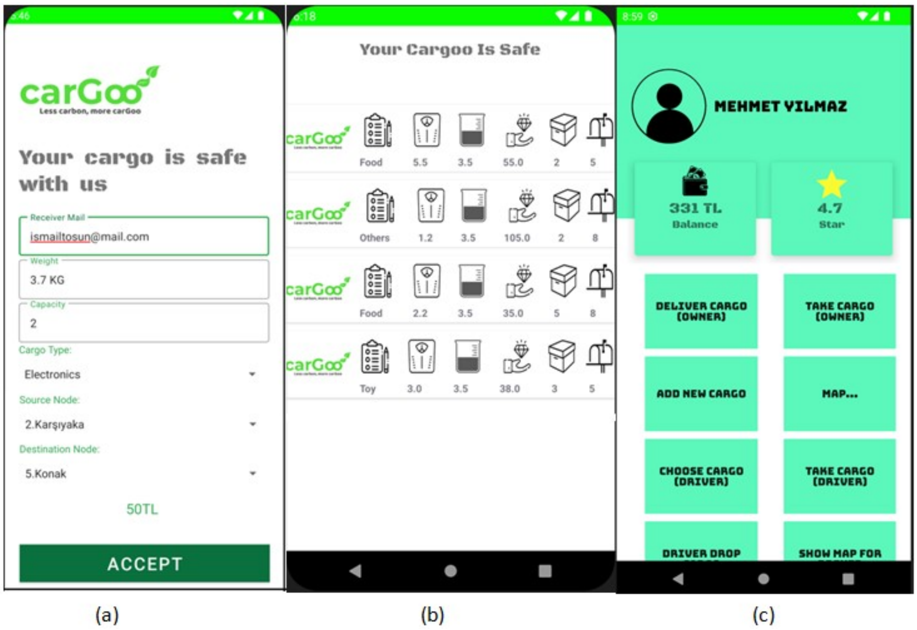

Figure 8. The mobile interface of the model **a)** Cargo information panel, **b)** Cargo properties, **c)** The user interface.

5. Discussion and Conclusions

This study presents a management model that will contribute to cargo transportation in the transportation sector. Intelligent route planning proposed in this model provides optimum savings in terms of time and energy. Considering the impact of cargo transportation on environmental factors, an eco-friendly model is proposed to reduce the cost of environmental damage. An interactive user-driver model emerges with the easy management model offered to users. Automatic nodes, which form an important part of the proposed model, provide delivery and receiving service nodes of the cargo. These nodes are managed from the mobile interface with the user encryption system, which is controlled the user's authority and cannot be accessed by other users.

The advantages of this study are as follows; 1) it is an economical transportation system management model where users will make a profit, 2) an effective route is planned through the system model with the A* algorithm, 3) in case of any server loss, the system continues to operate without being affected. Because there are load balancers on more than one server against server infrastructure problems, 4) the node infrastructure can be reproduced, 5) it is packaged and distributed using Docker containers to accommodate possible different hardware infrastructures in the future, 6) it includes users in the system. They have a role of cargo carrier, 7) it provides a reference model for smart logistics systems.

The disadvantages of this study are as follows; 1) Learning Curve: initial learning curve associated with adapting to a new cargo transportation system. Users may need time to understand how the system operates, including managing routes, tracking deliveries, and navigating the mobile or web interface. 2) Time Management: for users acting as cargo transporters, balancing their personal travel plans with cargo deliveries could pose a challenge. If the timing and routes of deliveries are not aligned with users' own schedules, this may create inconvenience, reducing the system’s appeal. Managing multiple deliveries simultaneously could also be overwhelming for some users. 3) Increased Responsibility: taking on the role of a cargo transporter adds an extra layer of responsibility for users. They must ensure the safe and timely delivery of the cargo. The potential risk of damage or loss of cargo could discourage participation. 4) Infrastructure Limitations: users in areas with poor infrastructure, such as limited GPS coverage or unreliable mobile networks, may experience difficulties using the application efficiently. This could result in inaccurate route tracking or delays in delivery updates, impacting user experience and satisfaction. 5) Legal and Safety Concerns: users might face legal concerns, such as liability for damaged or lost cargo. Without clear guidelines or insurance policies, users may hesitate to participate due to potential risks. Additionally, safety concerns during the pick-up and drop-off process, particularly in unfamiliar locations, might discourage user engagement.

While the proposed model offers significant benefits in terms of energy savings and route optimization, it has some limitations. The model depends on user participation, which may lead to inconsistent performance if user engagement is low. Additionally, the model assumes a robust urban infrastructure, limiting its applicability in rural or underdeveloped areas. The system also lacks provisions for handling specialized cargo types, such as hazardous materials, which would require additional safety and regulatory measures. This model has an abstract framework. It can be adapted and scaled to various regions, and run more complex cargo operations. However, it would require additional considerations, including infrastructure, legal regulations, and operational complexities. It may be necessary to invest in local partnerships In regions where infrastructure is lacking. When scaling to new regions, the model would need to comply with local laws, including cargo insurance requirements, liability policies, and environmental regulations.

Proposed solutions and preventive measures for improving the system can be evaluated as follows; 1) User-Friendly Interface and Training: to minimize the learning curve, the application should feature an intuitive and user-friendly interface. Additionally, onboarding tutorials, instructional videos, and customer support services can help users quickly understand the system. Providing ongoing support will ensure users feel confident in using the platform. 2) Flexible Scheduling and Route Optimization: to address time management concerns, the system can allow users to select deliveries that fit within their existing travel plans. Additionally, incorporating flexible scheduling and route optimization based on user preferences will make it easier for users to balance personal and cargo-related tasks. 3) Cargo Insurance and Safety Measures: offering cargo insurance and clear guidelines for handling cargo can reduce the burden of responsibility on users. By implementing digital verification processes for cargo pick-up and drop-off, such as barcode scanning or signature verification, the system can ensure accountability and security, thus easing users' concerns. The risk of unauthorized access can be significantly reduced by implementing two-factor authentication (a verification code sent to the user's mobile device). 4) Offline Mode and Infrastructure Investment: in areas with poor infrastructure, the application could include an offline mode that allows users to continue using the system without a strong internet connection. Once connectivity is restored, the system can sync data automatically. Additionally, investing in partnerships with local infrastructure providers could improve GPS accuracy and network reliability. 5) Clear Legal Guidelines and User Safety: providing clear legal guidelines, such as terms of liability and comprehensive insurance policies, will help address users' legal concerns. Offering safety tips for handling deliveries and ensuring secure pick-up and drop-off points can also encourage users to feel safe and comfortable using the system.

Sustainable transportation can be achieved within the scope of the following strategic issues emphasized by this study; using electric and low carbon footprint tool, efficient routes and loading planning, packaging and waste management, safety and insurance [39-42]. This study also highlights operational challenges and obligations: (a) renewing the vehicle fleet as much as possible with electric or low carbon footprint vehicles in order to minimize the emission of environmentally damaging greenhouse gases, (b) minimizing fuel consumption by using optimized routes, (c) using high-capacity transport methods and intelligent loading planning, (d) encourage customers to prefer their cargo packaging materials with sustainable and recyclable materials, (e) taking the necessary security measures for the safety of the transported cargo, and (f) gain the trust of the customers by providing appropriate insurance policies.

In real-world implementation, the usability of this model depends largely on the suitability of urban infrastructure and the availability of technical support. For the system to be successfully adopted, cities need to have a widespread mobile communication infrastructure and GPS-supported systems. Additionally, there must be a sufficient number of users. The system should be backed by user-friendly interfaces to ensure that users can easily manage their cargo and routes. In the future, integrating the system with green technologies, such as electric vehicles will further enhance the environmental sustainability.

The widespread use of electric and hybrid vehicle technology allows parameter tuning in the route planning algorithm proposed in this study. Defining the cargo type information on the application provides a classification label for the recycling of cargo packages. Also, defining cargo size information on the application can create a data set for load planning and utilization capacities of the node boxes. The model has the potential to run dynamically when infrastructure is provided in local areas. It is important to develop such application models to promote the desired transition towards more sustainable energy sources in the logistics and transportation sector.

This study is recommended that the model be tested with different parameters. Specifically, the impact of factors such as the size and diversity of the dataset, as well as real-world user scenarios, could be evaluated. Additionally, states such as processing volume, changes in the number of users, and the system's performance under different network conditions should be taken into account to enable a more comprehensive analysis of the results. Such extended analyses would provide a clearer understanding of the model's effectiveness in real-world applications. In future works, a global-scale application with a wider logistics network can be considered by strengthening the infrastructure of this model. Expanding the model to accommodate different types of cargo and regions with varying infrastructure will be critical for scalability. Integrating advanced technologies, such as machine learning for predictive analytics and electric vehicles for greener logistics, could enhance the model's performance. Furthermore, conducting real-world pilot tests will provide insights into practical challenges and help refine the system for broader adoption. A comprehensive financial analysis for this system can assume that including development expenses for software, infrastructure setup (servers, data storage), and integration of GPS and mobile technologies, and hardware costs (mobile devices, sensors).

References

[1] Smirnov SA, Smirnova OY. Magnetic Levitation Cargo Ransport Role in World Economy, Transportation Systems and Technology, 2019; 5(2), 106-117.

[2] Prokofieva E. Review of research in cargo transportation reliability, E3S Web of Conferences, 157, 05008, 2022,

[3] Amiri-Khorheh M, Moisiadis F, Davarzani H. Socio-environmental performance of transportation systems, Management ofEnvironmental Quality: An International Journal, 2015; 26, 826-851.

[4] Schodl R Eitler S, Ennser B, Breinbauer A, Hu B, Markvica K, Prandtstetter M, Zajicek J, Berger T, Pfoser S, Berkowitsch C, Hauger G. Innovative means of cargo transport: A scalable method for estimating regional impacts, Transportation Research Procedia, 2018; 30, 342-349.

[5] Rodrigue JP. Transportation and Energy (Chapter 4). The Geography of Transport Systems, 5th ed., 2020.

[6] Oubnaki H, Haouraji, C, Mounir, B, Mounir, I, Farchi, A. Energy Consumption in the Transport Sector: Trends and Forecast Estimates in Morocco. E3S Web of Conferences 336, 00078, 2022.

[7] Juan AA, Mendez CA, Faulin J, Armas J, Grasman SE. Electric Vehicles in Logistics and Transportation: A Survey on Emerging Environmental, Strategic, and Operational Challenges. Energies, 2016; 9(2), 86,

[8] Speranza MG. Trends in transportation and logistics, European Journal of Operational Research, 2016; 264(3), 830-836.

[9] Figliozzi M. Vehicle routing problem for emissions minimization, Transportation Research Record 2010; 2197(1), 1–7.

[10] Berechman J. Urban and regional economic impacts of transportation investment: a critical assessment and proposed methodology. Transportation Research Part A: Policy and Practice, 1994, 28(4), 351-362.

[11] Zubkov V, Sirina N. Improvement of Cargo Transportation Technology in Rail and Sea Traffic. In: Popovic, Z., Manakov, A., Breskich, V. (eds) VIII International Scientific Siberian Transport Forum. TransSiberia, 2019. Advances in Intelligent Systems and Computing, 2020, 1116. Springer, Cham.

[12] Kern J. The Digital Transformation of Logistics: Demystifying Impacts of the Fourth Industrial Revolution, A Review About Technologies and Their Implementation Status (Chapter 25), 2021.

[13] Ivanov D, Dolgui A, Sokolov B. The impact of digital technology and Industry 4.0 on the ripple effect and supply chain risk analytics, International Journal of Production Research, Taylor & Francis Journals, 2019; 57(3), 829-846.

[14] Gesing B, Peterson SJ, Michelsen D. Artificial Intelligence in Logistics, DHL Customer Solutions & Innovation, 2018, DHL CSI, 53844 Troisdorf, Germany.

[15] Soltani ZK. The applications of artificial intelligence in logistics and supply chain, Turkish Journal of Computer and Mathematics Education, 2021; 12(13), 4488–4499.

[16] Adıgüzel S. Use of artificial intelligence in logistics management, Proceedings of the 1st International Conference on Interdisciplinary Applications of Artificial Intelligence, 2021, pp. 17– 25.

[17] Boute RN, Udenio M. Ai in logistics and supply chain management, 2021.

[18] Toorajipour R, Sohrabpour V, Nazarpour A, Oghazi P, Fischl M. Artificial intelligence in supply chain management: A systematic literature review, Journal of Business Research, 2021; 122, 502–517.

[19] Sinha K, Labi S. Transportation Decision Making: Principles of Project Evaluation and Programming, JohnWiley & Sons, New Jersey, NY, USA, 2007.

[20] Grimm N, Faeth S, Golubiewski N, Redman C, Wu J, Bai X Briggs, J. Global change and the ecology of cities, Science, 2008; 319(5864), 756–760.
[21] Schliwa G, Armitage R, Aziz S, Evans J, Rhoades J. Sustainable city logistics — making cargo cycles viable for urban freight transport, Research in Transportation Business & Management, 2015; 15, 50–57.
[22] Nüesch T, Cerofolini A, Mancini G, Cavina N, Onder C, Guzzella L. Equivalent consumption minimization strategy for the control of real driving nox emissions of a diesel hybrid electric vehicle, Energies, 2014; 7(5), 3148–3178.
[23] Colin G, Chamaillard Y, Charlet A, Nelson-Gruel D. Towards a friendly energy management strategy for hybrid electric vehicles with respect to pollution, battery and drivability, Energies, 2014; 7(9), 6013–6030.
[24] Chen Z, Xiong R, Wang K, Jiao B. Optimal energy management strategy of a plug-in hybrid electric vehicle based on a particle swarm optimization algorithm, Energies, 2015; 8(5), 3661–3678.
[25] Hwang T, Ouyang Y. Urban freight truck routing under stochastic congestion and emission considerations, Sustainability, 2015; 7(6), 6610–6625.
[26] Bektas T, Laporte, G. The pollution-routing problem, Transportation Research Part B: Methodological, 2011; 45(8), 1232–1250.
[27] Min H. Artificial intelligence in supply chain management: theory and applications, International Journal of Logistics Research and Applications, 2010; 13(1), 13–39.
[28] Karur K, Sharma N, Dharmatti C, Siegel JE. A survey of path planning algorithms for mobile robots, Vehicles, 2021; 3(3), 448–468.
[29] Dilmegani C. Top 15 use cases and applications of ai in logistics. https://research.aimultiple.com/logistics-ai/ Accessed 19 August 2023.
[30] McKinnon AC. Preparing Logistics for the Low-Carbon Economy. In: Merkert, R., Hoberg, K. (eds) Global Logistics and Supply Chain Strategies for the 2020s. Springer, 2023.
[31] Altunsoy U. An investigation on the use of electric vehıcles in the cargo transport system, International Anatolia Academic Online Journal Sciences Journal, 2021; 7(2), 1–14.
[32] Nathanail E, Papoutsis K. Towards a Sustainable Urban Freight Transport and Urban Distribution, Journal of Traffic and Logistics Engineering 2013; 1(1), 58-63.
[33] Arif SM, Lie TT, Seet BC, Ayyadi S, Jensen K. Review of Electric Vehicle Technologies, Charging Methods, Standards and Optimization Techniques. Electronics, 2021; 10(16):1910.
[34] Aydın GT, Öğüt KS. Logistic villages in Europe and Turkey, Proceedings of the 2nd International Railway Symposium, 2008, pp. 1471–1481.
[35] Amazon Flex. Website https://flex.amazon.com/ Accessed 18 September 2024.
[36] Uber Freight. Website https://www.uberfreight.com/ Accessed 18 September 2024.
[37] CargoX. Website https://cargox.io/ Accessed 18 September 2024.
[38] Convoy. Website https://convoy.com/ Accessed 18 September 2024.
[39] Kaplanseren B, Mercan B, Özdemir B., Kadıoğlu HH, Sel C. Carbon footprint in vehicle routing and an industrial application, International Journal of Engineering Research and Development, 2019; 11(1), 239–252.
[40] McBain B, Lenzen M, Albrecht G, Wackernagel M. Reducing the ecological footprint of urban cars, International Journal of Sustainable Transportation, 2018; 12(2), 117–127.
[41] Kumar A, Anbanandam R. Development of social sustainability index for freight transportation system, Journal of Cleaner Production, 2019, 210, 77–92.
[42] Chi G, Stone B. Sustainable transport planning: Estimating the ecological footprint of vehicle travel in future years, Journal of Urban Planning and Development, 2005; 131(3), 170–180.