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RESEARCH ARTICLE

Fleet Size and Mix Vehicle Routing Problem (FSMVRP), Adapted Large Neighbourhood Search Heuristic Optimization Proposal With a Plant-capacity and Multi-day Planning Algorithm: A Livestock Feed Industry Case Study

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ABSTRACT
The vehicle routing problem (VRP) is of great importance for feed factories that do not work with the dealership system. This is especially important in the Central Anatolian region, where customers' number of animals is low. Data used in the study came from the order data of a feed mill which operates in Turkey. Before selecting the most suitable VRP software vendor, the logistics manager of the plant was urged to analyse the results with the scope of percent fleet capacity used, service level (on-time deliveries), and total transportation cost incurred. As a requirement of the enterprise strategy, a multi-day planning algorithm was developed to level the daily production capacity of the factory while maintaining minimum transportation costs and maximum service level. It has been determined that better results are achieved with the developed multi-day planning algorithm for both methods of Simulated Annealing (SA), Genetic Algorithm (GA), and our Adapted Large Neighbourhood Search (ALNS) heuristic. The data set of the real-life problem that was used was applied to those three methods, and 0.45%, 0.81%, and 1.39% improvements were achieved using the methods, respectively.

Keywords: Vehicle routing problem, fleet size mix with time windows, multi-day planning, feed distribution, adapted large neighbourhood search

1. Introduction

Customer satisfaction is a result of multidimensional and hierarchical efforts, which companies have to satisfy simultaneously (C.-M. Liu, 2005). In the feed industry, where this case study is conducted, companies have to produce feed within the quality requirements (Citation, 2001) and deliver the final product on time with the desired vehicle at a competitive shipment cost (Hoff, Andersson, Christiansen, Hasle, & Løkketangen, 2010). On-time and minimum cost delivery stipulates time dependency (Zhang, Lam, & Chen, 2016), a cleverly balanced fleet mix (Sungur, Ordóñez, & Dessouky, 2008),(Hoff et al., 2010) and tight utilization of the capacity of the fleet. Managing all of these requirements requires robust planning of the supply chain. At the end of a planning day, one has to adapt the time frame for customer orders, fill the trucks up to the utmost capacity and respond to order revisions and minimise the total distance travelled. Because of the nature of the problem, it is a daunting task to code in-house software, even if the company has a strong IT department. This study aims to provide suggestions to practitioners for cost reduction and on-time delivery in multi-point feed distribution with a heterogeneous fleet. In order to make these suggestions and use them in real-life problems, the software has been designed to be used by the feed mill. SA, GA, and our ALNS algorithms were compared. Analysis was carried out during the design process of the software.

1.1. Objectives

In the literature search, to the best of my knowledge, there is no study that attempts to design a multi-day plan considering the daily shipping capacity in the feed industry. The main contribution of this study is that it creates a tool that enables multi-day planning taking into account the factory capacity while minimizing the total transportation cost with an acceptable deviation from

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the time windows. Based on the request of the enterprise where the case study was conducted, the above-mentioned algorithm has been developed.

1.2. Literature review

The study is organized as follows: a brief summary of the vehicle routing problem (VRP) literature and related variants of the VRP is given. In the second section, the problem definition for the feed industry is given. In the third section, the optimization model framework related to the SA, GA, and ALNS heuristics is explained as applied by the algorithm. Section 2.2 defines the multi-day planning algorithm in detail. The output of the VRP solutions and earnings gained from the method for the real data of the feed mill (multi-day order file, fleet mix, time dependencies) is compared for SA, GA, and ALNS algorithms in the results section. In the conclusion, inferences and future research directions are given according to the results and algorithm proposed.

1.2.1. Basics of Vehicle Routing Problem

VRP is one of the most frequently encountered topics in the supply chain management literature. The method was introduced first by Dantzig and Ramser (Dantzig, G. B., and Ramser, 1959). “The Truck Dispatching Problem” is defined as the generalization of the Travelling Salesman Problem (TSP) with more than one identical truck capacity. In the more than fifty years since the first study, the method has been improved to satisfy the real-world problem requirements with more than 100 constraints (Laporte, 1992). Some additional features are time windows (time intervals suitable for customer deliveries), and heterogeneous VRP, which deals with the capacitated VRP (CVRP) for mixed-type vehicles. One type of the CVRP is the fleet size and mix vehicle routing problem (FSMVRP), where the planner has to choose how many vehicles of each type to use given a mix of vehicle types with varying loading capacity and unit costs. FSMVRP was first introduced by Golden et al. (Golden, Assad, Levy, & Gheysens, 1984). In this type of problem, the fleet is heterogeneous, but the available number of vehicles in the fleet for each type remains unrestricted. This problem is similar to the CVRP, but the difference is that FSMVRP has different types of vehicles to choose from, while CVRP has only one type of vehicle. One has to decide on both the fleet mix and the vehicle routing to be optimised. There are two cost aspects of FSMVRP to manage the total cost. The first cost type is related with the vehicle types having a uniform variable cost (varies by the total route distance) and different fixed costs, which vary by the vehicle types. Golden et al. (1984) presented the first mathematical model for this FSMVRP. The second cost type was offered by Salhi (Salhi, Sari, Saidi, & Touati, 1992). This type ignores the fixed cost and builds the model only with variable cost. This vehicle fleet mix heuristic has the advantage of being flexible enough to generate more than one single solution. This additional information is invaluable to planning managers when faced with conflicting objectives and many external constraints. While VRP proved to be an NP-Hard problem in the 1980s, solution time grows exponentially with the increase of distribution points. It was impossible to find the optimal solution in the cases with an excess of 50 nodes (Cordeau, Gendreau, & Laporte, 1997). In the current setting, modern exact algorithms can solve VRP instances with roughly a hundred nodes (Irnich & Villeneuve, 2006, Danna & Pape, 1998). Researchers implemented some heuristics to find a near-optimal solution. The scope of the study includes three of those algorithms. The first one is the Genetic Algorithm. Genetic algorithm was first proposed by John Holland (Holland, 1975) for the sake of finding solutions to problems that were otherwise computationally intractable. Some FSMVRP-related genetic algorithm heuristics applications can be found in the literature in the following papers: F. H. Liu & Shen (1999), Chen, Gu, & Gao (2020), Nazif & Lee (2010), Mohammed, Ahmad, & Mostafa (2012), Baker & Ayechew (2003), Prins (2004), ant colony systems algorithms can be found in papers Reimann et al and particle swarm optimization algorithms in Ai and Kachitvichyanukul (Ai & Kachitvichyanukul, 2009). The second algorithm is the Large Neighbourhood Search. A large neighbourhood search was first proposed by (Shaw, 1998). The potential of the heuristic for large-sized problems was revealed by Pisinger and Ropke (2007). Some FSMVRP-related heuristics applications are those developed by Erdoğan (2017), Demir, Bektaş, & Laporte (2012), and Tellez et al. (2017). The third algorithm is the simulated annealing algorithm. The simulated annealing is a random search algorithm proposed by Kirkpatrick et al. (Kirkpatrick, Gelatt, & Vecchi, 1983). It was developed based on the similarity between the metallurgical annealing process and the research of the minimum value in a more general system. Some FSMVRP-related simulated annealing applications include Osman (1993) and Kuo (2010). The multi-workday planning approach has been studied by Rattanamanee, Nanthavanij, & Dumrongsiri (2020) within the vehicle routing problem. The method was concentrated in terms of balancing the workload of the employees. In this study, the issue of balancing the workload of the employees was evaluated in terms of the factory loading capacity constraints.

2. MATERIAL AND METHODS

The feed mill manages customer orders on a weekly basis. Delivery of orders is promised within up to 7 days, taking into account the urgency of the order. Feed factories and dairy factories of the same company are integrated. Feed is delivered to milk suppliers. Due to the seasonality effect on milk production, milk supply decreases in the winter period and increases in the spring and summer periods. Since milk and feed are integrated and half a unit of feed consumption is required for one unit of milk production, the feed mill is also affected by these fluctuations. The enterprise manages its production capacity within flexible production capacity principles. The company works with three different vehicle types for the shipment of products in line with the geographical location of the customers, dairy sizes, and needs. Since the company finds it expensive to set up its vehicle fleet compared to the rental method, it chooses to rent the necessary vehicles according to the status of the orders. Contrary to the general acceptance of VRP, the business ignores the costs of returning to the factory, as it rents vehicles from the factory to the final delivery point. Fixed costs vary according to vehicle types, and variable costs are formed according to the length of the route. The company analysed its expectations from the VRP software as follows:

Requirement Analysis

- In order to reduce the fixed costs, vehicle occupancy should be maximized according to vehicle types.
- Depending on the geographical location of the dairies and the conditions of the facilities, the vehicle types chosen by the customers should be complied with.
- The final point is the destination; factory return should be ignored.
- The earliest and latest delivery times determined by the customers must be complied with.
- The planned routes should be displayed on the geographical graphic interface, and revisions should be made manually by planning staff if necessary.
- After taking the load from the factory, the total mileage of the vehicles, the routes they followed, and the delivery hours should be seen on the mobile application.

2.1. Research methodology

After the analysis and software suppliers were investigated, demo studies were conducted with candidate suppliers. According to the analysis performed, the mathematical model of VRP was created. The notation is as follows: vertex set F_D means factory (one factory for the demo), F_C means customers where F = $F_D \cup F_C$.

Let graph G = (F,A) be a fully connected (when a direct line exists between all nodes) network. F=0,. . . ,n is the node set and A is the line set defined between these nodes. In the node cluster, the ’0’ node represents the factory, and the 1,. . . n nodes represent the customers. p_i is the amount loaded on the vehicle from the factory and r_i is the amount delivered to the customer, where $i \in F_C$. The unloading time at the customer depot is q_i. The early and late delivery time interval at the customer depot is $[s_i, e_i]$. The set of vehicles ready to be leased by the company is denoted by V and each vehicle v ∈ V. The starting point for all vehicles as $z^v \in F_D$, the work start time of the vehicle as β^v, the fixed cost (can be thought as opportunity cost of leasing the vehicle) of the vehicle v as γ^v, the capacity of the vehicle v as ^{v}, driving distance limit as L^v, working time limit as E^v. For each arc (i, j) ∈ A, the distance between i and j is d_ij and the duration for this arc is τ_ij. Also, there is a variable travel cost for all arcs (i, j) is $c_i j$. The service time required by the customer as S_i.

Decision variables can be defined as follows:

The binary variable $x_i^v j$ is equal to 1 if vehicle v directly travels from i to j, and is 0 otherwise; the binary variable a_i^v is equal to 1 if vehicle v visits and serves vertex i, and is 0 otherwise. The amount of the order delivered by vehicle v on arc (i, j) is given as $d_i^v j$. For the time windows restrictions, variable Ω_i^v is defined as the time that vehicle v arrives at vertex i.

According to the notation given, a desired mathematical model for the FSMVRPTW problem can be given as:

$$\text{Minimise} \quad \sum_{(i,j)\in A v\in V} \sum c_{ij}^v x_{ij}^v \quad \sum_{j\in F_G v\in V} \sum_{Y^v X_{z^v}^v, j} \tag{1}$$

$$\text{Subject to} \sum_{v\in V} \alpha_i^v = 1 \qquad \forall i \in F_M \tag{2}$$

$$\sum_{v} \in V \alpha_i^v \leq 1 \qquad \forall i \in F_C \; F_M \tag{3}$$

$$\sum_{j\in F\setminus i} x_{ij}^v \leq \sum_{j\in F\setminus i} x_{ji}^v \qquad \forall i \in F_C, v \in V, \tag{4}$$

$$\sum_{p\in S, r\in F\setminus S} x^v_{pr} \geq \alpha^v_i \qquad \forall i \in F_C, v \in V, S \subset F : z^v \in S, i \in F \setminus S, \tag{5}$$

$$\sum_{j\in F_G} x^v_{z^v}, j \leq 1 \qquad \forall v \in V \tag{6}$$

$$\sum_{j\in F\setminus i} d^v_{ij} - \sum_{j\in F\setminus i} d^v_{ji} = r_i \alpha^v_i \qquad \forall i \in F_C, v \in V, \tag{7}$$

$$\sum_{i\in F_C} d^v_{z^v}, j = \sum_{i\in F_C} r_i \alpha^v_i \qquad \forall v \in V, \tag{8}$$

$$\Omega^v_i + (\tau_{ij+q_i}) x^v_{ij} - E^v(1 - x^v_{ij}) \leq \Omega^v_j \qquad \forall (i,j) \in A : j \in F_C, v \in V, \tag{9}$$

$$s_i \leq \Omega^v_i \leq e_i - q_i \qquad \forall i \in F_C, v \in V, \tag{10}$$

$$\Omega^v_{z^v} = \beta^v \qquad \forall v \in V, \tag{11}$$

$$\rho'^v_{ij} + d^v_{ij} \leq C^v x^v_{ij} \qquad \forall (i,j) \in A, v \in V, \tag{12}$$

$$\sum_{(i,j)\in A} \tau_{ij} x^v_{ij} \leq L^v \qquad \forall (i,j) \in A, v \in V, \tag{13}$$

$$\sum_{(i,j)\in\ A} \tau_{ij} x^v_{ij} + \sum_{i\in F_C} q_i \alpha^v_i \leq E^v \qquad \forall (i,j) \in A, v \in V, \tag{14}$$

$$x^v_{ij} \in \{0,1\} \qquad \forall (i,j) \in A, v \in V, \tag{15}$$

$$\alpha^v_i \in \{0,0\} \qquad \forall i \in F_C, v \in V, \tag{16}$$

$$\rho'^v_{ij} \geq 0 \qquad \forall (i,j) \in A, v \in V, \tag{17}$$

$$d^v_{ij} \geq 0 \qquad \forall (i,j) \in A, v \in V, \tag{18}$$

The objective function (1) minimises the total cost (fixed hiring cost and variable driving cost). Visiting rules are, by constraint (2), that all of the customers must be visited only once. (3) means by the contribution of the vehicle v all of the customers must be visited by the fleet. (4) is the flow conservation constraint, which means, if there is an inflow there must also be an outflow at the customer site. The connection between the factory of the vehicle v and the visited customer is guaranteed by (5). Vehicles can be used only once, as stated by (6).

Customer order completion constraints are (7) – (8); those are for delivery completion. Constraint (9) is stated for the Miller-Tucker-Zemlin sub-tour elimination constraints (Miller, Zemlin, & Tucker, 1960) and provides the framework for the time windows. (10) designs the upper- and lower-time limits. Vehicle restrictions are given as follows: (11) sets the start time for vehicle v, (12) prohibits the violation of the vehicle capacity C^v, (13) limits the driving time, and (14) limits the total working time for each vehicle v. Integrality and the nonnegativity constrains are stated by (15) – (18).

2.2. Algorithm proposal

Feed factory officials aim to see the extra cost reductions that can be achieved by adding the multi-day planning algorithm to the given model in order to reduce uncertainty, dispatch close customers on the same day and with the same vehicle if possible, and reduce their costs. Thus, while reducing the total cost, it is expected that the fewest concessions will be made in the delivery dates. In order for the specified development to be completed, under the factory loading capacity constraint, the orders with daily delivery dates should be resolved together as if they were to be shipped the same day, and the total deviation from the delivery date should be minimised. Rather than the same vehicle periodically visiting the same customers, as in Rodríguez-Martín, Salazar-González, & Yaman (2019), the proposed algorithm combines the geographically close points of the mixed vehicle fleet with minimal deviation from the late delivery date. In this respect, it differs from periodic VRP.

The daily loading capacity of the factory was determined as ∅, if desired by the factory k is to be the factory tolerance limit, and the deviation from the latest delivery date as θ. t, the day the vehicles are loaded, is an integer between the earliest first delivery date of orders (s_i) and the last delivery date (e_i).

The objective function (19) should be revised as follows.

$$\text{Minimise} \quad \sum_{(i,j)\in A} \sum_{v\in V} c_{ij}^{v} x_{ij}^{v} + \sum_{j\in F_C} \sum_{v\in V} \gamma^{v} x_{z^v}^{v}, j + \sum_{i\in F} \vartheta_i \tag{19}$$

In order not to exceed the daily loading capacity of the factory, the following constraint should be added.

$$\sum_{i\in F_C} p_{z^v}^{v}, j \geq \phi_t + k_t \quad \forall i \in F_C, v \in V, z^v \in F_D, \forall t \in (s_i, e_i) \tag{20}$$

In order to allow deviation from the latest delivery date, constraint (21) must be revised as follows:

$$s_i \leq \Omega_i^v \leq e_i - q_i + \vartheta_i \quad \forall i \in F_C, v \in V, \tag{21}$$

Nonnegativity constraints related to the factory capacity (22), tolerance limit for factory capacity flexibility (23), and deviation from the latest delivery date (24) are added as follows:

$$\phi_t \geq 0 \quad \forall t \in (s_i, e_i), \tag{22}$$

$$k_t \geq 0, \quad \forall t \in (s_i, e_i), \tag{23}$$

$$\vartheta_i \geq 0 \quad \forall i \in F_C \tag{24}$$

The solutions to be produced by the developed algorithm will occur depending on the factory capacity $\varnothing_t$ and factory capacity flexibility limit k_t, which are new inputs to be taken from the user.

ALNS Algorithm's Pseudocode

1. **Begin**
2. **Inputs:** factory, distances, customers, vehicles, durations, capacity limit, capacity limit tolerance, CPU time limit
3. Calculate the total order quantity
4. Divide the quantity to factory $\varnothing_t + k_t$
5. Round value to first upper integer n
6. Build the index t ($t_1..t_n$), build the loop index m (1..n)
7. Build the first solution by adding the customers to the initial routes
8. Choose the most cost-decreasing at every phase
9. Advance the candidate solution by using the local search engine with Exchange, one-opt, two-opt, and vehicle-exchange operators.
10. Record the candidate solution as the best-known solution
11. Repeat
12. a. Randomly destroy the candidate solution by removing vertices
    b.Heuristically repair the candidate solution by adding vertices
    c. Advance the candidate solution by using the local search engine
13. If the candidate solution is better than the best-known solution
    Then
    Change the best-known solution value
    Else With probability α first solution is the best-known solution
    Until processing time reaches the CPU time limit
14. End ALNS.

The exchange operator changes pairs of customers and checks whether the objective function value decreases. One-opt changes the order of the customer in the route and checks for minimization. Two-opt removes arc a-b and c-d and crosses the arc as a-c and c-d, and checks for feasibility and improvement in the objective value. Both the operators have a neighbourhood size of $O([F])^2$.

In step 12.b, two of the constructive heuristics are applied. Those are the greedy insertion method and the max regret method. The second heuristic selects the customer, for which the difference between the cost of the cheapest insertion and the second cheapest insertion decision is the largest. At each iteration selection of the heuristics is made with equal probability. Each heuristic searches for several best candidates and selects randomly among them at each step. The probability p of rejecting a candidate solution is set at 15% in the preliminary phase and decreases linearly with time, and reaches 0% at the end of the CPU time limit.

Multi-day Optimization Algorithm's Pseudocode

1. **Begin**
2. **Assign** $\varnothing_t = 0$
3. For $\boldsymbol{m}$ = 1 to $\boldsymbol{n}$
4. For v = 1 to end of the vehicle set V
5. Compute the average delivery date of the orders in vehicle v.
6. Sort every vehicle v's average delivery date in an ascending order
7. Assign it to the nearest t value.Assign it to the nearest t value.
8. Calculate θ_t value.
9. For t = 1 to n-1
10. Update best solution date if total deviation $theta_t$ decreases
11. Keep old date if total deviation $theta_t$ tincreases
12. t = t + 1
13. Repeat
14. If $\varnothing_m$ < Capacity assigned by the user
15. $\varnothing_m = \varnothing_m + P^{v}_{z^v},_j$
16. Else m=m+1
17. $\varnothing_m = \varnothing_m + P^{v}_{z^v},_j$
18. Repeat
19. Return best known solution as the solution
20. End ALNS.

The multi-day optimization algorithm takes over the heuristic solution and sorts every vehicle v's average delivery in an ascending order. Starting from t=1 to n, without changing the routes and order combinations in the vehicles, it checks whether the target function increases or decreases by advancing the current day value one by one for all vehicles. If there is a decrease in the target function, it updates the best solution as the best-known solution. It iterates the planning horizon from the first vehicle to the last by filling the factory capacity with the least deviation from the delivery dates. Iteration of the day exchange operator stops when all vehicles are planned .

To compare the ALNS algorithm, GA and SA algorithms were used. The detailed pseudocodes of the algorithms used can be obtained from Liu (S. Liu, Huang, & Ma, 2009) for the GA heuristic and Kuo (2010) for the SA heuristic.

3. RESULTS AND DISCUSSION

The algorithm was tested with a dataset using the real order data of 2025.95 tons, which was delivered to the feed factory by sales representatives. A summary of the data is given in Table I (details can be seen from the dataset reference).

Table 1. Order Data Set

Number of Distribution Points	Total Order Quantity	Maximum Distance	Fleet Mix	
		LATITUDE / LONGITUDE	Truck	18
			4 Axle Lorry	2
107	2025,95 tons	234 km / 177 km	3 Axle Lorry	2

Before testing the designed algorithm, the solution to the problem described in §2.2 was provided. In order to test the performance of the proposed Adaptive Large Neighbourhood Search (ALNS) heuristic and the multi-day scheduling algorithm, the data set was compared with the solutions provided by well-known Simulated Annealing (SA) and Genetic algorithms (GA). First of all, a solution was provided without implementing the multi-day planning algorithm. This solution and comparison of ALNS with other methods are given in Table II.

Solution routes can be seen in Figure I.

As can be seen in Table II, the developed ALNS algorithm has been compared with some other heuristic algorithms. With the developed ALNS algorithm, the vehicle occupancy rate increased by up to 5.58% with respect to SA and GA. It reduced the distance travelled by up to 3.41%. By making the vehicle selection more accurate, it reduced fixed costs by up to 4.68%. Likewise, it provided a decrease of up to 3.82% in variable costs. The data sets of the study were created to solve real-life problems which

Table 2. Computational results for the benchmark of Data Set

Best Found Solutions	Capacity		Quantity Utulized			Amount Carried (Kg)			Occupancy (%)			Distance Traveled (Km)			Fixed Cost (TL)			Variable Cost (TL)			Total Cost Incurred		
	(Kg/Type)	Vehicle Type	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS*
Day 1	27,000	Truck	15	15	15	389,500	393,500	393,500	96.2	97.2	97.2	1,859	1,744	1,744	4,500	4,500	4,500	8,175.6	7,817.9	7,817.9	12,675.6	12,317.9	12,317.9
	21,000	4 Axle Lorry	1			5,500			26.2			25			200			80.5			280.5		
	17,000	3 Axle Lorry	2	2	2	28,250	29,750	29,750	83.1	87.5	87.5	163	163	163	200	200	200	744.6	830.7	830.7	944.6	1,030.7	1,030.7
Sum			**18**	**17**	**17**	**423,250**			**92.0**	**96.4**	**96.4**	**2,048**	**1,907**	**1,907**	**4,900**	**4,700**	**4,700**	**9,000.7**	**8,648.5**	**8,648.5**	**13,900.7**	**13,348.5**	**13,348.5**
Day 2	27,000	Truck	18	18	18	452,350	474,350	474,350	93.1	97.6	97.6	1,690	1,743	1,739	5,400	5,400	5,400	7,792.2	7,811.5	7,792.0	13,192.2	13,211.5	13,192.0
	21,000	4 Axle Lorry	2			32,000			76.2			149			400			620.8			1,020.8		
	17,000	3 Axle Lorry	2	2	2	21,000	31,000	31,000	61.8	91.2	91.2	29	57	57	200	200	200	304.6	289.9	289.9	504.6	489.9	489.9
Sum			**22**	**20**	**20**	**505,350**			**89.9**	**97.2**	**97.2**	**1,868**	**1,800**	**1,795**	**6,000**	**5,600**	**5,600**	**8,717.6**	**8,101.4**	**8,081.9**	**14,717.6**	**13,701.4**	**13,681.9**
Day 3	27,000	Truck	12	12	12	300,250	317,250	317,250	92.7	97.9	97.9	909	944	944	3,600	3,600	3,600	4,506.0	4,230.5	4,230.5	8,106.0	7,830.5	7,830.5
	21,000	4 Axle Lorry	2	2	2	42,000	42,000	42,000	100.0	100.0	100.0	56	58	58	400	400	400	448.4	257.0	257.0	848.4	657.0	657.0
	17,000	3 Axle Lorry	2	1	1	27,500	10,500	10,500	80.9	61.8	61.8	65	29	29	200	100	100	477.6	149.4	149.4	677.6	249.4	249.4
Sum			**16**	**15**	**15**	**369,750**			**92.4**	**96.5**	**96.5**	**1,030**	**1,032**	**1,032**	**4,200**	**4,100**	**4,100**	**5,432.1**	**4,637.0**	**4,637.0**	**9,632.1**	**8,737.0**	**8,737.0**
Day 4	27,000	Truck	7	7	7	186,500	186,500	186,500	98.7	98.7	98.7	853	886	886	2,100	2,100	2,100	3,814.2	3,970.6	3,970.6	5,914.2	6,070.6	6,070.6
	21,000	4 Axle Lorry	1	1	1	20,000	20,000	20,000	95.2	95.2	95.2	126	119	119	200	200	200	439.8	523.7	523.7	639.8	723.7	723.7
	17,000	3 Axle Lorry	1	1	1	10,500	10,500	10,500	61.8	61.8	61.8	39	40	40	100	100	100	180.5	205.8	205.8	280.5	305.8	305.8
Sum			**9**	**9**	**9**	**217,000**			**95.6**	**95.6**	**95.6**	**1,018**	**1,045**	**1,045**	**2,400**	**2,400**	**2,400**	**4,434.5**	**4,700.0**	**4,700.0**	**6,834.5**	**7,100.0**	**7,100.0**
Day 5	27,000	Truck	12	12	12	318,500	318,500	318,500	98.1	97.6	97.7	1,646	1,583	1,583	3,600	3,600	3,600	7,197.1	7,094.5	7,094.5	10,797.1	10,694.5	10,694.5
	21,000	4 Axle Lorry																					
	17,000	3 Axle Lorry	2	2	2	23,000	23,000	23,000	54.4	77.9	76.5	95	91	91	200	200	200	510.9	462.3	462.3	710.9	662.3	662.3
Sum			**14**	**14**	**14**	**341,500**			**95.4**	**95.4**	**95.4**	**1,741**	**1,674**	**1,674**	**3,800**	**3,800**	**3,800**	**7,707.9**	**7,556.8**	**7,556.8**	**11,507.9**	**11,356.8**	**11,356.8**
Day 6	27,000	Truck	6	5	5	139,000	133,000	133,000	85.8	98.5	98.5	703	488	488	1,800	1,500	1,500	2,833.0	2,188.7	2,188.7	4,633.0	3,688.7	3,688.7
	21,000	4 Axle Lorry	1	1	1	16,000	20,100	20,100	76.2	95.7	95.7	34	251	251	200	200	200	80.5	1,105.7	1,105.7	280.5	1,305.7	1,305.7
	17,000	3 Axle Lorry	2	1	1	14,100	16,000	16,000	41.5	94.1	94.1	77	36	36	200	100	100	369.4	182.4	182.4	569.4	282.4	282.4
Sum			**9**	**7**	**7**	**169,100**			**77.9**	**97.7**	**97.7**	**813**	**775**	**775**	**2,200**	**1,800**	**1,800**	**3,283.0**	**3,476.8**	**3,476.8**	**5,483.0**	**5,276.8**	**5,276.8**
Sum	27,000	Truck	70	69	69	1,786,100	1,823,100	1,823,100	94.5	97.9	97.9	7,660	7,388	7,384	21,000	20,700	20,700	34,318.1	33,113.7	33,094.2	55,318.1	53,813.7	53,794.2
	21,000	4 Axle Lorry	7	4	4	115,500	82,100	82,100	78.6	97.7	97.7	391	428	428	1,400	800	800	1,670.0	1,886.4	1,886.4	3,070.0	2,686.4	2,686.4
	17,000	3 Axle Lorry	11	9	9	124,350	120,750	120,750	66.5	78.9	78.9	468	416	416	1,100	900	900	2,587.7	2,120.4	2,120.4	3,687.7	3,020.4	3,020.4
			88	**82**	**82**	**2,025,950**			**91.1**	**96.5**	**96.5**	**8,519**	**8,233**	**8,228**	**23,500**	**22,400**	**22,400**	**38,575.8**	**37,120.5**	**37,101.0**	**62,075.8**	**59,520.5**	**59,501.0**

Table 3. Computational results for the benchmark of Data Set with multi-day planing algorithm applied

Best Found Solutions	Capacity (Kg/Type)	Vehicle Type	Quantity Utulized			Amount Carried (Kg)			Occupancy (%)			Distance Traveled (Km)			Fixed Cost (TL)			Variable Cost (TL)			Total Cost Incurred		
			SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS	SA	GA	ALNS*
Day 1	27.000	Truck	18	18	17	453.500	472.600	446.750	93,3	97,2	97,3	2.144	1.934	1.865	5.400	5.400	5.100	9.105,2	8.669,9	8.358,9	14.505,2	14.069,9	13.458,9
	21.000	4 Axle Lorry	2	1	1	15.500	21.000	19.750	36,9	100	94,0	90	27	87	400	200	200	310,9	118,7	383,0	710,9	318,7	583,0
	17.000	3 Axle Lorry	2		2	28.750		33.000	84,6		97,1	102		55	200	-	200	552,8		280,8	752,8	-	480,8
Sum			**22**	**19**	**20**	**497.750**	**493.600**	**499.500**	**88,6**	**97,4**	**97,2**	**2.336**	**1.961**	**2.007**	**6.000**	**5.600**	**5.500**	**9.968,9**	**8.788,6**	**9.022,7**	**15.968,9**	**14.388,6**	**14.522,7**
Day 2	27.000	Truck	17	17	18	448.850	447.500	476.250	97,8	97,5	98,0	1.385	1.628	1.970	5.100	5.100	5.400	6.705,8	7.295,6	8.828,9	11.805,8	12.395,6	14.228,9
	21.000	4 Axle Lorry	1	1	1	21.000	21.000	20.850	100	100	99,3	21	95	90	200	200	200	269,1	419,7	397,8	469,1	619,7	597,8
	17.000	3 Axle Lorry	2	1		29.000	16.250		85,3	95,6		184	54		200	100	-	744,6	274,5		944,6	374,5	-
Sum			**20**	**19**	**19**	**498.850**	**484.750**	**497.100**	**97,1**	**97,5**	**98,0**	**1.589**	**1.777**	**2.060**	**5.500**	**5.400**	**5.600**	**7.719,6**	**7.989,8**	**9.226,7**	**13.219,6**	**13.389,8**	**14.826,7**
Day 3	27.000	Truck	17	17	17	428.750	451.500	451.350	93,4	98,4	98,3	1.891	1.761	1.443	5.100	5.100	5.100	8.605,0	7.893,6	6.469,1	13.705,0	12.993,6	11.569,1
	21.000	4 Axle Lorry	2	2	2	41.000	41.000	41.000	97,6	97,6	97,6	161	139	139	400	400	400	619,1	612,4	612,4	1.019,1	1.012,4	1.012,4
	17.000	3 Axle Lorry	2			13.500			39,7			76			200	-	-	496,5			696,5	-	-
Sum			**21**	**19**	**19**	**483.250**	**492.500**	**492.350**	**90,3**	**98,3**	**98,3**	**2.128**	**1.900**	**1.582**	**5.700**	**5.500**	**5.500**	**9.720,6**	**8.506,0**	**7.081,5**	**15.420,6**	**14.006,0**	**12.581,5**
Day 4	27.000	Truck	17	16	18	450.100	424.100	477.500	98,1	98,2	98,3	1.920	1.983	2.286	5.100	4.800	5.400	8.577,5	8.887,6	10.247,8	13.677,5	13.687,6	15.647,8
	21.000	4 Axle Lorry		1			19.000			90,5			40			200	-		175,8		-	375,8	-
	17.000	3 Axle Lorry	2	2	1	24.500	32.500	16.500	72,1	95,6	97,1	134	103	41	200	200	100	674,6	524,8	208,8	874,6	724,8	308,8
Sum			**19**	**19**	**19**	**474.600**	**475.600**	**494.000**	**96,3**	**97,7**	**98,2**	**2.054**	**2.126**	**2.327**	**5.300**	**5.200**	**5.500**	**9.252,2**	**9.588,2**	**10.456,6**	**14.552,2**	**14.788,2**	**15.956,6**
Day 5	27.000	Truck	2	3	1	53.000	79.500	27.000	98,1	98,1	100	316	349	45	600	900	300	1.317,8	1.563,4	203,2	1.917,8	2.463,4	503,2
	21.000	4 Axle Lorry														-	-				-	-	-
	17.000	3 Axle Lorry	2		1	18.500		16.000	54,4		94,1	92		36	200	-	100	519,4		182,4	719,4	-	282,4
Sum			**4**	**3**	**2**	**71.500**	**79.500**	**43.000**	**81,3**	**98,1**	**97,7**	**407**	**349**	**81**	**800**	**900**	**400**	**1.837,2**	**1.563,4**	**385,6**	**2.637,2**	**2.463,4**	**785,6**
Total Sum	27.000	Truck	71	71	71	1.834.200	1.875.200	1.878.850	95,7	97,8	98,0	7.656	7.655	7.610	21.300	21.300	21.300	34.311,4	34.310,0	34.107,8	55.611,4	55.610,0	55.407,8
	21.000	4 Axle Lorry	5	5	4	77.500	102.000	81.600	73,8	97,1	97,1	272	301	316	1.000	1.000	800	1.199,1	1.326,7	1.393,2	2.199,1	2.326,7	2.193,2
	17.000	3 Axle Lorry	10	3	4	114.250	48.750	65.500	67,2	95,6	96,3	587	157	132	1.000	300	400	2.987,9	799,3	672,0	3.987,9	1.099,3	1.072,0
			86	**79**	**79**	**2.025.950**			**92,4**	**-**	**-**	**8.514**	**8.113**	**8.058**	**23.300**	**22.600**	**22.500**	**38.498,4**	**36.436,0**	**36.173,0**	**61.798,4**	**59.036,0**	**58.673,0**

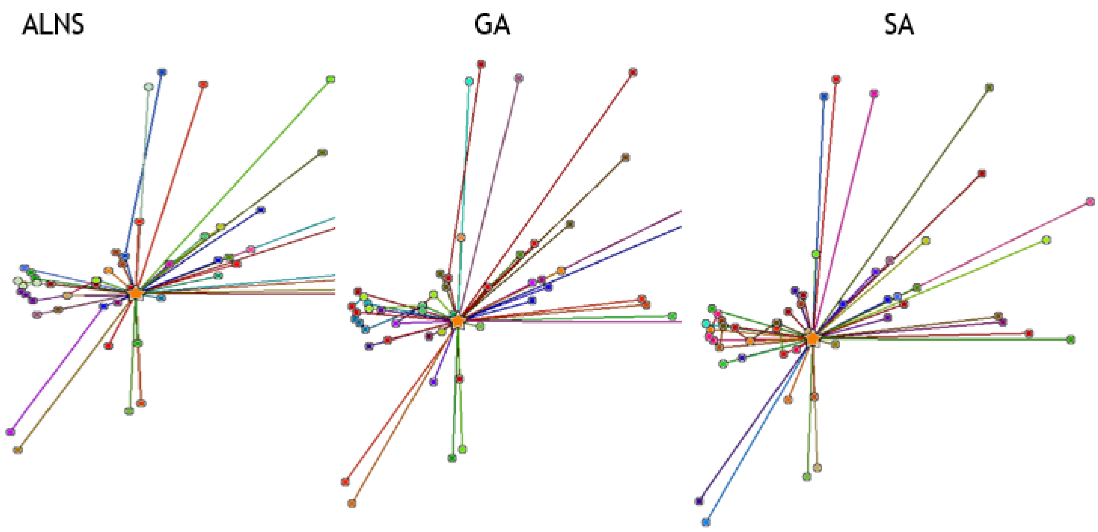

Figure 1. ALNS / GA / SA Heuristics Route Mapping

can be reached from the dataset link. The benchmarked data set was used in the study by creating a distance matrix based on the latitude and longitude information of customers. One can use open street maps (information was obtained from the following world map, whose use is under free and open license: https://www.openstreetmap.org/). For the repeatability of the study, one can check against other heuristic solutions or recode the proposed method.

Table 4. Absolute Deviations (Improvement Rates)

Performance Indicator	SA	GA	ALNS
Occupancy (+)	1.46	1.30	1.50
Distance Traveled (-)	0.05	1.45	2.07
Total Cost Incurred (-)	0.45	0.81	1.39

The algorithm proposed in §2.2 (multi-day planning) was coded in C++ and run in an Intel(R) Core (TM) i7-6500U CPU @ 2.50GHz 2.60 GHz with 8 GB RAM. Daily factory capacity is 500 tons/day for the given period. The multi-day planning algorithm was run for all of the ALNS, SA, and GA algorithms where the benchmarks were made, and the results were given comparatively. The obtained solution can be seen in Table III. Regardless of which heuristic method was applied with the proposed algorithm, all results showed significant improvement. This provides an important contribution in terms of being an algorithm that improves each method at the same time rather than comparing the heuristic methods that are dominant in the literature.

Absolute deviations (AD) occur in heuristic solutions with the developed algorithm. These improvement rates can be calculated by (25) as follows.

$$AD = [Abs(WithoutAlgoritm - WithAlgorithm)/WithoutAlgorithm]x100 \tag{25}$$

AD values can be seen in Table IV for benchmark heuristics.

With the proposed algorithm, vehicle occupancy was increased. Total travel distance, fixed, and variable costs are reduced. As a result of these improvements, the total cost was reduced by up to 1.39 percent. Although all methods have provided more successful results with the multi-day planning algorithm, the improvement achieved in the ALNS heuristic is remarkable. When Tables III and IV are compared, it is seen that there are backward and forward changes in the desired delivery dates to level the factory capacity. For benchmark heuristics, the percentage, quantity, and deviation days of the revised orders are given in Figure II, respectively.

As can be seen in the SA heuristic, 93.1% of the orders were planned with a deviation of only up to one day. The weighted average number of deviation days was realized as 0.53 days. In the GA heuristic, 95.4% of the orders were planned with a deviation of only up to one day. The weighted average number of deviation days was realized as 0.46 days. In the ALNS heuristic, 93.0% of

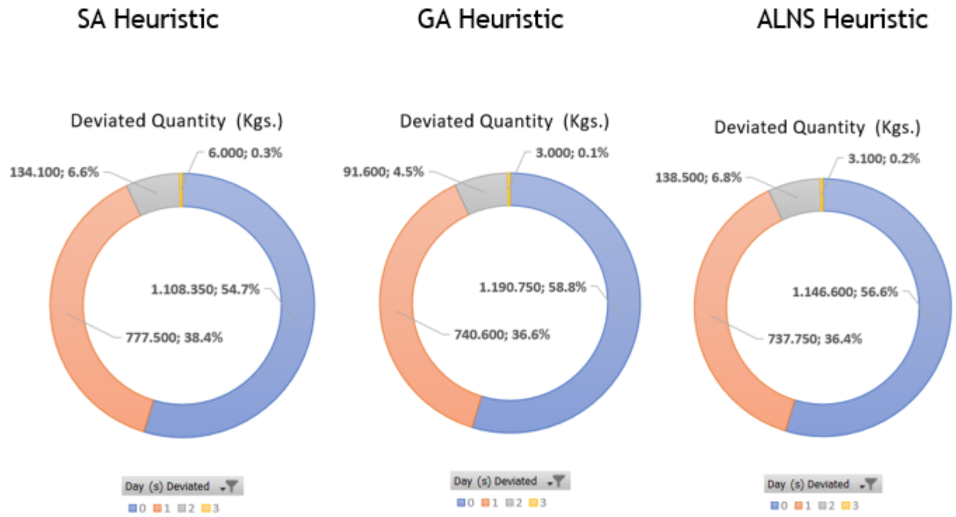

Figure 2. Total Deviation from Desired Shipment Time Windows

the orders were planned with a deviation of only up to one day. The weighted average number of deviation days was realized as 0.51 days.

4. CONCLUSION

As stated by Hoff et al. 3 [3], VRP is seen as a success story of operations research. New extensions and intuitive solutions are needed to make this method more practical in solving real-life problems. The proposed algorithm attempts to gain the ability to organize the planning horizon and reduce uncertainty in the VRP method. The method developed has achieved success in all dimensions, such as fleet occupancy, and reduction of fixed and variable costs, which are parts of the multi-dimensional success factors mentioned at the beginning of the study. Companies mostly invest in VRP software by deciding to develop intuitive solutions according to their needs. The algorithm detailed in the study can be easily adapted to the existing software of businesses that already use VRP software. The use of multi-day planning and uncertainty reduction methods has undeniable improvement opportunities, as can be seen from the results of the study.

5. RECOMMENDATIONS

In future studies, as a suggestion, instead of reaching a solution one at a time with a single heuristic, an algorithm can be developed that uses several heuristic algorithms at the same time and selects the one that provides the most cost reduction with the least delivery day deviation.

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RESEARCH ARTICLE

Pricing of Contractual Shipments and Slot Allocation in Container Liner Shipping under Stochastic Environment

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ABSTRACT
This study aimed to propose an optimization model for slot allocation and contractual pricing that considers spot and contractual shipments and empty container repositioning under a stochastic environment. In that respect, a two-stage stochastic non-linear programming model was proposed. The model considers contractual pricing that is overlooked by previous studies. Experimentation results revealed that decreasing market demand and spot market prices could cause serious profit loss while creating a high level of idle capacity. With the increasing market demand, capacity utilization reaches saturation at 90% requiring a capacity increase in the service. In the increasing market, slots allocated to empty containers get reduced while taking advantage of other options for empty container supply. Experimentation of symmetric uncertainty revealed that the range of uncertainty should be minimized since it creates a serious loss in profits and capacity utilization. Calculations also demonstrated that the applications of the stochastic modeling solutions would provide higher profit margins than the solutions of their deterministic equivalents. The model can easily be applied to the real-life situations of container liner services for managing and optimization of their service capacities as well as determining optimum contractual prices.

Keywords: Container shipping, contractual pricing, slot allocation, revenue management, capacity management

1. Introduction

Container liner companies must plan for optimal slot allocation for the sake of efficiency and profitability of their operations to survive and prosper in such a competitive market. Optimal slot allocation is not only crucial for the economic sustainability of container liner companies, but also beneficial for environmental sustainability since it increases container ship capacity utilization which in turn reduces environmental emissions per ton-kilometer cargo transported.

Customers of container liner companies, namely the shippers of containers, are mainly segmented as contractual shippers and spot shippers (Wang & Meng, 2021). Contractual shippers can be either freight forwarders or big industry players with a high volume of export/import cargo and regular shipment needs. They draw contracts with container liners to bargain for lower and fixed prices and guarantee a regular shipment of their cargo. Drawing contracts with shippers and freight forwarders are also beneficial for container liners as they guarantee the availability of cargo and stable income. Binding to a contract raises a pricing issue - how should contractual shipments be priced? They are usually priced by considering the expectations regarding future demand and future spot market prices. If the expectation regarding the market is upward, prices negotiated for a contract can be too high, resulting in the loss of the contractual customer. In the future, if the market goes down contrary to past expectations, the container liner company would face a serious loss in its revenue. On the contrary, if the expectation regarding the market is downward, the container liner company would settle for a contract price that is too low. This will again result in a serious loss in revenue if the market goes up contrary to past expectations. Either situation affects the profitability of a container liner company. In addition, in some legs of the service, containers for contractual shipments might not as many as others, and those empty slots can be used for spot shipments so that efficiency and profitability can be maximized. Additionally, it is not possible to predict the future demand and future spot market prices with certainty; therefore, along with the pricing of contractual shipments, stochasticity of demand and spot price expectations must be considered in the modeling of slot allocation in container shipping.

In this regard, considering different segments i.e., contractual spot, and empty container shipments altogether is necessary for efficient slot allocation and profitability. The main research question of this study is how container shipping slot allocation

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with those different segments can be modelled and optimized. To answer the question, this study proposes a slot allocation and contractual pricing model that explicitly considers spot and contractual shipments and empty container repositioning under a stochastic environment. Empty container repositioning must be considered together with contractual and spot shipments in modeling container slot allocation since it is inevitable and uses the capacity of container ships because of the nature of the container shipping industry.

The remainder of this paper is organized as follows. Section 2 reviews the previous studies and reveals the contribution of this study. Section 3 states the slot allocation and container shipping pricing problem that motivated this study. Section 4 formulated the model as a non-linear two-stage stochastic programming model. Section 5 describes the application case and the data for the application instances. Section 6 reveals experimental results. Finally, conclusion was provided in Section 7.

2. Literature Review

The focus of the previous studies has been mostly on spot markets. Feng & Chang (2008) developed a model for slot allocation that maximizes operational profit. To eliminate capacity misutilization because of no-show ups, Wang et al. (2019) proposed a slot allocation model that considers two strategies: overbooking and delivery-postponement. From a different perspective from these two studies, Fu et al. (2016) considered demand uncertainty by putting forward a robust optimization model for slot allocation. Their model accounted for minimum quantity commitment and two types of uncertainty in the demand: bounded and symmetric uncertainty. These studies assumed that a fixed capacity was put aside for empty container repositioning.

Capacity for empty containers on container ships can be arranged more efficiently if empty container repositioning took advantage of the idle capacity resulting from demand fluctuations and demand differences in the different legs of a service route. Considering this fact, optimal slot allocation models proposed in the previous studies accounted for slots allocated for empty containers. Including empty container repositioning, Ting & Tzeng (2004) constructed an optimal slot allocation model that maximizes total freight profit. Feng & Chang (2010) proposed a slot allocation optimization model which considers empty container repositioning while maximizing operational profit. They improved the model developed by Feng & Chang (2008) to include empty container relocation decisions. Zurheide & Fischer (2012) developed a slot allocation optimization model that considers transshipment and prioritization of urgent container shipments. Zurheide & Fischer (2015) modified and improved the model developed by Zurheide & Fischer (2012). Their slot allocation model considered transshipment and proposed a new booking limit strategy called the bid-price strategy. Additionally, they conducted a simulation to compare the newly proposed bid-price strategy with previously presented booking limit strategies. Wong et al. (2015) developed a profit maximization model that incorporates empty and laden container slot allocation. Wang et al. (2015) proposed a non-convex mixed-integer non-linear optimization model to maximize the profits for seasonal container shipping. Their model included shipping speed and realistic non-convex bunker consumption function. Chang et al. (2015) came up with a bi-level optimization model for slot allocation and empty container repositioning. While the upper level maximizes operational profits with optimal slot allocation, the lower level minimizes empty container repositioning costs. Lu & Mu (2016) provided a model for slot reallocation caused by adjustments to shipping schedules after major disruptions. The model put forward by Ting & Tzeng (2016) not only accounted for empty container repositioning, but also considered uncertainties. They proposed a fuzzy multi-objective slot allocation model with uncertain demand and container weight. Contrary to previous studies, their model maximizes both total revenue and agents' degree of satisfaction. In all these studies, capacity for contractual pricing was not considered at best few of them assumed that a certain percentage of the capacity was put aside for contractual containers.

In another study, Wang et al. (2020) constructed an optimal slot allocation and dynamic pricing model considering uncertain demand and port congestion for time-sensitive cargo. Contrary to the other previous studies, their model considers slot allocation for contractual shipments and spot shipments together with pricing of spot shipments, but their model is not applicable for contractual pricing.

2.1. Contribution of the Study

Pricing and slot allocation of contractual shipments can significantly impact the profitability of container shipping lines. Additionally, optimum slot allocation of contractual shipment can increase capacity utilization of container ships thus reduce emissions for per ton kilometers of containerized freight. To the best of the author's knowledge, none of the previous studies related to slot allocation in container shipping considered slot allocation and pricing of contractual shipments. At best some of the previous studies assumed certain percentage of container ships were set aside for contractual shipments and their pricing were determined in an ad hoc manner. In this regard, this study aimed to propose an optimal slot allocation and contractual pricing model that explicitly considers spot and contractual shipments and empty container repositioning under a stochastic environment.

Therefore, a two-stage stochastic non-linear programming model was proposed. The first stage includes the prices for contractual cargo while the second stage includes slot allocation for spot and contractual shipments and empty containers.

3. Problem Statement

Figure 1 illustrates the container liner shipping service provision. Two hypothetic services of a container liner are illustrated in the figure. Service-1 includes four ports, and Service-2 includes five ports, and both of the services are provided in typical cyclic routes that start from P1 and end at P1. A full shipping sequence of a container ship throughout the route i.e., P1-P2-P3-P4-P1 or P1-P5-P6-P7-P8-P1 is called a voyage. And a single shipping activity of a container ship from one port to another such as P1 to P2 is called a leg. The routes and shipping schedules of a container liner shipping service are predetermined and declared to shippers so that they can arrange shipping requirements accordingly. Typically, container liner service is provided according to a weekly schedule, which means that at least once a week a port in a container liner service is called by a container ship. The transportation capacity of a container liner service, particularly how many container ships are to be assigned to that service is determined according to demand predictions. The capacity of a container liner service is fixed unless new container ships are added to the company's fleet, or the company redesigns its container liner services.

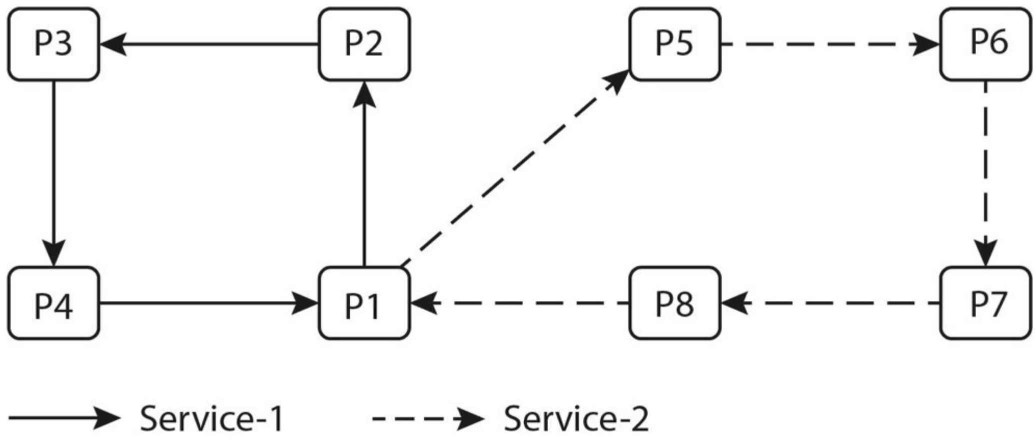

Figure 1. Container Liner Shipping Services

When a port in a container liner service is called by a container ship, certain containers are discharged, certain containers remain on ships, and certain containers are loaded on ships. The discharged containers at a port are the ones that are destined to that port from other ports in the service. The containers that remain on ships are the ones that are shipped from the ports in the previous legs of the ships and destined to upcoming ports in the ships' voyage. The loaded containers at a port are the ones that are shipped from that port and destined to upcoming ports in the ships' voyage. As an example to clarify the container liner service provision, the reader can look at Figure 1 and consider P3 as focal port and consider P1 as starting and ending port of the voyages performed in Service-1. Containers discharged at P3 are the ones sent from P2 to P3 and P1 to P3 in the current voyage and the ones sent from P4 to P3 in the previous voyage. Containers loaded at P3 are the ones sent from P3 to P4 and P3 to P1 and P3 to P2 in the current voyage. The ones sent from P3 to P2 in the current voyage will be discharged at P2 in the next voyage. Containers that remain on ships at P3 are the ones sent from P1 to P4, P2 to P4, and P2 to P1 in the current voyage, and all of them will be discharged in the current voyage. On the other hand, containers that remain on ships at P4 are the ones sent from P2 to P1, P3 to P1, and P3 to P2 in the current voyage, but the ones sent from P3 to P2 will be discharged at P2 in the next voyage.

Considering contractual, spot, and empty container shipments all together is necessary for efficient slot allocation and profitability. As in some legs of a container liner service, demand in the spot market is not as high as others, and similarly, in some legs of the service, containers for contractual shipments are not as many as others, the idle slots resulted in one kind of shipment can be used for the other kinds of shipments so that efficiency and profitability can be maximized.

Pricing of the contractual shipments rises as another issue for slot allocation. The price of the spot shipments is determined by the market. And in turn, spot market prices are determined by demand. Since a container liner company competes with other container liners in destinations where they provide services, the divergence of their spot prices from the spot market prices is usually minuscule. On the other hand, contractual prices are determined by the expectations regarding the future spot market prices as they are usually signed annually, and the contractual prices are fixed in the term of the contract. If the price negotiated for a contract is high, it can cause the loss of a contractual customer. On the other hand, if the price settled for a contract is low, it can result in too many slots being allocated to contractual shipments with a low price. Either situation affects the number of slots allocated to contractual shipments, therefore, the profitability of a container liner company.

4. Model Description

The model proposed in this study is a two-stage stochastic non-linear programming model. There are various types of stochastic programming approaches (Birge & Louveaux, 2011). Two-stage stochastic programming was chosen because it is the most suitable modelling technique for modelling uncertainty for the problem considered in this study. In a two-stage stochastic programming model, uncertainty is revealed in the second stage. The first stage decision variables take values that are best for all occurrences of considered scenarios of the second stage. This is compatible with contractual pricing and slot allocation of contractual shipments. Contractual pricing and slot allocation of contractual shipments are generally decided annually before knowing what the price for spot shipments thorough the year will be. In the first stage of the proposed model, contractual price and slot allocation of contractual container shipments are decided. In the second stage possible occurrence of spot prices are revealed. The solution values of the first stage variables will be the best ones for all considered scenario occurrences of spot prices.

In this section, notations, the objective function, and constraints of the stochastic programming model were also presented. Notations used for sets, parameters, and decision variables of the model are demonstrated in Table 1. While P sands for the set of seaports, V stands for the set of voyages. Ω stands for the set of scenarios. Since it is a stochastic programming model, stochasticity is included in the model through various scenarios.

Table 1. Notations used in the model

Sets	
P	Set of seaports
V	Set of voyages
Ω	Set of scenarios
Parameters	
$r_{ijv}(w)$	The spot price for transportation of 1 container between port i and port j on voyage v
c_{ij}	Cost for transportation of 1 container between port i and port j
$D_{ijv}(w)$	Demand for transportation of container between port i and port j on voyage v
ESD_{iv}	Empty container supply or demand at port i on voyage v
ps	Share of spot shipments
cap	The capacity of the container liner service
h	Inventory holding cost of an empty container per day
l	Leasing cost of an empty container
First-stage Decision Variables	
P_{ij}	Contractual price for transportation of 1 container between port i and port j
Second-stage Decision Variables	
$\beta_{ij}(w)$	The coefficient for contractual price and contractual demand
$XS_{ijv}(w)$	Number of full spot containers transported between port i and port j on voyage v
$XC_{ijv}(w)$	Number of full contractual containers transported between port i and port j on voyage v
$XE_{ijv}(w)$	Number of full empty containers transported between port i and port j on voyage v
$XRS_{iv}(w)$	Number of full spot containers remain on ships at port i on voyage v
$XRC_{iv}(w)$	Number of full contractual containers remain on ships at port i on voyage v
$XRE_{iv}(w)$	Number of full empty containers remain on ships at port i on voyage v
$W_{ijv}(w)$	Auxiliary variable for linearizing $P_{ij} * XC_{ijv}(w)$
$L_{iv}^{+}(w)$	Number of empty containers leased at port i on voyage v
$L_{iv}^{-}(w)$	Number of excess empty containers returned to lessors at port i on voyage v
$EI_{iv}(w)$	Number of empty containers stored at port i on voyage v

Parameters, the data to be included in the model instances, are also described in Table 1. ESD_{iv} denotes empty container demand or supply at port i on the voyage v. When it takes a positive value, it is the supply of empty containers at port i on the voyage v, and when it takes a negative value, it is the demand for empty containers at port i on the voyage v. c_{ij} denotes costs of transporting 1 container between port i and port j. ps denotes the share of the spot shipments in the total demand. While h denotes the storage cost of 1 container at a seaport, l denotes the average costs of leasing 1 container at a seaport. D_{ijv} (w) and $r_i jv$ (w) are stochastic parameters that take a different value in each scenario. D_{ijv} (w) denotes transportation demand from port i to port j on voyage v in scenario w.$r_i jv$ (w) denotes spot market prices for transportation of 1 container from port i to port j on voyage v in scenario w.

Table 1 shows the decision variables of the model. Because the model is a two-stage stochastic programming model, decision variables are distinguished in terms of two stages. P_{ij} denotes the price for contractual shipments from port i and port j. It is the first stage variable since the decision regarding the price of contractual shipments is decided before the uncertainty is revealed. P_{ij} is not scenario dependent - the solution of a model instance will provide a value for the variable that is robust for the realization of all considered scenarios. Other decision variables are the second-stage variables. β_{ij} (w) is the coefficient of the functional relationship between spot market prices and the demand for contractual shipments. XS_{ijv} (w), XC_{ijv} (w), and XE_{ijv} (w) denote the number of full spot containers, the number of full contractual containers, and the number of empty containers that are transported between port i and port j on voyage v, respectively. XRS_{iv} (w), XRC_{iv} (w), and XRE_{iv} (w) denote the number of full spot containers, the number of full contractual containers, and the number of empty containers that are remained on ships at port i on voyage v, respectively. W_{ijv} (w) denotes the auxiliary variable used for linearizing the expression P_{ij}* XC_{ijv} (w) in the objective function. L_{iv}+ (w) and L_{iv}^{-}(w) denote the number of empty containers leased and the number of excess empty containers returned to lessors at port i on voyage v, respectively. At last, EI_{iv} (w) denotes the number of empty containers stored at port i on voyage v.

Model has several assumptions:

1. Containers were segmented under three categories: spot container shipments, contractual container shipments, and empty container shipments.
2. There is an inverse linear relationship between price and demand.
3. Proportion of contractual shipments to spot shipments needs to be decided before solving model instances.
4. The decision variables regarding number of containers included in the model are continuous variables.

The first assumption is straightforward and in line with industry practices were customers of container shipping lines are segmented as shippers of contractual and spot containers (Y. Wang & Meng, 2021). The second assumption is also reasonable because increases in the price of a service or a product reduces its demand. However, the shape of relation might be different for different services or products and may not be linear. The third assumption can be eliminated by solving model insurances for different proportions of contractual and spot shipments. Therefore, the best proportion can be found for different model instances. The fourth assumption also can have a very little impact. Containers are non-dividable entities, but in cases where integer decision variables took high values, they can be treated as continuous variables and rounded to the closest integers with a very minuscule difference compared to integer solutions since it is a lot easier to solve linear programming model instances.

4.1. Objective Function

The expressions from 1.1 to 1.5 present the objective function of the model. As can be seen, the objective function of the model is the profit maximization function. Since the model is a stochastic programming model, the first term in the expression 1.1 is the weighted sum of all the terms in the objective function in terms of the occurrence probability of each scenario. The sum of the occurrence probabilities of all scenarios must be equal to 1. The second term in expression 1.1 represents the profit margin of contractual shipments while expression 1.2 represents the profit margin of spot shipments. The remaining expressions represent the costs; thus, they are subtracted from the profit margins. Expression 1.3, expression 1.4, and expression 1.5 represent the costs of empty container transportation, empty container leasing, and empty container storage, respectively.

$$max\{\sum_{w\epsilon\Omega} pr(w)\{\sum_{i\epsilon P}\sum_{j\epsilon P}\sum_{v\epsilon \vee}(P_{ij}-c_{ij})XC_{ijv}(w)+ \tag{1}$$

$$\sum_{i\epsilon P}\sum_{j\epsilon P}\sum_{v\epsilon \vee}(r_{ijv}(w)-c_{ij})XS_{ijv}(w)- \tag{2}$$

$$\sum_{i\epsilon P}\sum_{j\epsilon P}\sum_{v\epsilon \vee}c_{ij}XE_{ijv}(w)- \tag{3}$$

$$l\sum_{i\epsilon P}\sum_{v\epsilon\vee}L^{+}_{iv}(w)- \tag{4}$$

$$h\sum_{i\epsilon P}\sum_{v\epsilon\vee}El_{iv}(w) \tag{5}$$

4.2. Demand Constraints

Constraints from 2 to 4 represent demand constraints. Constraint 2 is the demand constraint for spot shipments. The number of spot containers that are transported is less than or equal to the spot container transportation demand which is equal to a certain percentage of the total transportation demand. The less than or equal sign indicates that the carrier has an option for accepting spot containers that maximize its profits. Constraints 3.1 and 3.2 represent the demand constraint for contractual shipments. Constraint 3.2 indicates that the contractual price for container transportation from port i to port j equals a ratio of the mean spot rate of all the voyages. Constraint 3.1 indicates that the demand for contractual shipments is inversely proportional to the price of contractual shipments. As can be seen in Constraint 3.1, the relationship is equality, indicating that contractual shipments must be provided by the carrier. Constraint 4 is the flow conservation constraint for empty containers. The terms on the left side of the equation are the incoming empty container flow, and the term on the right side of the equation is the outgoing flow. The first term on the left side is the sum of empty containers that come to port i from each port j while the second and third terms are equal to empty containers stored at port i from the previous voyage and empty containers leased from lessors at port i, respectively. The last term on the left side of the equation is the demand/supply of empty containers at port i. When the parameter is negative, it equals the demand, and when the parameter is positive, it equals to supply of empty containers.

$$XS_{ijv}(W) \leq psD_{ijv}(w)\forall i \in P, \forall j \in P, \forall v \in V, \forall W \in \Omega \tag{6}$$

$$XS_{ijv}(W) = (1-ps)D_{ijv}(W) - (1-ps)D_{ijv}(W)\beta_{ij}(W)\forall i \in P, \forall j \in P, \forall v \in V, \forall W \in \Omega \tag{7}$$

$$P_{ij} = meanr_i jv(w) : v\epsilon V\beta_i j(w)\forall i \in P, \forall j \in P, \forall w \in V, \forall W \in \Omega \tag{8}$$

$$\sum_{i\epsilon P} XE_{ijv}(W) + EI_{iv-1}(W) + L^{+}_{iv}(W) + ESD_{iv}(W) = \sum_{i\epsilon P} XE_{ijv}(W) + EI_{iv}(W) + L^{-}_{iv}(W) \tag{9}$$

$$\forall i \in P, \forall v \in P, \forall w \in V, \forall W \in \Omega \tag{10}$$

4.3. Capacity Constraints

Constraints from 5.1 to 5.4 are capacity constraints. Constraints 5.1, 5.2, and 5.3 describe the number of spot containers, contractual containers, and empty containers that remain on ships at port i on voyage v, respectively. As it can be seen, all three constraints are identical except for the type of containers so only one of them will be described in detail. In Constraint 5.1, on the left-hand side of the equation is the decision variable for the number of spot containers that remain on ships at port i on voyage v. The first term on the right-hand side of the equation is the sum of the number of containers that come from preceding ports and are destined to be delivered to upcoming ports on the current voyage. The second term on the right-hand side of the equation is the sum of the number of containers that come from preceding ports and are destined to upcoming ports that precede the origin ports on the cyclic route. And those containers are to be delivered to destination ports on the next voyage. The third and the last terms on the right-hand side of the equation are the sum of the number of containers that come from upcoming ports on the previous voyage and are destined to be delivered on the current voyage to the upcoming ports that precede the origin ports. Constraint 5.4 indicates the ship capacity limitations for the containers that are to be loaded on ships at port i on voyage v. The terms on the left-hand side of the equation represent the sum of the number of spot containers, contractual containers, and empty containers transported from port i to each port j. The first term on the right-hand side of the equation is the total capacity of ships operated on the service. In practice, on a container liner service route, ships' calls to ports are arranged in such a way that each port is visited at least once a week. The slots allocated to the total capacity of ships operated on a container liner service can easily be distributed to each ship operated on that container liner service. The second, third, and last terms on the right-hand side of the equation are, respectively, spot containers, contractual containers, and empty containers that remain on ships at port i on voyage v. As it can be seen in Contraint 5.4, the number of containers to be loaded on ships at port i on voyage v can be at most the remaining empty capacity on the ships at port i on voyage v.

$$XRS_{iv} = (W) = \sum_{\substack{j\epsilon P \\ i>j}} \sum_{\substack{k\epsilon P \\ k>i}} XS_{jkv}(w) + \sum_{\substack{j\epsilon P \\ i>j}} \sum_{\substack{k\epsilon P \\ j>k}} XS_{jkv}(w) + \sum_{\substack{j\epsilon P \\ j>k}} \sum_{\substack{k\epsilon P \\ k>i}} XS_{jkv-1}(w) \tag{11}$$

$$\forall i \in P, \forall v \in V, \forall W \in \Omega \tag{12}$$

$$XRC_{iv} = (W) = \sum_{\substack{j\epsilon P \\ i>j}} \sum_{\substack{k\epsilon P \\ k>i}} XC_{jkv}(w) + \sum_{\substack{j\epsilon P \\ i>j}} \sum_{\substack{k\epsilon P \\ j>k}} XC_{jkv}(w) + \sum_{\substack{j\epsilon P \\ j>k}} \sum_{\substack{k\epsilon P \\ k>i}} XC_{jkv-1}(w) \tag{13}$$

$$\forall i \in P, \forall v \in V, \forall W \in \Omega \tag{14}$$

$$XRE_{iv} = (W) = \sum_{\substack{j\epsilon P \\ i>j}} \sum_{\substack{k\epsilon P \\ k>i}} XE_{jkv}(w) + \sum_{\substack{j\epsilon P \\ i>j}} \sum_{\substack{k\epsilon P \\ j>k}} XE_{jkv}(w) + \sum_{\substack{j\epsilon P \\ j>k}} \sum_{\substack{k\epsilon P \\ k>i}} XE_{jkv-1}(w) \tag{15}$$

$$\forall i \in P, \forall v \in V, \forall W \in \Omega \tag{16}$$

$$\sum_{jeP} XS_{ijv}(w) + \sum_{jeP} XC_{ijv}(w) + \sum_{jeP} XE_{ijv}(w) \leq cap - XRS_{iv}(w) - XRC_{iv} - XRE_{iv}(w) \tag{17}$$

$$\forall i \in P, \forall v \in V, \forall W \in \Omega \tag{18}$$

4.4. Linearization of Non-Linear Objective Term

The objective function includes a bilinear term $P_{ij}\ XC_{ijv}$ (w) since it is a non-linear and non-convex expression that is very difficult to solve, and algorithms that are used for solving linear programming model instances cannot be applied. However, the bilinear term can be linearized using various modeling approaches. One of the modeling approaches used for linearizing bilinear terms in a very efficient way is using McCormick's inequalities (or McCormick's envelopes) (Costa et al., 2017; McCormick, 1976). P $_{ij}$* XC_{ijv} (w) is the bilinear term, and the lower and the upper bounds for the two variables can be defined as $P_{ij} \in [L_{Pij}, U_{(P_ij)}$ and XC_{ijv} (w)$\in [L_{XCijv}(w), U_{XCijv}(w)]$. According to McCormick's inequalities (McCormick, 1976), the convex envelope of the bilinear term is defined by the following inequalities:

$$W_{ijv}(w) \geq L_{XCijv(w)} P_{ij} + Lp_{ij} XC_{ijv}(w) - L_{XCijv}(w) Lp_{ij} \forall i \in P, \forall j \in P, \forall v \in V, \forall w \in \Omega \tag{19}$$

$$W_{ijv}(w) \geq U_{XCijv(w)} P_{ij} + Up_{ij} XC_{ijv}(w) - U_{XCijv}(w) Up_{ij} \forall i \in P, \forall j \in P, \forall v \in V, \forall w \in \Omega \tag{20}$$

$$W_{ijv}(w) \leq L_{XCijv(w)} P_{ij} + Up_{ij} XC_{ijv}(w) - L_{XCijv}(w) Up_{ij} \forall i \in P, \forall j \in P, \forall v \in V, \forall w \in \Omega \tag{21}$$

$$W_{ijv}(w) \leq U_{XC_{ijv}(w)} P_{ij} + Lp_{ij} XC_{ijv}(w) - U_{XC_{ijv}}(w) Lp_{ij} \forall i \in P, \forall j \in P, \forall v \in V, \forall w \in \Omega \quad (22)$$

P_{ij}* XC_{ijv} (w) on the objective function is replaced by W_{ijv} (w).

4.5. Non-Negativity and Integrality Constraints

All of the decision variables included in the model are non-negative real numbers.

5. Model Application

5.1. Application Case

The model was applied to a case that includes a container liner service of a leading local container liner company that mainly provides services throughout ports of the Mediterranean and the Black Sea. The container liner service is illustrated in Figure 2. The service includes 9 ports, 4 of which are located in Western Turkey (Istanbul, Izmit, Bursa, and Izmir), 3 of which are located in Spain (Valencia, Castellon, and Barcelona), 1 of which is located in France (Fos Sur Mer), and 1 of which located in Greece (Piraeus). The route of the service follows the sequence of ports as Valencia-Castellon-Barcelona-Fos Sur Mer-Piraeus-Istanbul-Izmit-Bursa-Izmir-Valencia. One voyage through the route takes around 3 weeks.

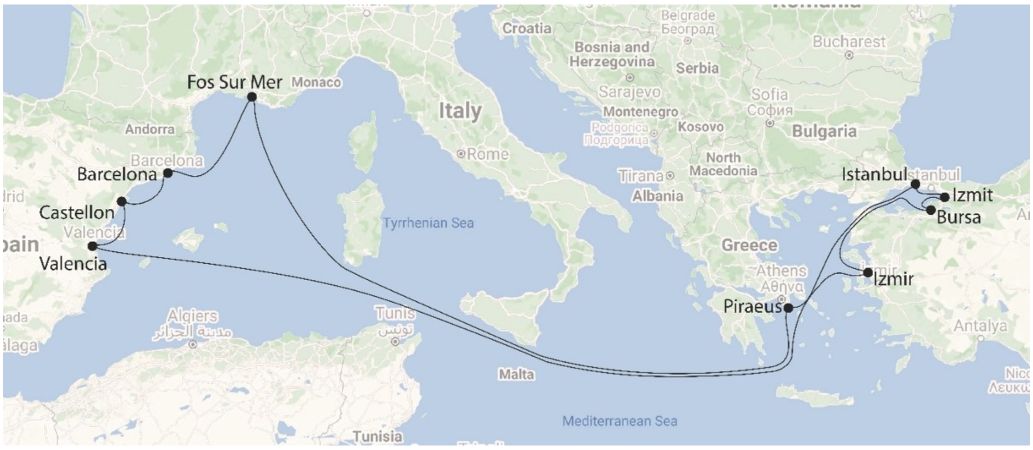

Figure 2. The Container Liner Service that the Model Applied

5.2. Data Description

The instances from the model are constructed by including parameter data regarding the application case of the container liner service. Table 2 shows the spot market price for transportation of 1 TEU full container between each port in the service. The spot market prices shown in the table are gathered from an online shipping platform called Freightos on March 9th, 2021. The prices are not symmetrical, for example, it is shown in the first line of Table 2 that the spot market price for transportation of 1 TEU from Valencia to Fos Sur Mer is $550, on the other hand, it is shown in the third line that spot market price for transportation of 1 TEU from Fos Sur Mer to Valencia is $964.

Table 3 illustrates the distance between each port in the service. Table 3 is created by using the data from an online shipping platform called Searates. Similar to the spot market prices, the distances shown in the table are also not symmetrical because they are not direct distances, but distances through the route. For example, it is shown in the first line of Table 3 that the distance from Valencia to Castellon through the route is 39 miles, but the distance from Castellon to Valencia through the route is 3386 miles since a ship must complete one voyage to arrive from Castellon to Valencia through the route of the service.

Table 4 shows the container transportation demand between each pair of ports in the service. The demand data is hypothetically created since it is considered sensitive information and not to be shared by container shipping lines. The main flows of container transportation through the service are between West Mediterranean (Valencia, Castellon, Barcelona, and Fos Sur Mer) and East

Table 2. Spot Price for Transportation of 1 TEU

	Valencia	Castellon	Barcelona	Fos	Piraeus	Istanbul	Izmit	Bursa	Izmir
Valencia	-	$793	$793	$550	$793	$848	$848	$848	$848
Castellon	$793	-	$793	$550	$793	$848	$848	$848	$848
Barcelona	$793	$793	-	$550	$793	$848	$848	$848	$848
Fos	$964	$964	$964	-	$964	$903	$903	$903	$903
Piraeus	$793	$793	$793	$550	-	$848	$848	$848	$848
Istanbul	$400	$400	$400	$500	$400	-	$500	$500	$500
Izmit	$400	$400	$400	$400	$400	$500	-	$500	$500
Bursa	$400	$400	$400	$400	$400	$500	$500	-	$500
Izmir	$400	$400	$400	$400	$400	$500	$500	$500	-

Source. www.freightos.com

Mediterranean (Piraeus) and Marmara Sea (Istanbul, Izmit, Bursa, and Izmir). The hypothetical demand data is created considering this fact to reflect the current sector practice. Table 4 illustrates that the container transportation demand between ports of West Mediterranean and East Mediterranean and the Marmara Sea is created according to uniform distribution between 200 and 500 containers. Since there is a minuscule number of containers transported among ports of the Marmara Sea and ports of Spain and France, the container transportation demands between those ports are created according to uniform distribution between 0 and 50 containers. It can be seen in Table 4 that there is a container transportation demand from Valencia to Castellon, but there is not from Castellon to Valencia. Since the transportation of containers from Castellon to Valencia requires one complete voyage, it is not economically and practically viable to transport containers from Castellon to Valencia. This is also applicable for other legs that require one complete voyage to transport containers between them.

Table 3. Distance Between Ports in the Service (Nautical Miles)

	Valencia	Castellon	Barcelona	Fos	Piraeus	Istanbul	Izmit	Bursa	Izmir
Valencia	-	39	168	345	1407	1738	1773	1816	2052
Castellon	3386	-	129	306	1368	1699	1734	1777	2013
Barcelona	3257	3296	-	177	1239	1570	1605	1648	1884
Fos	3080	1746	3248	-	1062	1393	1428	1471	1707
Piraeus	2018	2057	2186	2363	-	331	366	409	645
Istanbul	1687	1726	1855	2032	3094	-	35	78	314
Izmit	1652	1691	1820	1997	3059	3390	-	43	279
Bursa	1609	1648	1777	1954	3016	3347	3382	-	236
Izmir	1373	1412	1541	1718	2780	3111	3146	3189	-

Source. www.searates.com

Data related to other parameters are also included in the instances. The time period included in the instances is 1 year. Since 1 voyage takes 21 days, the number of voyages equals 17. Inventory holding cost of 1 empty TEU (h) for a duration of 1 voyage at a port in the service equals $105 ($5 per day). The average cost of leasing 1 empty TEU (l) is $300. The share of spot container transportation demand in the market (ps) equals 0.6 meaning that 60% of the container transportation demand in the market is for spot container transportation. The empty container demand/supply at each port (ESD_{iv}) is hypothetically created according to uniform distribution between -100 and 100. When it is below zero, it means the number of empty containers demanded at port i on voyage v. When it is above zero, it means the number of empty containers supplied at port i on voyage v. Container transportation cost between each pair of ports is determined according to transportation distance (L_{ij}), which is shown in Table 3. The transportation cost equals $0.05 per TEU per mile ($c_{ij} = 0.05 * L_{ij}$). Additionally, upper, and lower bounds for the two decision variables, i.e.,

XC_{ijv}(w) and P_{ij}, must be determined as described in equations (6), (7), (8), and (9). Lower bound for contractual price P_{ij} equals $0.1 * L_{ij}$, which is higher than the transportation cost of 1 container between port i and port j ($L_{(P_{i}j)} = 0.1 * L_{ij}$) since it is not reasonable that a container shipping company would provide contractual transportation prices lower than or equal to transportation cost. At least reasonable profits should be made; thus, it is twice as much higher than the transportation costs. The upper bound of the contractual price is the average spot market price throughout all 17 periods $U_{(P_{i}j)} = meanr_{i}jv(w) : v$. It is reasonable that the contractual price should be less than the average spot market price, otherwise there is no reason for customers to sign a contract, they can get the transportation service from the spot market. The lower bound for XC_{ijv} (w) equals 0 ($L_{XC_{ijv}}(w) = 0$) since the company can choose not to provide service for contractual shipments. The upper bound for XC_{ijv}(w) equals the total demand for contractual shipments ($U_{XCijv}(w) = (1 - ps)\ D_{ijv}(w)$. The transportation capacity of the service (cap) equals 8200 TEUs. The capacity is determined by turning the capacity parameter (cap) into a decision variable and solving the deterministic equivalent of the model instance. The solution showed that to maximize the profits, the container liner company should provide at least 8201.89 TEUs of transportation capacity in the service. Assuming that the container liner company determined the service capacity that maximizes its profits as consistent with industry practice, the capacity parameter *(cap)* was set to 8200 TEUs.

Table 4. Distance Between Ports in the Service Container Transportation Demand Between Ports in the Service (Number of TEUs)

	Valencia	Castellon	Barcelona	Fos	Piraeus	Istanbul	Izmit	Bursa	Izmir
Valencia	-	$U[0,50]$	$U[0,50]$	$U[0,50]$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$
Castellon	0	-	$U[0,50]$	$U[0,50]$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$
Barcelona	0	0	-	$U[0,50]$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$
Fos	0	0	0	-	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$
Piraeus	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	-	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$
Istanbul	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	-	$U[0,50]$	$U[0,50]$	$U[0,50]$
Izmit	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	0	-	$U[0,50]$	$U[0,50]$
Bursa	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	0	0	-	$U[0,50]$
Izmir	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	$U[200,500$	0	0	0	-

5.3. Sampling approach

The uncertain input parameters of the model, namely spot container transportation price r_{ijv} (w) and container transportation demand D_{ijv} (w), are included in the instances as a finite number of scenarios that are constructed from a random sample with equal occurrence probabilities as consistent with the usual stochastic modeling practice (Birge & Louveaux, 2011). The random samples in the application case are taken from uniform distribution, and the lower and upper bounds of the uniform distribution were determined according to probable market expectations that were investigated. For example, when the expectation of a down to 10% decrease in the market demand is tested in the experiments, it is assumed that the demand will gradually decrease down to 10% at the last voyage of 17 voyages. In that situation, the created scenarios include random demand realizations between the current level and 10% lower than the current level at the last voyage. As an example, in one of the scenarios, if the random demand realization is -8.4%, it is assumed that the demand on the last voyage will be 8.4% lower than on the first voyage with a gradual decrease of 8.4/17% in each voyage. When drawing random samples for spot price and transportation demand, the correlation between those two random parameters was also considered according to the 0.8 Pearson correlation. For instance, if a 10% decrease in the market demand is assumed, it is also assumed that it will create down to a 10% decrease in the spot market price, and random realization of those demands and spot market prices are 0.8 correlated in terms of Pearson correlation.

Because stochastic modeling instances are required to include a finite number of scenarios, the number of scenarios to be included needs to be decided. If the number of scenarios is too many, the instance would not be solved in a reasonable time. However, if the number of scenarios is too few, some portion of uncertainty would not be captured in the instances. Table 5 shows the solution performance with regard to the number of scenarios. Model instances with 80, 90, and 100 scenarios as shown in Table 5 were solved by Gurobi Solver. The differences in the objective values in each set of scenarios are less than 1%. This indicates that increasing the number of scenarios to more than 100 would bring very little improvement. Therefore, it is decided that 100 scenarios can provide adequate representation for uncertainty performing experimentations that will be explained in the next section.

Table 5. Solution Performance with Different Number of Scenarios

Number of Scenarios	Solution Time (Seconds)	Objective Value ($)
80	184	126,301,214
90	211	127,162,364
100	221	128,736,500

6. Experimental Results

6.1. Sensitivity Evaluations for Market Expectations

Experimentations have been performed considering various market situations in the application context. Particularly, three market situations were evaluated concerning the expectation toward the future market. They include downward market expectations down to 50%, upward market expectations up to 50%, and expectations in a range between down to 50% and up to 50%. In the experimentation, it is evaluated how these market situations impact various performance criteria i.e., average contractual price, gross profit (objective value), and capacity utilization.

6.1.1. Downward Market Expectations

The impacts of downward market expectations are evaluated by assuming that the future demand and spot market price will be lower than the current level. 5 different levels of downward demand are evaluated. Each time, it is considered that the demand and spot market prices would take values in between the current values and the downward level. For example, in the first level, it is considered that the demand and spot market prices would take random values in between their current values and 10% downward of the current market level. Down to 50% decreases in the demands and spot market prices were considered and illustrated in Figure 3 and Figure 4.

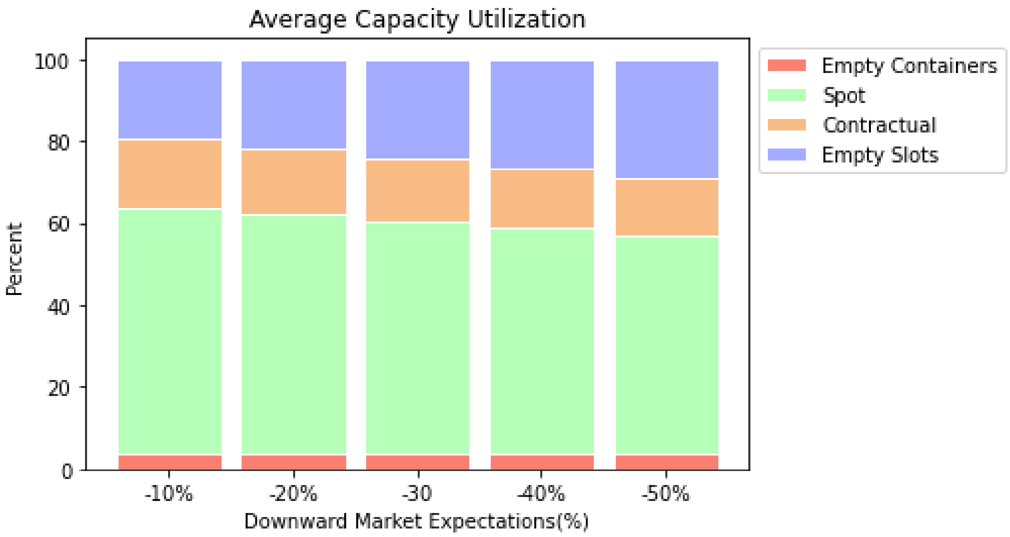

Figure 3. Sensitivity of Capacity Utilization

Figure 3 shows that when a down to 10% decrease is expected in the market, the average capacity utilization would be around 80%. However, if the expected decrease is steeper i.e., 50%, the capacity utilization decreases a little less than 10% and becomes 71%. Increasing the range of downward uncertainty reduced the number of both contractual and spot containers while the number of empty containers stayed about the same. A similar decrease is also observed for contractual freight as shown in Figure 4. When the expected market decrease goes down to a range of 50% from a range of 10%, the contractual price decreases from 359to324.8, which is around 10%. Objective value, however, is more sensitive as it decreases 23% by going down from $123,060,930 to

$94,485,490. These results indicate that a possible decrease in demand might cause serious financial difficulties and a high level of idle capacity. Therefore, the liner company should prepare for the downward market in advance. One solution can be redeploying its fleet to shift the capacity to the markets where the market outlook is more promising. Forming long-term relations with their customers can be another option. The experiment instances assumed that 60% of the total demand is spot market demand while 40% of it is contractual demand from the contractual market. By forming long-term relations with customers, this share of the contractual market can be increased.

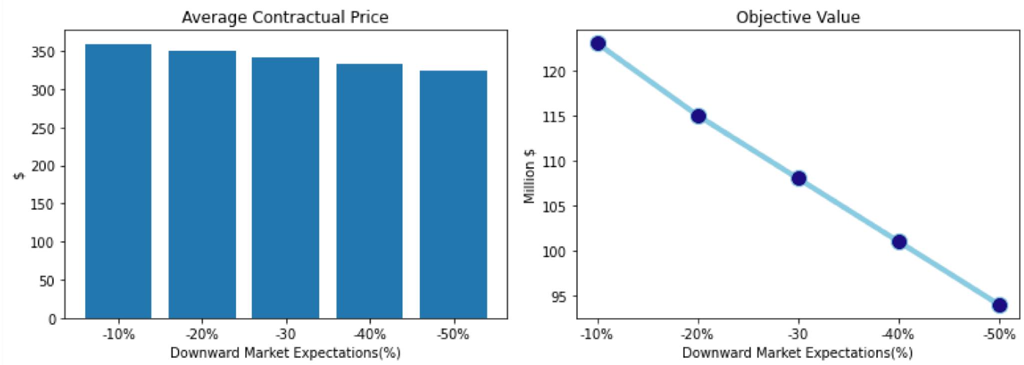

Figure 4. Sensitivity Contractual Price and Objective Value

6.1.2. Upward Market Expectations

Upward market expectations were evaluated in the same way as the downward expectations, but the five-level demand changes were upward as illustrated in Figure 5 and Figure 6. As shown in Figure 5, the capacity utilization resulted from the increasing number of spot containers. When the range of upward market expectations goes to 50% from 10%, the increase in the average capacity utilization would be around 5% increasing from 84.5% to 88.6%. Compared to the impact of downward expectations, the change is almost half of the change resulting from the same amount of change in the downward expectations range. This indicates that capacity utilization is more sensitive to demand decreases than demand increases. Additionally, at around 90%, the increase in capacity utilization slows down and reaches saturation point even though there is enough demand for further increase. At this point, the liner company should take measures to increase the capacity of the service to take advantage of the high demand. Various options can be considered depending on the situation in the market. The capacity from other services that are less profitable can be redeployed to the current service or extra container ships can be bought from the second-hand market or chartered or capacity can be hired from other alliance members' services.

An interesting result regarding empty containers was observed as illustrated in Figure 5. When the upward range increases, the number of empty containers decreases. This result partially sheds light on the current empty container shortage in the market. Among other reasons, when the market is expected to increase, it is more profitable for the liner company to allocate its slots to spot containers instead of empty containers and looking for other options for empty container supply such as leasing since the option of empty container leasing is included in the model. Even if the other options are more expensive than relocating empty containers, the profit generated from increased spot rates and demand would compensate for it.

Figure 6 illustrates the sensitivity of contractual prices and gross profit (objective value). Contrary to capacity utilization, the contractual price is more sensitive to the upward market expectations because the changes in the average contractual price resulting from upward market expectations are higher compared to the changes resulting from downward market expectations. When the upward expectations range goes up to 50% from 10%, the average contractual price increases 12% from $423 to $377.25. And the objective value increases around 22% from $138,675,370 to $168,865,890.

6.1.3. Expectations towards Both Sides

In addition to downward and upward demand expectations, the symmetrical expectations towards both sides were evaluated by assuming the market will be in a particular range between a certain percentage lower and upper than the current market. Experiments were conducted the same way as the previous experiments, by evaluating 5-level range changes as illustrated in Figure 7 and Figure 8.

Figure 7 illustrates the impacts on average capacity utilization. For example, the first level range in the graph shows the market

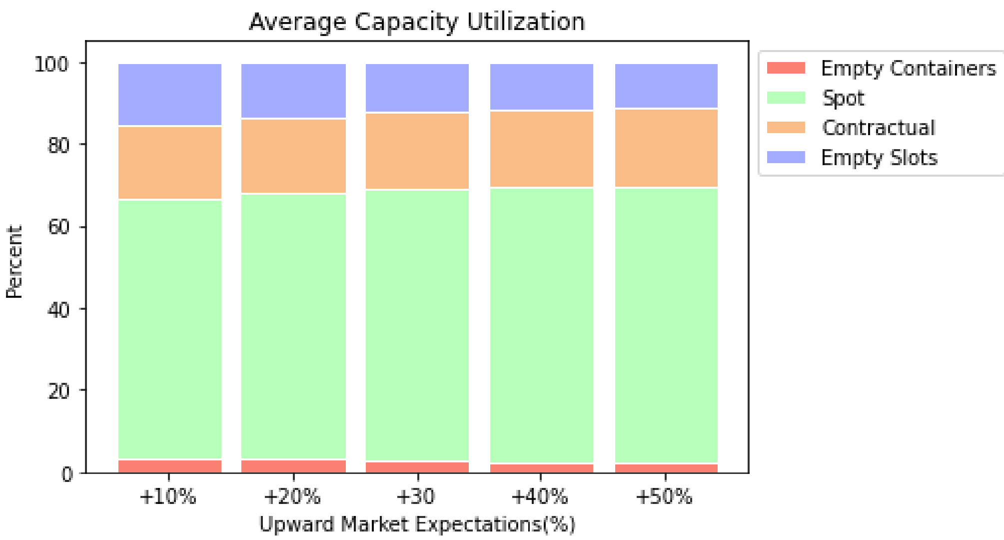

Figure 5. Sensitivity of Capacity Utilization

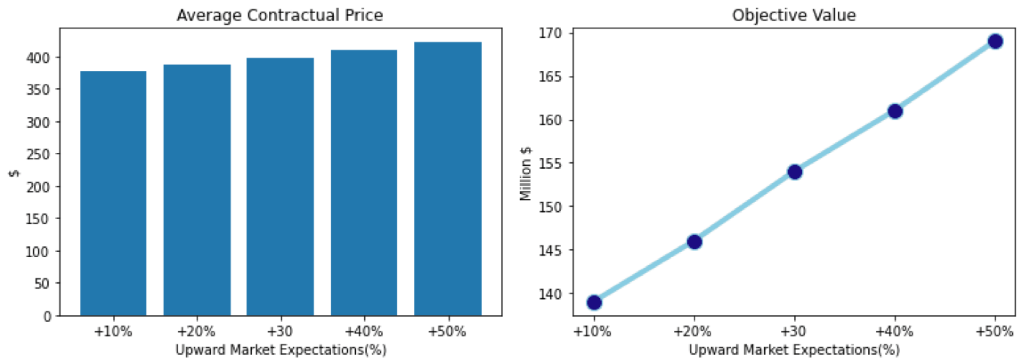

Figure 6. Sensitivity of Contractual Price and Objective Value

expectations between 10% up and 10% lower than the current market, and the demand and spot market prices take random values in between this range. The graphs in Figure 5 show that even if the market expectations are symmetrical on both sides (downward and upward), the increasing uncertainty ranges negatively affect both capacity utilization and objective value while increasing contractual price. When the uncertainty exceeds the range between -20% and +20%, the number of contractual and spot containers starts to shrink. While the number of empty containers stays about the same unit the uncertainty range hits -40% and +40% then the number of empty containers starts to shrink as well. The increase in the uncertainty ranges from between +10% and -10% to between +50% and -50% decreases average capacity utilization around 5% from 82.4% to 78.5% while decreasing objective value around 1.5% from $130,600,900 to 128,736,500$. On the other hand, this change in the uncertainty range increases the average contractual price by around 5% from $369.47 to $390.43.

These results indicate that the increasing range of uncertainty negatively impacts the business of the liner company. Therefore, the level of uncertainty should be reduced by taking various measures. To minimize uncertainty, a company can increase its integration and information sharing with its customers. This can be accomplished by long-term relationships as stated earlier as a measure to deal with downward market expectations. Additionally, taking advantage of state-of-the-art forecasting techniques can help to reduce the level of uncertainty.

6.2. Value of Stochastic Solution

The value gained from including stochasticity in the modeling is evaluated in this section. The value of the stochastic solution (VSS) is defined as the benefit gained from including uncertainty in a model (Birge, 1982; Birge & Louveaux, 2011; Maggioni & Wallace, 2012). Equation 11.1 shows that in a maximization problem, it equals the recourse problem (RP) solution minus

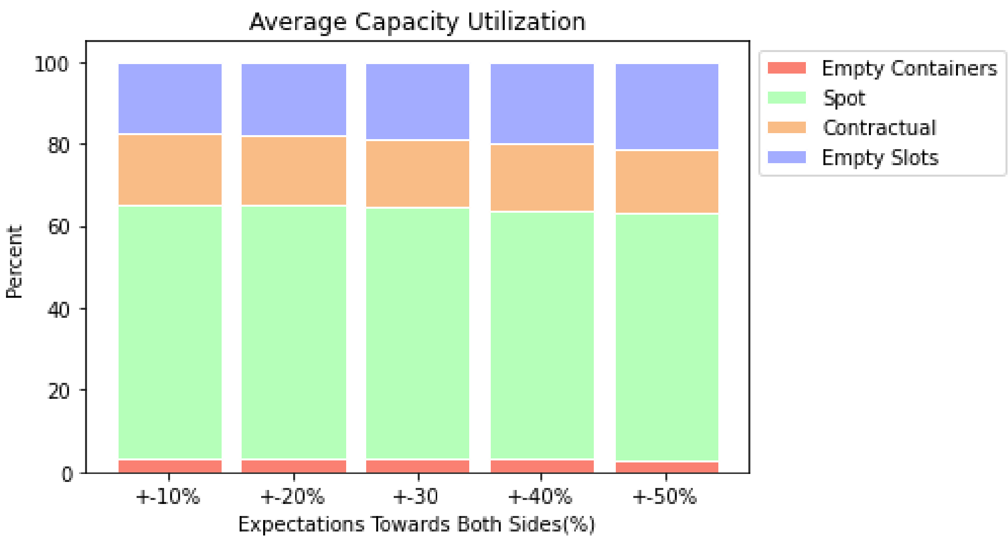

Figure 7. Sensitivity of Capacity Utilization

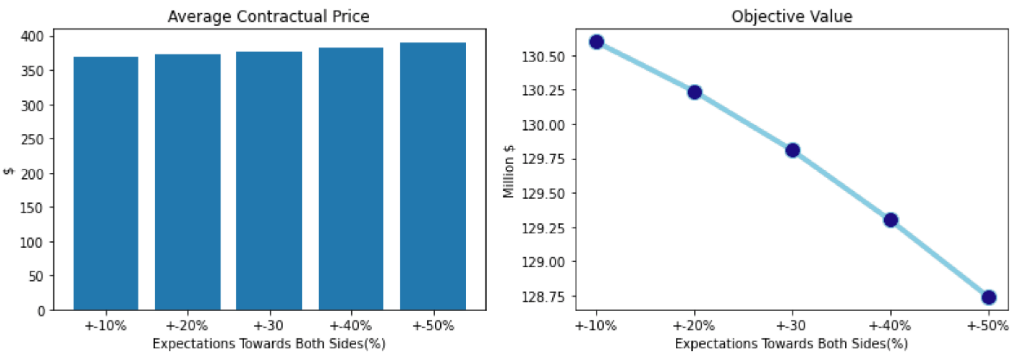

Figure 8. Sensitivity of Contractual Price and Objective Value

the expectation of the expected value solution (EEV). Recourse problem solutions equal the solution of the stochastic instance. Expectations of the expected value solutions equal the mean of deterministic instance solutions of every scenario by fixing the first stage variable values to the deterministic instance solution of the mean value scenario (Birge (1982), Birge & Louveaux (2011), and Maggioni & Wallace (2012).

$$VSS = RP - EEV \tag{23}$$

$$RP = \min_{x} E_{\omega} z(x, \omega) \tag{24}$$

$$EEV = E_{\omega}(\min_{x} z(x(\omega), \omega)) \tag{25}$$

Table 6 shows values of stochastic solution calculated for three instances; the first instance includes downward expectations in a range from the current level to down to 50%, and the second instance includes upward expectations in a range from the current level to up to 50%, and the third instance includes the expectations in a range between down to 50% and up to 50%. Table 6 shows that when the market is expected to decrease by 50%, applying stochastic modeling would bring up to $1,815,490 more profit instead of applying a deterministic equivalent. The benefit of stochastic solution would be higher, particularly $4,390,640 when the market is expected to increase up to 50%. On the other hand, when the market is expected to be in a range between up to 50% and down to 50%, the value of the stochastic solution would be $386,980. Results for all three instances confirm that including stochasticity in the modeling brings benefits. Since life is full of uncertainties, it can be assumed that it is certain, but it is not possible to avoid the impacts of uncertainties. Therefore, accounting for uncertainty in the modeling of slot allocation and contractual pricing of container liner shipping would be beneficial.

Table 6. Value of Stochastic Solutions ($)

Instance	EEV	RP	VSS
Down to 50%	92,670,000	94,485,490	1,815,490
Up to 50%	164,475,250	168,865,890	4,390,640
Between down to 50% and up to 50%	128,349,520	128,736,500	386,980

7. Conclusions

The product of container liner companies is their transportation capacity, and by selling their transportation capacities in particular routes to their customers, they generate revenue. Therefore, managing their transportation capacity is a topmost priority for container liner companies. The capacity usage can be segmented into three as the capacity for contractual, spot, and empty containers. Additionally, the number of slots allocated to contractual and spot containers depends on the prices provided to each type of customer. The transportation price for spot containers is determined in accordance with the spot market prices; however, contractual prices are determined according to future expectations regarding demand and spot market prices. Container shipping lines usually have room for deviating from the contractual prices of their competitors. Therefore, optimum contractual prices and slot allocation that maximize profitability and capacity utilization of container shipping lines can be determined by taking advantage of optimization modelling. In this regard, this study aimed to propose an optimization model for slot allocation and contractual pricing that considers spot and contractual shipments and empty container repositioning under a stochastic environment. The model was applied in the case of container liner shipping service in between ports of western Mediterranean and ports of Marmara Sea.

Experimentation for evaluating the downward market expectations showed that a possible decrease in the demand and spot prices could cause a tremendous loss in revenue and create a high level of idle capacity. The liner company should take measures to soften the blow by redeploying its ships to services that have promising outlooks or focusing on developing long-term relationships with its customers to increase the share of contractual shipment demand in terms of total demand. Experiments regarding the upward demand expectation showed that the capacity utilization reach a saturation point at around 90%. After this point, the company needs to increase its service capacity to take advantage of the increasing market. Increasing range of upward demand results in a reduction of empty container transportation since it becomes more profitable to allocate the slots to spot market demand rather than empty containers and to take advantage of other means of empty container supply. Experimentation of symmetric uncertainty revealed that the increasing range of uncertainty creates a serious loss in profits and capacity utilization. It can be minimized by higher integration and information sharing with customers and taking advantage of state-of-the-art demand forecasting techniques.

The results of this study can have various implications. Decreases in demand for container transportation can have a tremendous impact on profitability of container lines. Container shipping lines can soften the impact by developing long-term relationships to increase the share of contractual shipments. Increases in the uncertainty can also cause big losses in profits. This shows container shipping lines the importance of integration with supply chain partners and taking advantage of new technologies such as AI and big data analytics for state-of-the-art demand forecasting. Besides, calculations of the value of stochastic solutions showed that the application of the stochastic modeling solutions would provide a higher profit margin than the solution of its deterministic equivalents. Therefore, container shipping lines should include uncertainty in their optimization modelling to increase their profitability.

This study has several limitations. First, it is apparent that the experimental results highly depend on the functional relationship between contractual price and the number of contractual slots. Second, the model includes only two stochastic parameters, namely sport prices and demand for container transportation. Third, the container transportation costs do not explicitly include speed and bunker consumption function. The application instances include container transportation cost that was determined according to transportation distance multiplied with a constant that equals to $0.05.

Future studies can overcome those limitations. First, the application of the model can be improved by providing a data-driven approach to determine the functional dependence between contractual price and the number of slots allocated to contractual shipments. Second, the model can include other stochastic parameters such as inventory costs, container leasing costs and transportation costs. Third, the model can be improved by including bunker consumption function and speed of container ships as decision variables. However, inclusion of more stochastic parameters and additional decision variables might increase the difficulty of model solution. Therefore, future studies can also develop specialized solution algorithms for their models.

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RESEARCH ARTICLE

Evaluating Trigger Effects of Covid-19 on Supply Chain Integration

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ABSTRACT
The Covid-19 pandemic affected almost all sectors of the economy. The maritime industry was also affected by the pandemic in various ways. During the pandemic period, the maritime industry experienced such challenges as empty container shortages, port congestion, labor shortages, etc. Different sectors of the maritime industry developed resilient strategies against these challenges. Liner shipping companies also developed horizontal integration strategies along supply chains to control and manage the whole process of door-to-door transportation. In this study, factors that accelerated the supply chain integration strategies of liner shipping companies during the Covid-19 pandemic period were investigated. In this context, the relevant literature was investigated in the SCOPUS database, and 24 articles were examined in a detailed manner. As a result of the literature review, the factors that accelerated the supply chain integration of liner shipping companies were coded through the MAXQDA 20 qualitative data analysis program, and the relationship between these factors was determined.

Keywords: *Liner Shipping, Covid-19, maritime industry, MAXQDA 20*

1. Introduction

Throughout history, societies and businesses have struggled several times with extraordinary epidemics that have had long-term effects on lives. 20 to 50 million people lost their lives due to the Spanish Flu epidemic between 1918-1919, and similarly, the Ebola virus had unique effects in all its dimensions. Major epidemics such as SARS, MERS, AIDS, cholera, and malaria affected the economy as well as society (Farooq et al. 2021). Covid-19 was discovered during a recent pneumonia outbreak in Wuhan in China's Hubei province in January 2020 (Ciottia et al. 2020). The Covid-19 outbreak was declared a pandemic by the World Health Organization (WHO) on March 11, 2020 (Ajmal et al. 2021). In the first phase, China was severely affected by the pandemic and had to reduce its economic and industrial activities, as well as introduce several quarantines in different cities. In a short time, cases were reported worldwide, and Covid-19 became a global emergency (Farooq et al. 2021).

One of the activities that has been greatly affected by Covid-19 becoming a global pandemic is the maritime industry and supply chain processes. The maritime transport sector, where an average of 90% of world trade is carried out, is also an important transportation system that provides the integration of global economic systems (Akkartal 2021). Maritime transport played an important role in the short-term emergency response to the pandemic by facilitating the transport of important commodities and properties, maintaining employment, and facilitating international trade (Keshta et al. 2020). Many countries had to partially or completely close their borders to prevent the spread of virus. This situation also caused the deterioration of global supply chains due to delays in the flow of goods, capital, and people. After the serious measures taken, many companies have begun to move into a new era to overcome the macroeconomic blow caused by the pandemic (Narasimha et al. 2021). On the other hand, major breakages were created by the effects of Covid-19 pandemic on the supply chain. When the remarkable effects of the pandemic on these processes are examined, it can be seen that the main problems were the increase in cargo waiting times at ports and congestion, due to many ships waiting for loading and unloading. An increase in waiting times at berths causes extra costs for ships. Therefore, this problem also causes decreased productivity and the loss of trade. (Chinedum 2018; Cremaschini and Monaco 2022). Among the top 20 global container ports, the ports of Los Angeles/Long Beach are the busiest container trade gateways in the USA, handling almost all goods from Asia to the USA. Ship waiting times for loading or unloading cargo at those ports reached the record level of the Covid-19 pandemic period in October 2021, with 100 ships waiting (UNCTAD 2021; Gui et al.

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2022). There were more than 8 days of waiting time from September to mid-December 2021 in both ports (Cremaschini and Monaco 2022). Therefore, these long waiting times and congestion in ports caused serious disruptions in supply chain processes.

A few companies that can be described as the giants of the maritime industry took steps to accelerate support for the end-to-end supply chain needs of customers during the pandemic period. The first example of these initiatives is that CMA CGM Group took an ambitious strategic growth step to provide its customers with first-class logistics services by owning 97.89% of the outstanding shares and voting rights of CEVA logistics, which was tendered on April 16, 2019. CMA CGM Group is able to meet the logistics needs of its customers around the world with a comprehensive solution-oriented spectrum across the supply chain (CMA CGM 2022). Following this strong merger, Maersk acquired Hong Kong-based logistics company LF Logistics, which has outstanding capabilities in omnichannel fulfilment services, inland transportation, and e-commerce in the Asia-Pacific region, developing comprehensive end-to-end global supply chain services (A. P. Moller – Maersk 2022). Recently, another industry giant, MSC Group, has reached an agreement with Bolloré Group to acquire Bolloré Africa Logistics. This further step reaffirmed the Group's longstanding commitment to invest in Africa and strengthen supply chains as well as to connect Africa to the rest of the world (Msc Statement 2022).

The aim of this study is to reveal the factors that caused supply chain integration of liner shipping companies during the pandemic period. Therefore, related studies in the existing literature were examined, and the determined factors were coded. While previous studies only emphasized a single element of supply chain integration, this study handles the elements from a holistic perspective.

In the next part of the study, the literature review is presented on the factors that accelerated the integration of maritime transport companies into the supply chain during the Covid-19 pandemic period. The factors outlined in the next section were coded using the MAXQDA 20 qualitative data analysis program, and their relationships with each other were examined. In the conclusion of the study, the findings are discussed in light of the information obtained from the literature.

2. Literature Review

Many different studies were performed in the related literature, and these studies were duly reviewed. Authors choose the Scopus database in order to reach the broadest range of comprehensive journals. Targeted articles were accessed using the following steps: TITLE-ABS-KEY (Maritime*) AND TITLE-ABS-KEY (Supply Chain*) AND TITLE-ABS-KEY (Covid-19*). According to the search results, 19 articles were chosen. The abstracts of each article were reviewed, and 3 articles were excluded from the scope of the study. The remaining 16 articles were examined for the literature review.

Most of the articles reached in the literature review focused on the effects of Covid-19 on the maritime industry. *Notteboom et al*. (2021) compared the crises that most affected maritime supply chains. *Narasimha et al*. (2021) investigated the negative effects of the Covid-19 pandemic in India. *Tianming et al*. (2021) emphasized that Covid-19 restrictions resulted in a significant loss for the maritime sector. Charlampowicz (2021) underlined that improving service quality is very important to achieve competitive advantage. *Perez et al.* (2021) made a comprehensive comparison between the car carrier ship traffic in the pre-pandemic era and under Covid conditions. *Koyuncu et al.* (2021) emphasized that container shipping actors experienced some serious problems due to the effects of pandemic. *Akyurek* and *Bolat* (2020) approached Covid-19 effects from a different perspective by investigating the inspection trends. They pointed out that with the new-normal inspection regulations, detentions decreased compared to the past. *Verschuur et al*. (2021) investigated the economic effects of the Covid-19 lockdowns on the maritime sector. They indicated that fund allocation helped the economic recovery.

Some studies investigated resilience strategies during the pandemic. *Bathke et al*. (2022) offers detailed scenarios on how to create dynamic capabilities for liner shipping companies to build resilience. *Praharsi et al*. (2021) gave such recommendations as provision of delivery forms, delivery schedule control, automatic data entry, warehouse capacity control, and internal company integration to increase performance during the pandemic.

The rest of the studies in the related literature also reviewed the pandemic situation and predicted the post-pandemic process. *Permal* (2021) predicted that post-pandemic processes might invert the globalization concept. *Donnan et al.* (2020) revealed the alternative resilience strategies for the initiatives that invest in maritime industry in the post-pandemic period. The most prioritized resilience strategy was determined to be rail-road connections. On the other hand, *Kesha et al.* (2020) and *Vano et al*. (2021) emphasized the importance of technological improvement adoption in maritime transportation to overcome the pandemic disruptions. *Dirzka* and *Acciaro* (2022) approached pandemic disruptions from a very different perspective. They perceived the pandemic situation as an opportunity to mitigate the mistakes of global shipping operations. *Lee et al. (2022)* proposed a strategic location for global logistics distribution centers along with the Belt and Road Initiative (BRI).

3. Methodology

Qualitative research attributes meanings, concepts, definitions, characteristics, metaphors, symbols, and descriptions to events and phenomena (Berg 2007). Qualitative research focuses on the examination of practices and the perceptions of participants in regard to processes or activities. Although qualitative research has specific constraints related to the generalizability of the results, contributing to knowledge by finding out the meanings of the research constructs is the main purpose (Wu et al. 2016). The main aim of this study is to determine the motives of liner shipping companies to invest in supply chain integration. Qualitative research was carried out to reveal the relationships between accelerating factors and to better define the effect levels of COVID-19 on the supply chain integration of ship managing companies.

Using software programs was suggested to researchers when it comes to organizing large and complex data sets (Atherton and Elsemore 2007). Therefore, in this study, MAXQDA 20, which is a qualitative data analysis software, was used for the analysis and includes the coding process of motives for supply chain integration. There are also many different applications in the maritime literature on MAXQDA 20 software, such as sustainable development goals, evaluation of the potential barriers for the automation of the twistlock handling process, bibliometric analysis of maritime scientific journals, national maritime policies based on safety, security, and environment, and resilience strategies of ports against the Covid-19 pandemic (Sciberras and Silva 2018; Kugler et al. 2021; Yorulmaz and Barış 2021; Turedi and Ozer-Caylan 2021; Ayaz et al. 2022). In MAXQDA 2020, the MaxMaps Creative Coding Section, Hierarchical Code-Subcodes Model, and Code Co-Occurrence Model were used to visualize the interacting codes and relationships. In the coding process, we firstly gathered the related literature that was explained in a detailed manner in the literature review section. We examined the studies in the literature, and we excluded 3 studies for not fitting the scope of the study. The remaining 16 studies were deeply analyzed and included in the coding process. In the coding process, the evaluations of the authors and experts in the related literature on supply chain integrations of liner shipping companies were coded. Subsequently, continuous comparisons between themes were made, and in conclusion, definite themes were explained. Experts made an assessment before and after the coding and sub-coding process to increase the validity and reliability of this study. In Table 1, the proficiency levels of the experts were presented.

Table 1. Proficiency Levels of the Experts

Expert	Position	Educational Status	Experience
Exp-1	Customer Service Manager	MSc.	16 years
Exp-2	Sales and Marketing Manager	MSc.	16 years
Exp-3	Sales and Marketing Manager	MSc.	17 years
Exp-4	Customer Service Chief	Bachelor	15 years
Exp-5	Sales and Marketing Chief	Bachelor	14 years

The codes revealed from the literature were evaluated in semi-structured interviews with the experts who perform in liner shipping companies in a managerial position. Accordingly, common opinions were reached on the expressive intelligibility of the codes and their suitability in terms of sectoral language integrity.

In Table 1, we present the work experience, educational background, and job titles of the experts. Table 1 demonstrates that each of the five chosen experts has held a managerial position for a minimum of ten years. While three of the experts have a master's degree, the rest have a bachelor's degree. In addition, each of the chosen experts has direct customer experience. Hence, they can easily conduct market research on supply chain integration issues.

4. Findings

This study investigated which factors are effective on the supply chain integration decisions of liner shipping companies, especially during the COVID-19 pandemic period. Thus, the related literature was reviewed, and prominent factors were coded in the MAXQDA 20 program. As a result of the analysis, the coding frequency of these factors and interaction levels of joint-coded factors were revealed and demonstrated in Figure 1.

As seen in Figure 1, the "port congestion" problem, "blank sailing" strategy, and "quarantined vessel" measures in the COVID-19 pandemic period were prominent factors that directed liner shipping companies to gain dominance in the supply chain. It is also seen that the blank sailing strategy and port congestion problem in the liner shipping market have a strong relationship with remainder factors. Additionally, the strongest relationships are seen between "port congestion" and "blank sailing," and

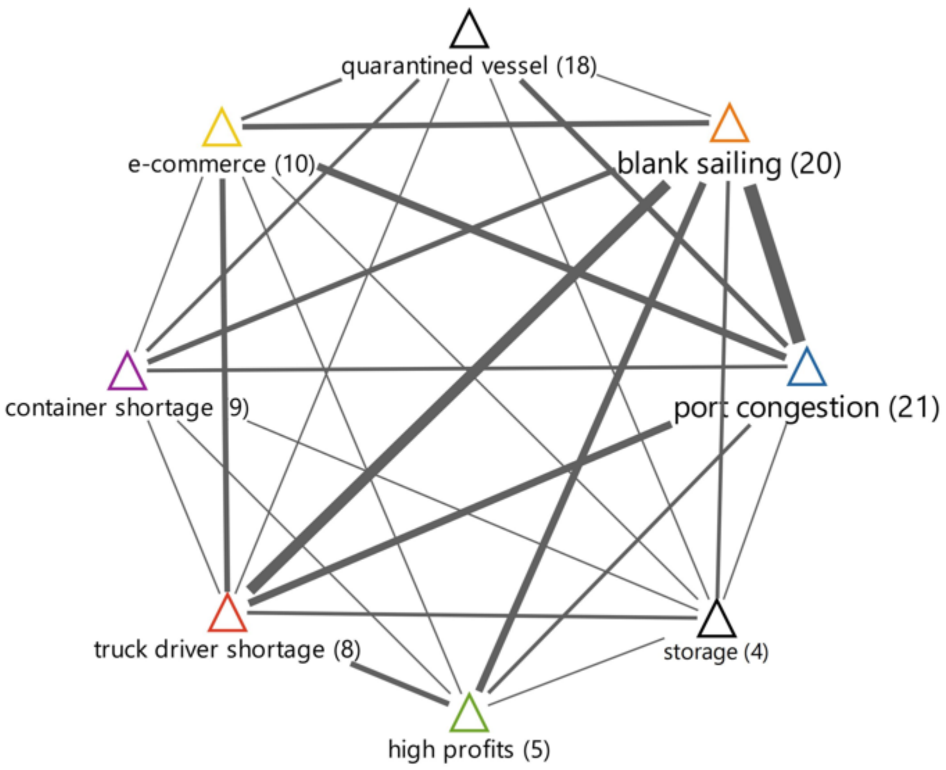

Figure 1. *Frequency and Code Relation Analyses of Factors in the Related Literature*

between "blank sailing" and "truck driver shortage." In Table 2, the frequency of jointly coding entire factors with each other was demonstrated.

Table 2. *Code Relations of Factors that Affect Supply Chain Integration Decisions*

Code System	storage	container shortage	quarantined vessel	truck driver shortage	blank sailing	e-commerce	high profits	port congestion
storage	0	1	1	1	2	1	1	1
container shortage	1	0	4	3	5	4	2	5
quarantined vessel	1	4	0	2	3	3	0	4
truck driver shortage	1	3	2	0	2	3	1	3
blank sailing	2	5	3	2	0	2	3	6
e-commerce	1	4	3	3	2	0	1	5
high profits	1	2	0	1	3	1	0	2
port congestion	1	5	4	3	6	5	2	0

In this study, factors that accelerated the supply chain integration decisions of liner shipping companies during the Covid-19 pandemic period were brought out from the related literature. For this purpose, these factors were coded in the MAXQDA 20 program. In the coding process, the factors were jointly coded several times. In Table 2, the frequency of factors that were jointly coded was displayed. It is seen in Table 2 that "blank sailing" and "port congestion" were jointly coded six times, and this is the highest frequency of any factors jointly coded with each other. It is also seen that the "container shortage" factor was jointly coded with “blank sailing” and “port congestion” five times. Similarly, the factors “e-commerce” and “port congestion” were jointly coded five times.

With the global changes created by the Covid-19 pandemic in all sectors, it is inevitable that supply chain processes would be affected by these changes. The pandemic has had an impact in a short time in many areas of life, such as the change in working culture, the use of information technology, and consumption habits. Uncertainties during the Covid-19 period have caused high demand for food and cleaning products. With the effect of digitalization and restrictions, people had to shop from their homes. For this reason, e-commerce reached its peak during the pandemic period (Ajmal 2021; Cullinane and Haralambides 2021). Personnel being unprepared for these sudden demand explosions resulted in serious congestion at ports. Due to quarantine practices in ports, ships waiting at anchorage areas for about 14 days caused delays in supply chain processes. On the other hand, cargoes that could reach the port were delayed due to insufficient storage areas and the shortage of personnel available for transshipment (Cremaschini and Monaco 2022). With the emergence of Covid-19 in China, the most strategic point of global industrial production, the slowdown of factory activities as a result of the serious precautions taken by the government, or even the complete closure of the factories, and the inability to deliver the containers reaching the ports to the factories created the problem of container shortage as well as port congestion (Karmaker et al. 2021; Toygar et al. 2022). Liner shipping companies started empty voyage practices in order to compensate for the time lost due to disruptions in supply chain processes. Directing the cargo flow to hub ports and transferring it from one point to other locations by long-distance land transportation is another factor that causes the slowdown of container circulation and, as a direct effect, the shortage of containers. In the Covid-19 period, it is possible to explain the increase in profitability with the concept of blank sailing. Bringing the loads to the designated hub port points provided cost advantages for line operators and had a direct impact on profitability (Kuźmicz 2022; Bucak and Demirel 2022).

5. Conclusion

The Covid-19 pandemic has considerably affected the supply chain as well as all other sectors. The transition to digital processes has been accelerated in all sectors to react to disruptions caused by Covid-19. In order to mitigate the effects of Covid-19 with the least damage, liner shipping companies have implemented some strategies. In the Covid-19 period, it was observed that the supply chain integration of liner shipping companies was accelerated just as occurred with digitalization. Various factors played an important role in the emergence of these integration strategies. In this study, the factors that caused supply chain integration during the Covid-19 period were examined. Relevant factors were coded after a comprehensive literature review, and the network of relations between the factors was revealed.

According to the results of the study, port congestion was the most encoded factor among the factors accelerating supply chain integration. In addition, some liner shipping companies wanted to avoid delays caused by port congestion with priority container applications with the help of their logistics company acquisitions in the pre-Covid-19 period. Another important factor is the blank sailing strategy. Blank sailing practices also paved the way for the formation of container shortages by optimizing the container cycle. This situation generated the strategies of providing cargo flow from feeder ports to hubs or vice versa, and providing cargo flow by long-distance land transport to hub ports. The other factor was the “quarantined vessel.” In this case, supply chain integrations can prevent delays that may occur to regain the time lost in anchoring by reducing dwell time.

It was seen that some factors were used together in the literature. This shows us that there is a relationship between them. The presence of blank sailing and quarantine vessels caused concentration in certain ports. At the same time, the high demand for certain products and the uncertain environment during the pandemic led to an increase in e-commerce and, accordingly, congestion in ports. Supply chain integrations that were implemented to solve these problems reduced costs and saved time.

This study examined the factors that accelerate supply chain integration of liner shipping companies. The limitations of the study are that the supply chain integration concept is new, and the number of studies examining the effects of Covid-19 is very limited. For future studies, the factors obtained from the literature can be examined using various analytical methods such as Best-Worst or the DEMATEL Method, and these factors can be prioritized or the cause-effect relationship between the factors can be revealed.

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RESEARCH ARTICLE

Risk Assessment of Solid Bulk Cargo Liquefaction Consequences in Maritime Transportation under a Fuzzy Bayesian Network Approach

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ABSTRACT
Solid bulk cargo liquefaction is hazardous for bulk carrier ships as they reduce the stability of the ship. Most dry bulk ship owners face solid bulk cargo liquefaction during the carriage of ore cargoes. The consequences of cargo liquefaction could have catastrophic effects such as the ship sinking or capsizing. To improve the process of safety during the shipment of bulk cargo and reduce potential consequences, a detailed risk analysis is needed. The purpose of this paper is to conduct a systematic probabilistic risk analysis of the liquefaction of solid bulk cargo in the marine sector in order to allay this concern in order to deal with complex causation and uncertainty resulting from complex interdependence among risk factors, limited data, and a complex environment. A Bayesian network (BN) method under fuzzy logic has been utilized in the research. Whilst the BN enables us to calculate the conditional probability of each basic event in the graph, the fuzzy logic tackles uncertainty and the vagueness of expert judgment. The findings of the paper will assist solid bulk cargo owners and shippers in reducing the risk of solid bulk cargo liquefaction during maritime transportation.

Keywords: Maritime transportation, Cargo liquefaction, Fuzzy logic, Probabilistic risk assessment, Bayesian Network.

1. Introduction

The definition of risk is the combination of the probability of hazards and the severity of that consequence (Goerlandt et al., 2015). The risk investigated in the article is the liquefaction of dry cargo carried on board. Shipmasters are likely to be aware of the risk of liquefaction associated with the cargo they are carrying on board. But it is unclear to know the extent of the damage, the environment, and how human life will be affected after the cargo it carries liquefies. Therefore, risk analysis of consequences plays a crucial role in different hazardous operations such as cargo handling, cargo transferring, etc. (Akyuz et al., 2020). Risk-based studies have been expanding in marine transportation with the use of both qualitative and quantitative risk assessment approaches. Risk-based methodologies such as the Failure Mode Effect Analysis (FMEA), Hazard and Operability study (HAZOP), Fault Tree Analysis (FTA), Bow-Tie, and the Bayesian Network have been cited in maritime transportation literature (Sarıalioğlu et al., 2020; Aydin et al., 2021a; Kaptan, 2021a; Akyuz & Celik, 2018; Aziz et al., 2019). Since the Bayesian Network (BN) technique can present conditional dependency by nodes in a directed graph, it has recently been used by many safety researchers to quantitatively identify risks. The Bayesian Network has been used by many authors in their research on different subjects in maritime research (Sakar et al., 2020; Kaptan, 2021b; Çakir et al., 2021; Özaydın et al., 2022; Aydin and Kamal, 2022).

The topic, solid bulk cargo liquefaction due to the presence of excess moisture and the motions of the ship, has not gained a sufficient level of attention in the maritime sector since the consequences of solid bulk cargo liquefaction may create life-threatening conditions. In terms of safety and risk analysis, there is a lack of studies that deal specifically with the phenomenon of cargo liquefaction. Therefore, this paper prompts a comprehensive probabilistic risk analysis of solid bulk cargo liquefaction to improve the process of safety in bulk cargo and reduce risks.

Since there is a lack of studies in the literature to address the above-mentioned constraint, this work contributes to the body of knowledge by addressing epistemic uncertainty. Furthermore, solid bulk cargo liquefaction consequences in maritime transportation involve significant risks. However, in the literature review, no comprehensive study has been found that makes solid bulk cargo liquefaction consequences risk analysis in maritime transportation with an improved Bayesian Network with a fuzzy

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logic approach. The BN is widely used in risk analysis and is a simulation of complicated system faults (Li et al., 2016). The BN is applied to examine potential failure problems, and fuzzy logic overcomes the ambiguity of expert evaluations.

In this context, the paper is organized as follows. This section gives a general assessment of the literature, and comprehensive information on the phenomenon of bulk cargo liquefaction while section 2 explains the method. The probabilistic risk analysis for solid bulk cargo liquefaction's consequences is performed in Section 3. Section 4 presents the findings of the research. Finally, section 5 gives the conclusions of the research.

1.1. Solid bulk cargo liquefaction phenomenon on-board ship

Cargo liquefaction is a quick transition of cargo-forming particles from a stable solid state to a viscous liquid form (Jonas, 2010). In such cases, the cargo loses shear strength due to the particle's loss of contact and behaves more like a liquid than a solid (IMO, 2012). For this reason, liquefaction is a significant difficulty for the transportation of ore cargoes such as iron and nickel. The cargo liquefaction may reduce the stability of ships due to the Free Surface Effect (FSE). Also, the loss of stability (reduction or loss of GM) leads the vessel to list at a dangerous angle to one side. In some cases, the angle of the heel continues to increase, resulting in the vessel listing heavily down, flooding or capsizing, and inducing the loss of the vessel, commodity, and crew.

Cargo liquefaction can be partially prevented by tests before loading. The TML (Transportable Moisture Limit) value indicates the maximum amount of moisture that the cargo can transport safely. There are three laboratory test methods used to measure the TML value: the flow table test, the penetration test, and the proctor test. Each test method is suitable for different types of cargo. (DNV-GL, 2015). Therefore, competent experts should be consulted for method selection. The "can test", which is used to approximate the probability of the flow of load, is a supplement for laboratory tests rather than a substitute. The margin of error is quite high in this test applied by the ship's captain. Although these tests give an idea of the moisture content of the load, they are likely to fail, because a test to determine the transportable moisture limit of a solid bulk cargo must be carried out within seven days before the loading date. As the time interval between test and loading increases, the margin of error increases. Also, if the environment where the cargo is stored is humid, the amount of moisture may increase after the test. Moreover, consignments originating from different stockpiles might have been mined separately and under varying conditions. Tests may give incorrect results if different stockpiles are not evaluated separately. Finally, the tests are highly dependent on the competence of the person conducting the test.

Numerous accidents have occurred due to cargo liquefaction in dry bulk transportation, and these accidents continue to result in the loss of seafarers (DNV-GL, 2015). Table 1 shows some accidents due to solid bulk cargo liquefaction (DNV-GL, 2019). There were 8 casualties of suspected cargo liquefaction among 39 cases between 2009 and 2019. The highest loss of life has been attributed to cargo shifting (liquefaction). A total of 106 lives were lost or 61.3% of the total loss of life was caused by 8 casualties. Also, when the 2018 and 2019 data are compared, it is seen that the rate of loss of life due to bulk cargo liquefaction increased from 53.7% to 61.3% (INTERCARGO, 2019).

Table 1. Accidents due to solid bulk cargo liquefaction (DNV-GL, 2019)

Vessel name	Dwt	Built	Loss of life	Loss of Vessel	Year	Cargo type	Area
Asian Forest	16k	2007	0	Yes	2009	Iron ore	India
Black Rose	39k	1977	1	Yes	2009	Iron ore	India
Jian Fu Star	45k	1983	13	Yes	2010	Nickel ore	Indonesia
Nasco Diamond	57k	2009	22	Yes	2010	Nickel ore	Indonesia
Hong Wei	50k	2001	10	Yes	2010	Nickel ore	Indonesia
Bright Rubby	27k	1987	6	Yes	2011	Nickel ore	Hong Kong
Vinalines Queen	56k	2005	22	Yes	2011	Nickel ore	Philippines
Sun Spirits	11k	2007	0	Yes	2012	Iron ore	Philippines
Anna Bo	57k	2009	0	Listing	2013	Nickel ore	Philippines
Harita Bauxite	50k	1983	15	Yes	2013	Nickel ore	Indonesia
Trans Summer	57k	2012	0	Yes	2013	Nickel ore	Philippines
Alam Manis	56k	2007	1	Listing	2015	Nickel ore	Philippines
Bulk Jupiter	56k	2009	18	Yes	2015	Bauxite	Malaysia
Emerald Star	57k	2010	10	Yes	2017	Nickel ore	Philippines
Nur Allya	52k	2002	25	Yes	2019	Nickel ore	Indonesia

2. Methodology

The main concepts of fuzzy logic and the Bayesian belief network are presented in this section. Figure 1 depicts the theoretical structure of the methodology.

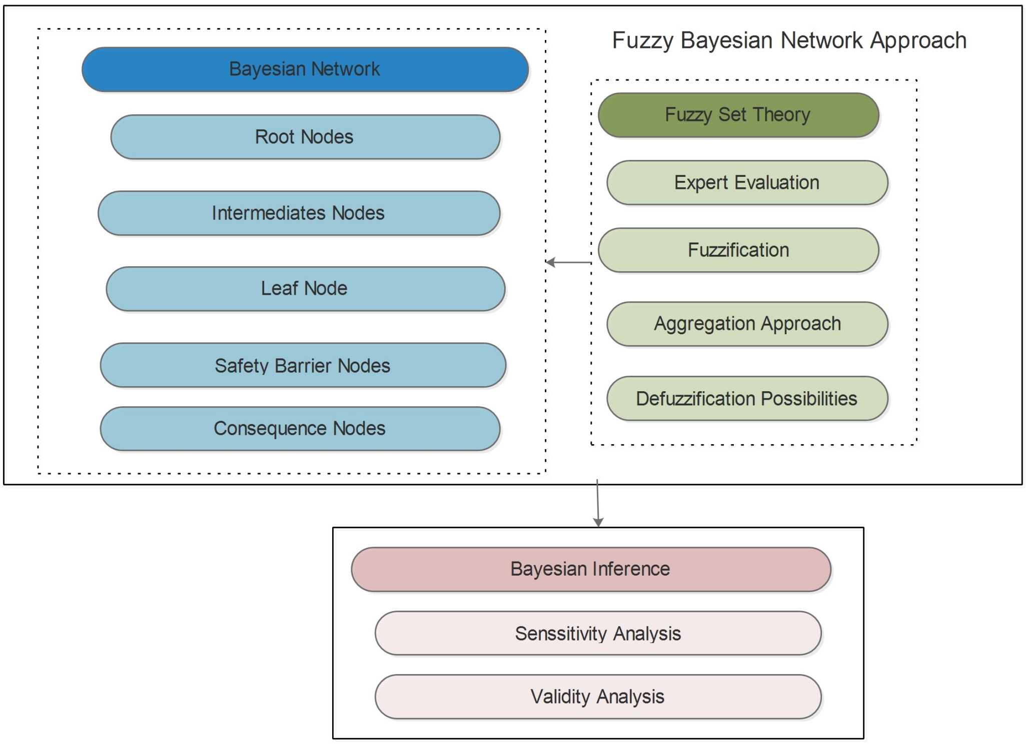

Figure 1. Conceptual framework of the Fuzzy Bayesian Network approach

2.1. Bayesian network

The BN is an efficient and flexible graphical model that illustrates the probabilistic correlations between variables. (Uğurlu et al., 2022). In the BN method, variables are represented as nodes in an oriented acyclic network, while conditional dependency between variables are represented by directional links (Şakar and Zorba, 2017). The network is represented graphically by nodes that represent the variables and directed arrows that represent their probabilistic causal dependency between them.

The probability tables include conditional probabilities as well as posterior probabilities for the variables in the network structure are managed by the quantitative part of the BN.

The Bayes Network's base is the Chain Rule, which addresses the joint probability distributions of variables. The marginal and conditional probabilities for each network node can be calculated using the chain rule. The joint probability of the variable Xi is given in the following equations if U= $X_1, X_2 . . . , X_n$ are variables (Jensen and Nielsen, 2007).

$$P(U) = \prod_{i=1}^{n} P(X_i | P_\alpha(X_i)) \tag{1}$$

Where $P_\alpha(X_i)$ is the parent set of variables and j≠i . The probability of Xi is calculated as:

$$P(X_i) = \sum_{x_j} P(U) \tag{2}$$

The Bayes theorem, utilized by the BN to calculate the posterior probabilities of events given updated observations, also known as evidence (E), in the form of incident occurrence, as stated by equation 3, is used to determine the likelihood that certain occurrences will occur (Kerner and Herrtwich, 2001).

$$P(U \setminus E) = \frac{P(U, E)}{P(E)} = \frac{P(U, E)}{\sum_u P(U, E)} \tag{3}$$

Where U is the universe of variables $X_1, X_2 . . . , X_n$

2.2. Bayesian network under fuzzy logic environment

It is mentioned that there are numerous methods, including statistical data, literature reviews, etc., for determining the prior and conditional probability of the nodes. If there is a lack of data or a high level of ambiguity in the statistical data or associated literature, fuzzy set theory can be used to reduce uncertainty by using linguistic values. A Fuzzy Bayesian Network (FBN) has been designed to derive the probability values of the nodes in the Bayesian network.

2.2.1. ***Expert elicitation***

The probabilities must be established in order to calculate the cargo liquefaction risk probability (leaf node) and the significance of nodes. The expert elicitation approach offers a solution and useful information for risk assessment. An expert is someone who has extensive training and expertise regarding the functioning of the system (Rajakarunakaran et al., 2015). The study involves experts at various levels, each bringing their own expertise, educational background, and professional experience.

As a result, experts may express various viewpoints on the same occurrences and offer subjectively differing assessments. At this point, the significance of each expert influences judgments of heterogeneous groupings of experts. An expert weighting score was employed by Senol et al. (2015) to illustrate the relative level of the experts. To get expert opinions for each node, linguistic phrases might be employed to make expert judgments. The ideal range for linguistic term selection is between 5 and 9, which will allow experts to make good judgments (Rajakarunakaran et al., 2015; Lavasani et al., 2012; Miller, 1956). The numerical approach method is used in the suggested method to translate the language phrases of marine professionals into trapezoidal fuzzy values.

Within this scope, Figure 2 shows ratings and membership functions of fuzzy sets.

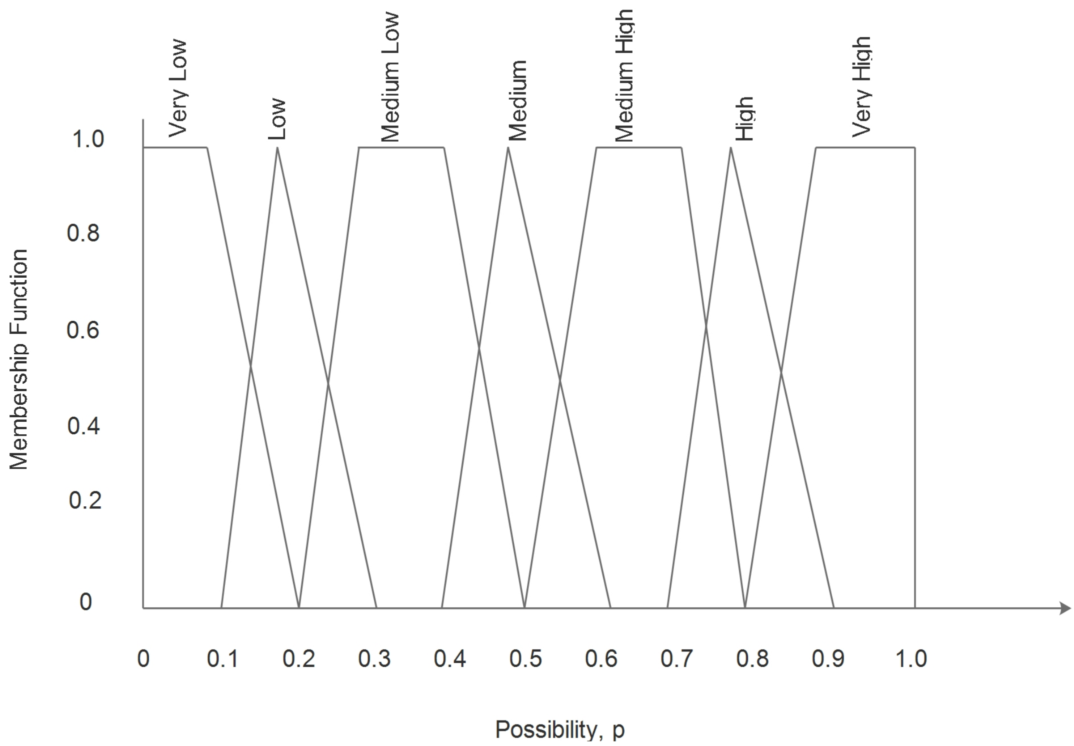

Figure 2. Fuzzy rating and membership functions

2.2.2. ***Fuzzy possibility***

The fuzzy sets are extensions and simplified forms of a traditional set of numbers. In fuzzy logic, a fuzzy subset A is qualified by a membership function that is correlated with each element x in the universe X to the real number in the interval [0, 1] (Zadeh, 1965). The equation μ_A (x) illustrates the membership of x in the fuzzy set A (Zarei et al., 2019; Akyuz et al., 2018) . The membership function μ_A (x) for the trapezoidal fuzzy set numbers (a,b,c,d)can be defined as:

$$\gamma = \left\{ \begin{array}{ll} 0, & \chi < \alpha \\ \frac{(x-a)}{b-a}, & \alpha \leq \chi \leq b \\ 1, & b \leq \chi \leq c \\ \frac{(d-x)}{d-c}, & c \leq \chi \leq d \\ 0, & \chi > d \end{array} \right\} \quad (4)$$

The fuzzy possibility score (FPs) is a crisp value that represents the experts' aggregated belief of the most likely score to indicate that an event may occur. Experts' judgments in the form of linguistic expressions that aggregated trapezoidal fuzzy numbers are converted into FPs under a fuzzy environment.

The linear opinion pool is an appealing approach to the aggregation of fuzzy possibility distributions. (Clemen & Winkler, 1999):

$$M_i = \sum_{i=1}^{m} W_j A_{ij} = 1, 2, ..., n \quad (5)$$

M_i is the fuzzy failure possibility representing the aggregated fuzzy value of event i,
W_j is the weighting score of experts j,
A_{ij} is the linguistic value obtained from expert j about event i,
m is the total number of events while n is the total number of experts.

The linear opinion pool is easily understandable and computable as it is a weighted linear combination of experts' judgments. The weighting factors of heterogeneous marine experts who participated in the survey are calculated according to Table 2 (Senol et al., 2015; Lavasani et al., 2015).

Table 2. Weighting scores of non-homogenous experts

Group	Classification	Score
Professional position	Academician	5
	Operation manager	4
	Deck inspector	3
	Master	2
	Chief Officer	1
Sea service time	≥ 16 years	5
	11-15	4
	6-10	3
	3-5	2
	≤ 3	1
Education Level	PhD	5
	Master	4
	Bachelor	3
	HND	2
	School level	1
Shore service time	≥ 26	5
	16-25	4
	11-15	3
	6 – 10	2
	≤ 5	1

Equations (6) and (7) are used to determine expert weights by determining expert weight scores and expert weight factors (Lavasani et al., 2012).

$$\begin{aligned}Weight\ Score\ of\ Expert\ i = {} & Score\ of\ Profesional\ Position\ of\ Expert\ i \\ & + Score\ of\ Sea\ Service\ Time\ of\ Expert\ i \\ & + Score\ of\ Education\ Level\ of\ Expert\ i \\ & + Score\ of\ Shore\ Service\ Time\ of\ Epert\ i\end{aligned} \tag{6}$$

$$Weight\ factor\ of\ Expert\ i = \frac{WeightScoreofExperti}{\sum_{i=1}^{n} WeightScoreofExperti} \tag{7}$$

2.2.3. *Defuzzification*

The aggregated trapezoidal fuzzy numbers are transformed into FPs in a fuzzy environment during the defuzzification process. Defuzzification methods include mean max membership, centroid method, weighted average method, center of largest area and center of sums (Wang, 1997). In this study, fuzzy possibility values of each basic event were calculated by using the most preferred center of area method because of its simplicity and comprehensibility (Lavasani et al., 2015). This technique was developed by Sugeno (1985).

$$X^* = \frac{\int u_i(\chi)\chi d\chi}{\int u_i(\chi)} \tag{8}$$

X^* is the defuzzified output i,
u_i(X) is the aggregated membership function,
χ is the output variable.

The obtained fuzzy possibilities are assigned as failure probabilities of the events and safety barriers in the developed BN model.

3. Probabilistic risk analysis of solid bulk cargo liquefaction in maritime transportation

For the stability of the vessels, the consequences of cargo liquefaction are extremely detrimental and catastrophic. As a result, the Fuzzy Bayesian Network technique was utilized to conduct a detailed risk analysis for the onboard liquefaction of solid bulk cargo.

3.1. Quantitative risk analysis of cargo liquefaction on-board ship

Due to a lack of data in the maritime industry, expert evaluation is utilized to characterize risk analysis for solid bulk cargo liquefaction. Six marine experts participated in the research. The experts were experienced in dry bulk cargo shipping, particularly for ore and mineral cargoes.

The root events that initiate cargo liquefaction onboard ships are partly taken from the articles (Akyuz et al., 2020) and P&I Club circulars. In addition, past accident results and information taken from face-to-face interviews with experts are used to determine possible consequences (INTERCARGO, 2019). The Bayesian Network is created by brainstorming meetings with maritime experts after identifying the underlying causes and effects. The scenario is depicted in the diagram, starting with the potential root causes of cargo liquefaction, and concluding with potential outcomes depending on whether safety barriers are successful or failures. Table 3 gives definitions of nodes and safety barriers. Figure 3 illustrates a BN diagram created by GeNIe program (BayesFusion, LLC).

Since the sample of maritime experts who responded to the survey was heterogeneous, it was necessary to use equations to explain the relative weight of each judgment (6-7).

Equations (5 - 8) are used for aggregate and defuzzified fuzzy numbers to calculate the fuzzy possibility of root events, safety barriers, and severity of consequences. Table 4 demonstrates the fuzzy possibilities of root events obtained by experts' evaluation. The findings of the failure potentials of safety barriers in the risk of cargo liquefaction are presented in Table 5. Table 6 illustrates the conditional probability of loading wet/humid cargo.

Table 3. Definitions of nodes and safety barriers

No	Nodes	Definitions
1	Independent survey	For the measurement of moisture in cargo, an independent surveyor or cargo specialist should be appointed.
2	Cargo sampling	In order to determine the average moisture content, the samples are taken from the full depth of the stockpile.
3	Cargo TML testing in suitable lab	In order to get reliable transportable moisture limit (TML) values, representative samples of the cargo have to be tested in laboratories.
4	Awareness of the risk of cargo liquefaction on-board ship	In case of unprocessed ore cargoes being transported, captain and officers should be aware of liquefaction.
5	Declaration of the average moisture content of the cargo before loading	The shipper has to present a declaration of the average moisture content of the cargo correctly before loading.
6	Cargo identification	The name of the cargo should be described by using the Bulk Cargo Shipping Name as detailed in the IMSBC Code.
7	Can test application	The can test, which is commonly used by Masters for approximately determining the possibility of flow on board a ship or at the port.
8	Procedures of IMSBC Code	The IMSBC Code procedures should always be followed when conducting transportable moisture limit tests
9	Understand of MSDS	A MSDS describes the properties and potential hazards of the cargo, how to carry it safely, and what to do in an emergency.
10	Stockpiles of cargo at port before loading	Different stockpiles might have been stored under varying conditions. Different stockpiles should be evaluated separately
11	Water or other liquids ingress into holds during loading	The moisture content will increase in case of precipitation and high humidity during loading.
12	Weight distribution	The IMSBC Code requires that, distributing the weight evenly over the hold top.
13	Cargo trimming status	The cargoes should be trimmed as necessary to ensure that they are reasonably level.
14	Cargo control/monitoring during voyage	During voyage, the cargo in the holds should be monitored for excess water or other signs of liquefaction.
15	Time İnterval between sampling/testing and loading	The interval between testing for moisture content and loading the cargo must be as small as practicable (7 days).
16	Loading wet/humid cargo	Loading wet cargo increases the risk of solid bulk cargo liquefaction risk.
17	Loading cargo whose moisture content above TML	TML indicates the maximum moisture content of the cargo which is considered safe for carriage.
18	Moisture content in cargo	High moisture content in cargo increases the risk of capsizing due to solid bulk cargo liquefaction.
19	GM Value	An excessively low or negative GM value increases the risk of a ship capsizing.
No	**Safety Barriers**	**Definitions**
1	Pumping out hold bilges	Discharging of the liquid accumulated in bilge wells out of the ship.
2	Cargo hold monitoring/controlling	Monitoring the holds for excess water during voyage.
3	Ballast operation	Attempting to correct the deteriorated stability due to cargo liquefaction by ballasting / de-ballasting operation.

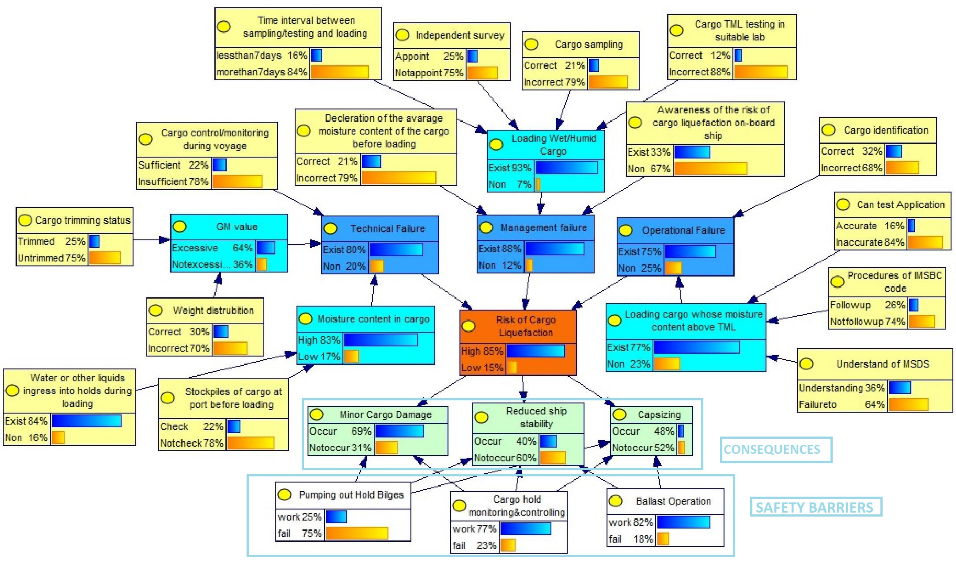

Figure 3. BN diagram for risk of solid bulk cargo liquefaction

Table 4. Linguistic expert evaluation and fuzzy possibility scores (FPs) of the root events

Root Events	Expert Judgments						Aggregation of Fuzzy Numbers				FPs
	1	**2**	**3**	**4**	**5**	**6**					
Independent survey	ML	L	ML	L	L	L	0,131	0,231	0,261	0,361	0,25
Cargo sampling	VL	ML	L	VL	ML	VL	0,095	0,149	0,235	0,335	0,21
Cargo TML testing in suitable lab	VL	L	L	VL	VL	VL	0,035	0,069	0,135	0,235	0,12
Awareness of the risk of cargo liquefaction on-board ship	L	ML	L	M	ML	ML	0,201	0,301	0,355	0,455	0,33
Declaration of the average moisture content of the cargo before loading	L	L	VL	VL	M	VL	0,116	0,172	0,216	0,316	0,21
Cargo identification	L	M	L	VL	M	ML	0,217	0,301	0,331	0,431	0,32
Can test Application	VL	VL	VL	ML	L	L	0,065	0,115	0,181	0,281	0,16
Procedures of IMSBC code	L	M	L	L	L	L	0,160	0,260	0,260	0,360	0,26
Understand of MSDS	M	ML	L	VL	M	M	0,252	0,336	0,372	0,472	0,36
Stockpiles of cargo at port before loading	L	L	L	ML	VL	ML	0,109	0,189	0,239	0,339	0,22
Water or other liquids ingress into holds during loading	H	H	H	VH	VH	H	0,736	0,836	0,872	0,936	0,84
Weight distribution	L	M	L	ML	L	ML	0,189	0,289	0,319	0,419	0,30
Cargo trimming status	ML	L	ML	L	L	L	0,131	0,231	0,261	0,361	0,25
Cargo control/monitoring during voyage	L	L	ML	L	L	L	0,115	0,215	0,229	0,329	0,22
Time interval between sampling/testing and loading	VL	L	L	VL	L	L	0,068	0,136	0,168	0,268	0,16

Table 5. Safety barrier assessment

Safety Barriers	Expert Judgments						Aggregation of Fuzzy Numbers				FPs
	1	2	3	4	5	6					
Pumping out hold bilges	ML	ML	L	L	VL	ML	0,129	0,209	0,279	0,379	0,25
Cargo hold monitoring/controlling	H	MH	M	H	VH	VH	0,649	0,749	0,803	0,869	0,77
Ballast operation	H	VH	H	MH	H	VH	0,701	0,801	0,851	0,917	0,18

Table 6. Conditional probability of loading wet/humid cargo

Independent survey	Appoint								Not appoint							
Cargo sampling	Correct				Incorrect				Correct				Incorrect			
Cargo TML testing in suitable lab	Correct		Incorrect		Correct		Incorrect		Correct		Incorrect		Correct		Incorrect	
Time interval between sampling /testing and loading	<7 days	> 7 days	<7 days	> 7 days	< 7 days	> 7 days	< 7 days	> 7 days	< 7 days	> 7 days	< 7 days	> 7 days	< 7 days	> 7 days	< 7 days	> 7 days
Exist	0.001	0.048	0.120	0.847	0.062	0.729	0.879	0.997	0.009	0.264	0.491	0.975	0.320	0.950	0.981	1.000
Non	0.999	0.952	0.880	0.153	0.938	0.271	0.121	0.003	0.991	0.736	0.509	0.025	0.680	0.050	0.019	0.000

3.2. Sensitivity analysis

The Bayesian network's sensitivity analysis can assist focus on the factors that can affect the target node the most while also verifying that the variables are ranked in significance for their impacts (Laskey, 1995). Some variables are chosen from various levels of the network structure in order to evaluate the extent of cargo liquefaction risk impacted by root nodes. The next step was to examine changes in the probabilities of the model's variables by increasing or decreasing their original probabilities (Kabir et al., 2015; Lampis and Andrews, 2009). Figure 4 shows the sensitivity analysis's outcome.

3.3. Validation

To confirm the reliability of model findings, validation is necessary. Three different axiom tests were applied to partially verify the suggested model in this study (Pristrom et al., 2016; Jones et al., 2010). The details of these tests are as follows:

Axiom 1: A specific increase or decrease in each parent node's prior probabilities should unquestionably cause a corresponding relative increase or decrease in the child nodes' posterior probabilities.

Axiom 2: The effect rates on the values of the child nodes and the rate of changes applied to the prior probability distributions of each parent node should be consistent.

Axiom 3: The aggregate impacts of the parent nodes on the child node are always anticipated to be bigger than the individual effects for a child node with multiple parent nodes.

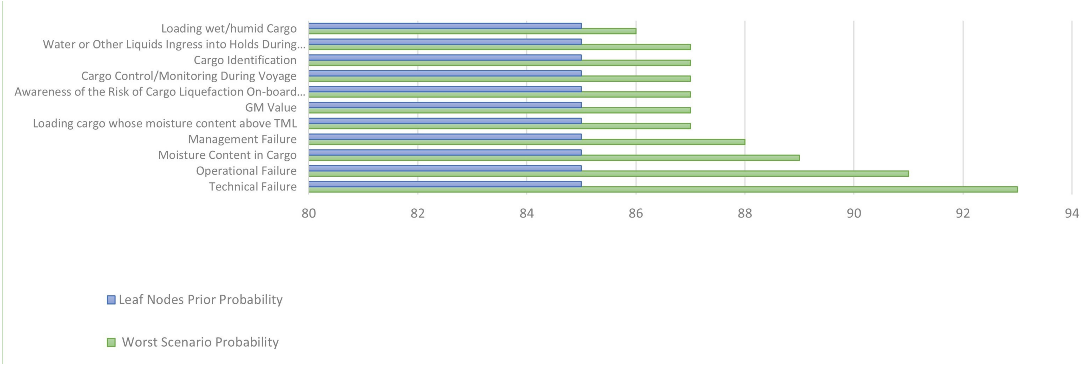

Figure 4. Sensitivity analysis for the BN

4. Findings and extended discussions

In this paper, a risk analysis for the consequences of solid bulk cargo liquefaction was performed under the Fuzzy Bayesian Network approach. In the view of the sensitivity analysis (figure 4), awareness of the risk of cargo liquefaction on-board ship, cargo control/monitoring during the voyage, cargo identification, and water or other liquids ingress into the hold during loading are the most important root causes which contribute to the risk of solid bulk cargo liquefaction

The findings of the sensitivity analysis also show that technical failure has a significant impact on cargo liquefaction risk. When the probability of occurrence of "technical failure" increases to 100%, the probability of cargo liquefaction occurring increases by 8%. Operational failure is another significant contributing intermediate event for solid bulk cargo liquefaction risk since the occurrence probability of solid bulk cargo liquefaction risk increases by 7%. In addition, axiom tests were performed for the risk of solid bulk cargo liquefaction to verify the results. As a result of axiom tests, technical failure (intermediate node) had the highest impact on cargo liquefaction risk. Likewise, operational failure had the second-highest impact on the risk of cargo liquefaction. Management failure is another important intermediate node that contributes to solid bulk cargo liquefaction. When the probability of management failure occurrence is increased to 100%, the risk of solid bulk cargo increases by 3%.

The consequences of cargo liquefaction are associated with safety barriers, which aim to mitigate damage. In case of cargo liquefaction, in high-risk situations without safety barriers, the probability of minor damage occurring, reduced ship stability, and capsizing is 99%. If safety barrier 1 (pumping out hold bilges) works and safety barrier 2 (cargo hold monitoring/controlling) works, the occurrence probability of minor damage decreased from 99% to 41%. Where the risk of cargo liquefaction is high is if barrier 1 works and barrier 2 fails. Then the occurrence probability of minor damage is 95%. If safety barrier 2 works and safety barrier 1 fails, probability of minor damage occurring is 84%.

If safety barriers 1, 2, and 3 (ballast operation) work, then the probability of reduced ship stability decreased from 99% to 5%. If only 1 and 2 of the safety barriers work and 3 fails, the probability of reduced ship stability decreased from 99% to 77%. If only 1 and 3 of the safety barriers work and 2 fails, the probability of reduced ship stability decreased from 99% to 42%. If only 2 and 3 of the safety barriers work and 1 fails, the probability of reduced ship stability decreased from 99% to 27%.

If safety barriers 1, 2, and 3 (ballast operation) work, then the occurrence probability of capsizing decreased from 99% to 21%. If only 1 and 2 of the safety barriers work and 3 fails, the probability of capsizing decreased from 99% to 80%. If only 1 and 3 of the safety barriers work and 2 fails, the probability of reduced ship stability decreased from 99% to 88%. If only 2 and 3 of the safety barriers work and 1 fails, the probability of reduced ship stability decreased from 99% to 38%.

In view of findings, it appears that safety barrier 2 is the most effective control action to minimize the capsizing consequences of solid bulk cargo liquefaction. To prevent the capsizing of the ship, cargo hold monitoring and controlling should be performed successfully during the voyage. Pumping out hold bilges is the most contributing factor for minor cargo damage and reduced ship stability consequences from solid bulk cargo liquefaction.

5. Conclusion

This paper aims to conduct a probabilistic risk analysis for solid bulk cargo liquefaction on-board ships since cargo liquefaction is a great hazard for bulk carrier ships due to the stability reduction. The stability of the ship can be reduced due to the free surface effect of cargo liquefaction and may result in capsizing. The topic, solid bulk cargo liquefaction due to the presence of excess moisture and the motions of the ship, has not been given the amount of attention it deserves in the maritime industry since the consequences of solid bulk cargo liquefaction may create life-threatening situations. Therefore, the Bayesian network and fuzzy logic methods were used for a detailed probabilistic risk analysis and carried out to find which can determine the conditional probability of each root and intermediate node of the solid bulk cargo handling operation.

The findings show that awareness of the risk of cargo liquefaction onboard ships, cargo control/monitoring during the voyage, cargo identification and water or other liquids ingress into hold during loading are focal points that may cause solid bulk cargo liquefaction. In the consequence analysis, safety barrier 2 (cargo hold monitoring/controlling) appears to be the most effective control action to avoid cargo liquefaction damage. Meanwhile, the findings of the paper were compared with a similar study where fuzzy bow-tie methodology was used (Akyuz et al., 2020). The fuzzy BN provides almost similar results to the fuzzy bow-tie approach if initial events/nodes are independent of each other. On the other hand, a scenario analysis provides updated an probability of the initial events/nodes to be given in the occurrence of cargo liquefaction precursors (Khakzad et al., 2011).

As a consequence, solid bulk cargo owners and shippers, maritime safety experts, and HSEQ managers (Health, Safety, Environment, and Quality) can benefit greatly from understanding the risks associated with solid bulk cargo liquefaction in the maritime industry. Perception awareness of risk of cargo liquefaction, cargo monitoring during the voyage, cargo identification, water, or other liquids not ingress into the hold during loading operation are paramount points to be considered by decision-makers before and during loading of solid bulk cargoes (such as nickel ore and iron ore) which may be liquefied.

Since there is lack of a detailed case study reports associated with solid bulk cargo liquefaction accidents, the paper applied the Bayesian Network method for assessing the probability of liquefaction for solid bulk cargoes without using a specific case study (a specific ship with a specific cargo that may be liquefied). A real-case application will be studied in future work once full-length accident reports will be available.

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RESEARCH ARTICLE

Traffic Analysis Model with Bayesian Network and Social Media Data: D100 Highway Travel İnformation System

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ABSTRACT

The traffic problem in Intelligent Transportation Systems has recently become a very important issue. Thanks to Intelligent Transportation Systems, the formation of large amounts of traffic data has led to the formation of data-oriented models. There is a growing interest in predicting traffic measures by modeling complex scenarios based on big data with data mining and machine learning methods. In this study, traffic events from Twitter traffic notifications and vehicle density from sensor data were obtained. Traffic density analysis and traffic incident analysis were performed with the machine learning method. In the analysis of traffic incidents, 36627 traffic incidents were digitized. This data was separated into categories including type of accident; day; month; year; season; left, right or middle lane; and vehicle failure, maintenance-repair work and accident notification. Between 2016 and 2020, 1400 daily vehicle data logs were obtained from the sensor data located at 59 points of the D100 highway. Traffic density and parameters affecting traffic incidents on the Anatolian and European sides of the D100 highway in Istanbul were determined. Traffic density and accident event models were designed with the Bayesian network approach. In the sensitivity analysis of the model, it was concluded that the parameter that has the strongest effect on traffic events and density formation on the D100 highway line is the strips. With these models, the infrastructure of the early warning system has been created for region-specific traffic density situations and possible traffic events.

Keywords: Traffic management, traffic analysis, machine learning, bayesian networks, big data, twitter

1. Introduction

Big data and data mining methods, which have become the focus of attention in many research areas, have become the focus of intelligent transportation systems (ITS). With developing technology, intelligent transportation systems have started to produce big data. Through the big data produced, it will have profound effects on the design and applications of smart transportation systems in terms of making them safer, more efficient, and more profitable. Data mining applications have started to be implemented in intelligent transportation systems as a result of obtaining beneficial results in many areas. Intelligent transportation technologies constantly generate data due to their systemic structure which uses sensor technologies, data transmission technologies and smart card applications. In smart transportation systems, data can be obtained from various sources such as GPS, sensors, video detectors, and social media. Big data obtained through smart cards, GPS, sensors, video detectors, and social media in ITS can move ITS to a more efficient point with accurate and effective data analysis (Shi & Abdel-Aty, 2015). Machine learning algorithms have become increasingly necessary to reveal complex and hidden patterns in the data produced by information processing and communication technologies. Thanks to these algorithms, studies that develop models that can automatically adapt to large and complex data sets and predict scenarios in real-time have become possible. A deep learning method is used in long-term traffic flow prediction (He et al.,2019; Guo et al.,2019; Diao et al.,2019), an artificial neural network in the detection of traffic events (Contreras et al., 2018; Dogru & Subasi, 2018), deep learning in detecting traffic incidents (Zhu et al.,2018; Ren et al.,2018; Fu & Zhou, 2011), traffic accident prediction with a support vector machine (Gu, et al., 2017; Mohamed, 2014), traffic accident analysis with machine learning techniques (Taamneh, et al.,2017; Özbayoğlu, et al., 2016; Vavasi, 2016; Geetha & Shanthi, 2012), traffic accident analysis with the fuzzy logic method (Razzaq et al., 2016), and traffic accident analysis with logistic regression (Agarwal, et al.,2016). These models provide the opportunity to increase the level of safety in ITS by effectively predicting the cause of traffic accidents. Intelligent transportation systems are also gradually becoming integrated based on data. The importance of accurately predicting

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traffic conditions, especially traffic flow density, is increasing. With this data, researchers focus on improving the efficiency of the current transport system of ITS applications by generating traffic flow models in real-time to predict future trends. Thus, it provides both traffic planners and users with accurate and reliable forecasts to help them decide on their plans. In this study, the vehicle density and traffic incidents analysis of the Istanbul D100 highway was carried out. Big data provided by Istanbul Metropolitan Municipality (IMM Data Portal) has been processed and organized. This data consists of instantaneous traffic notifications of users on Twitter. In the analysis of traffic incidents, 36627 traffic incidents were digitized into categories including: accident days, months, years, seasons, left, right, middle lanes, and traffic incidents, including vehicle breakdown, maintenance-repair work, and accident notification. 1400 daily vehicle data logs were obtained from the sensor data located at 59 points of the D100 highway between 2016-2020. With the models created with Bayesian networks, it will lead to the formation of the infrastructure of a warning system based on predicting the traffic density and traffic events on the European Side and the Anatolian Side along the D100 highway line. With these models, the vehicle density and traffic events that will take place on the D100 highway line will be predicted in advance and will make great contributions to taking precautions.

2. Literature Search

In the literature, the Bayesian network has been used in many studies in estimating traffic events and in traffic density analysis. The Bayesian network approach was used in traffic flow estimation (Sun, et al., 2006; Kim and Wang, 2016). An analysis of traffic accidents on rural roads was carried out using the Bayesian network approach (De Ona, et al., 2013). A road traffic safety analysis of developing countries was carried out with a bayesian network (Mbakwe, et al., 2016). A factor analysis of traffic accidents in China was carried out with a Bayesian network (Chen, et al., 2020). The analysis of the injury severity of traffic accidents on Spanish highways was carried out using a Bayesian network (De Ona, et al., 2011). The Bayesian network was used to estimate the severity of traffic accidents (Zong, et al., 2013; Zong, et al.,2019). The role of travel purpose of injuries in traffic accidents was analyzed with a Bayesian network (Febres, et al.,2019). The Bayesian network was used in traffic flow estimation (Pascale and Nicoli, 2011). The probabilistic estimation of traffic congestion was performed with a Bayesian network (Afrin and Yodo, 2021). Analysis of the injury severity of traffic accidents on highways with a Bayesian network was performed (Mujalli and De Oña, 2011; Yang, et al., 2022). The analyses of the factors affecting the severity of traffic accidents were performed with a Bayesiann network (Liu, et al., 2022). The severity of traffic accidents were estimated with a multidimensional and layered Bayesian network (Li, et al., 2022). The severity analysis of the accidents of vehicles carrying dangerous goods on highways was carried out with theBayesiann network (Sun, et al., 2022). The Bayesian network approach was used to understand the effects of traffic congestion on the roads (Blackwell, et al., 2022). The analysis of the leading causes of fatal and injury accidents was carried out with the Bayesian network model (Lalika, et al., 2020). In the literature, it has been used in many studies in the analysis of traffic events and traffic density using social media data. Real-time traffic incident detection was performed using Twitter data (Gu, et al., 2016; Paule, et al., 2019). Social media data was used in the detection of traffic accidents (Bao, et al., 2017), a spatial analysis of accidents (Salas, et al., 2017), detection and monitoring of traffic incidents (Nguyen, et al., 2016), detection and situation analysis of traffic accidents (Ali, et al.), 2021; Zhang, et al., 2018; Suat-Rojas, et al., 2022; Alkouz & Al Aghbari, 2022), and social media data was used to detect traffic events (Dabiri, and Heaslip 2019). The studies examining the analysis of traffic accidents in Turkey using the Bayesian method are as follows: 378.800 accident records were examined using the amirik bayesian analysis method, and the areas where there was no traffic safety were clustered (Erdoğan, et al., 2022). The factors causing traffic accidents were analyzed through the Bayesian network (Çinicioğlu, et al., 2013). In order to determine the locations of traffic accident points, a descriptive model has been proposed by using the empirical Bayesian analysis method (Dereli and Erdoğan, 2017).

3. Methodology

A structure has been developed that presents traffic information for locations during travel along the D100 highway line. Thanks to this system, traffic analysis for locations is performed and instant information is provided to users. Depending on the input variables such as month, day, time, lane of the locations, density, and traffic events analyses were carried out with Twitter data and the Bayesian Network. An infrastructure has been created that will instantly inform users about the possibility of density and traffic incidents according to input variables such as month, day, time and lane of each location. Especially on the D100 highway line, traffic analyses of the locations where traffic incidents and density occur a lot were carried out. In the traffic analysis model, big data was created by dividing the location, time, day, month, season, lane of the traffic incidents in the messages from Twitter users, accident notification of traffic incidents, vehicle breakdown, maintenance and repair work and density parameters. Traffic incidents and traffic density estimation models were carried out w ith theBayesian network, which is one of the machine learning methods.

3.1. Twitter as data source in traffic management

Social media platforms have become an important resource for increasing the efficiency of traffic management systems, thanks to the large data produced, by providing significant opportunities in the generation and dissemination of information. Twitter, one of the social media platforms, also allows users to report events and express their opinions about the events. Information such as traffic incidents, traffic jams, accidents and maintenance and repair works in many countries are shared with passengers in real time via Twitter. The use of Twitter big data in traffic management is increasing day by day. With the Dub STAR (Dublin's Semantic Traffic Annotator and Reasoner) application, the temporal and spatial relationships with traffic events were scanned and their causes were investigated by means of data derived from social media (Daly et al., 2013). Traffic performance analyses of California highways were carried out using Twitter data. Relationships related to the place and time of traffic incidents were revealed (Mai and Hranac, 2013). The SNSJam application has been developed using many social media data sources to predict traffic congestion on the road. It aims to predict future traffic events using current and past posts (Alkouz & Aghbari, 2020). According to Gu et al. 2016, they performed automatic detection and analysis of their events using Twitter data. Tweets from Traffic Incidents (TI) are manually labeled as 'TI' or 'no TI'. TI tweets are classified into categories such as accidents, roadworks and incidents (Ribeiro et al). In 2012, the Traffic Observatory established a system and scanned the tweets on Twitter and classified the traffic incidents of Belo Horizonte, one of the big cities of Brazil. In this study, the classification of tweets about the events that took place on the D100 highway line, which has an important place in the traffic flow of Istanbul, was carried out. The D100 Highway Traffic Information System was created. The traffic events and traffic density probabilities that will occur in the locations determined by this system were calculated with the Bayesian Network. The traffic notifications received from Twitter are as follows: 15 Temmuz Şehitler Köprüsü Europe-Anatolia Direction, left lane traffic accident (damaged). 15 Temmuz Şehitler Köprüsü, Europe-Anatolia Direction, 1 lane is closed to traffic due to a right lane traffic accident (with injuries). The accident is being dealt with. D100 Haramidere-Beylikdüzü, vehicle malfunction. The faulty vehicle has been removed. Heavy traffic continues in the area. D100 Acıbadem-Çamlıca Direction, right lane, 1 lane is closed to traffic due to Maintenance-Repair Work. There is heavy traffic in the area. In fig. 1, the classification of tweets has been carried out.

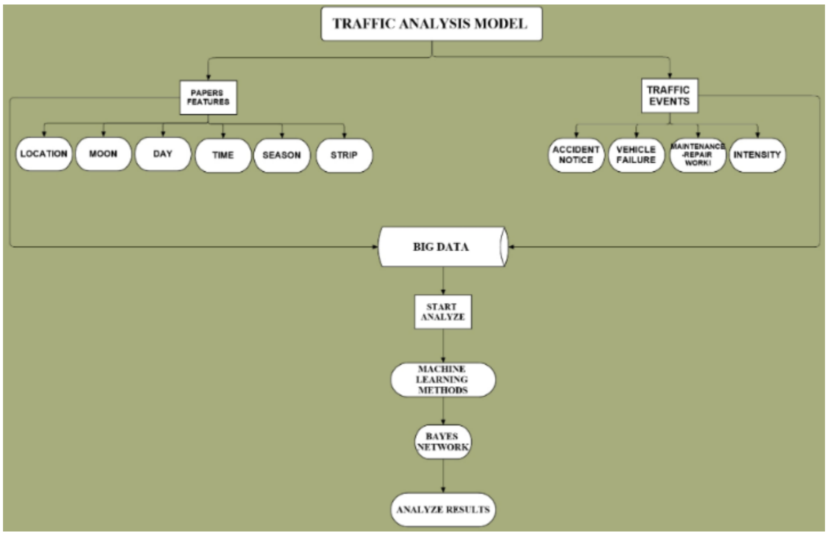

Figure 1. Research model flowchart

3.2. Research Data

In Table 1, frequencies of vehicle failure, accident notification and maintenance-repair works that occurred in 36627 traffic notification messages on the D100 highway were determined according to time, day, month, lane and season.

The number of vehicles passing 59 different locations on the D100 highway line according to day, month, season and year are given in Table 2. The values are as follows: more than 10 thousand (>=10B), more than 20 thousand (>=20B), more than 40 thousand (>=40B), according to days, months, seasons and years, More than 60 thousand (>=60B), more than 80 thousand (>=80B), more than 100 thousand (>=100B), more than 130 thousand (>=130B), more than 150 thousand (>=150B), more than 180 thousand (>=180B), and more than 200 thousand days (>=200B).

Table 1. Digitization of Traffic Notifications

Hours	Vehicle failure	f	Maintenance-Repair Work	f	Accident Notification	f
Morning	5808	31.67%	971	39,98%	4482	30,02%
Noon	6749	36,80%	715	29,44%	5403	36,19%
evening	5276	28,77%	241	9,92%	4025	26,96%
night	507	2,76%	502	20,67%	1018	6,82%
Total	18340	51,38%	2429	6,80%	14928	41,82%
Days	**Vehicle failure**	**f**	**Maintenance-Repair Work**	**f**	**Accident Notification**	**f**
Monday	3175	17,31%	295	12,14%	2284	15,30%
Tuesday	2966	16,17%	383	15,77%	2225	14,90%
Wednesday	2956	16,12%	372	15,31%	2261	15,15%
Thursday	3036	16,55%	389	16,01%	2297	15,39%
Friday	2998	16,35%	358	14,74%	2406	16,12%
Saturday	1918	10,46%	325	13,38%	1833	12,28%
Sunday	1291	7,04%	307	12,64%	1622	10,87%
Total	18340	51,38%	2429	6,80%	14928	41,82%
Months	**Vehicle failure**	**f**	**Maintenance-Repair Work**	**f**	**Accident Notification**	**f**
January	2013	10,98%	246	10,13%	1605	10,75%
February	1723	9,39%	228	9,39%	1314	8,80%
March	1683	9,18%	220	9,06%	1428	9,57%
April	946	5,16%	239	9,84%	961	6,44%
May	962	5,25%	128	5,27%	909	6,09%
June	1729	9,43%	153	6,30%	1251	8,38%
July	1952	10,64%	287	11,82%	1403	9,40%
August	1376	7,50%	176	7,25%	1178	7,89%
September	1535	8,37%	193	7,95%	1296	8,68%
October	1597	8,71%	246	10,13%	1302	8,72%
November	1348	7,35%	149	6,13%	1197	8,02%
December	1476	8,05%	164	6,75%	1084	7,26%
Total	18340	51,38%	2429	6,80%	14928	41,82%
Strips	**Vehicle failure**	**f**	**Maintenance-Repair Work**	**f**	**Accident Notification**	**f**
Left	2172	12,41%	879	40,01%	4959	38,05%
Middle	1235	7,06%	11	0,50%	1240	9,51%
Right	14094	80,53%	1307	59,49%	6835	52,44%
Total	17501	53,47%	2197	6,71%	13034	39,82%
Seasons	**Vehicle failure**	**f**	**Maintenance-Repair Work**	**f**	**Accident Notification**	**f**
Spring	3591	19,58%	587	24,17%	3298	22,09%
Summer	5057	27,57%	616	25,36%	3832	25,67%
Autumn	4480	24,43%	588	24,21%	3795	25,42%
Winter	5212	28,42%	638	26,27%	4003	26,82%
Total	18340	51,38%	2429	6,80%	14928	41,82%

Source: https://data.ibb.gov.tr/en/dataset

Table 2. Number of Vehicles

Days	>=10B	>=20B	>=40B	>=60B	>=80B	>=100B	>=130B	>=150B	>=180B	>=200B
Monday	319	866	910	905	1884	3292	2226	1498	199	46
Tuesday	337	912	899	767	1935	3455	2344	1328	177	16
Wednesday	273	829	933	741	1800	3438	2357	1578	210	21
Thursday	358	822	920	733	1754	3424	2330	1612	222	25
Friday	349	856	917	670	1704	3381	2315	1704	238	35
Saturday	778	925	968	654	1428	2806	2332	1809	236	58
Sunday	873	843	1101	1063	1397	2702	2175	1311	151	5
Months	**>=10B**	**>=20B**	**>=40B**	**>=60B**	**>=80B**	**>=100B**	**>=130B**	**>=150B**	**>=180B**	**>=200B**
January	425	651	804	773	1088	1874	1197	701	87	0
February	274	547	628	531	998	1758	1295	870	89	13
March	359	669	669	532	1101	1833	1382	825	81	15
April	512	650	639	517	1075	1789	1209	860	91	10
May	554	834	633	443	863	1820	1413	906	131	13
June	171	418	583	381	971	1887	1466	1081	152	33
July	149	390	509	458	947	1919	1456	1152	162	47
August	164	329	466	376	939	2051	1426	1014	145	36
September	125	348	417	350	987	1998	1413	1045	136	20
October	113	368	413	292	1030	2088	1629	1030	153	8
November	188	441	466	453	1004	1880	1145	721	113	8
December	253	408	421	427	899	1601	1048	635	93	3
Seasons	**>=10B**	**>=20B**	**>=40B**	**>=60B**	**>=80B**	**>=100B**	**>=130B**	**>=150B**	**>=180B**	**>=200B**
Spring	1425	2153	1941	1492	3039	5442	4004	2591	303	38
Summer	484	1137	1558	1215	2857	5857	4348	3247	459	116
Autumn	426	1157	1296	1095	3021	5966	4187	2796	402	36
Winter	952	1606	1853	1731	2985	5233	3540	2206	269	16
Years	**>=10B**	**>=20B**	**>=40B**	**>=60B**	**>=80B**	**>=100B**	**>=130B**	**>=150B**	**>=180B**	**>=200B**
2016	653	2221	2711	1684	3172	4900	3503	1747	124	4
2017	602	1374	1338	973	2586	4917	3655	2373	314	77
2018	354	662	1007	792	2001	3998	3822	2811	353	66
2019	784	934	897	1080	2344	4342	2732	2174	344	58
2020	894	862	695	1004	1799	4341	2367	1735	298	1

Source: https://data.ibb.gov.tr/en/dataset

3.3. Models of Research

In fig. 2, Bayesian Network traffic events and density probability models are shown. The number of vehicles probability model is shown in fig. 3.

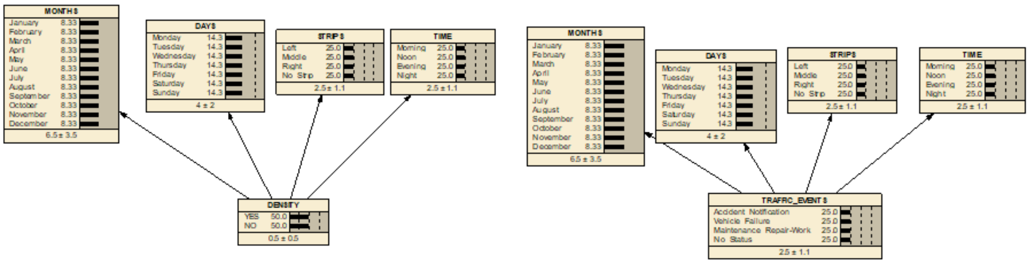

Figure 2. Bayesian Network Traffic Event and Density Analysis Models

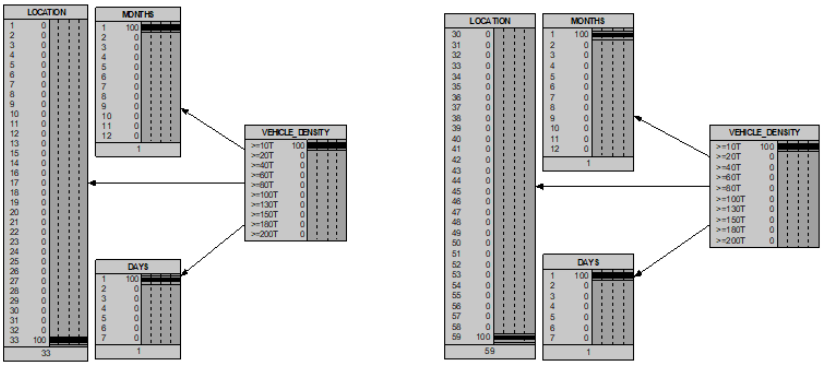

Figure 3. Bayesian Network Europe and Anatolian Line Vehicle Density Analysis Model

4. Result

Models were created that report the vehicle density of 59 locations along the D100 highway line (in fig.4) and evaluate the density and traffic incident probabilities of important points along the D100 highway line. As a result of the Bayesian Network Traffic Model, the sample information that users will benefit from the traffic information system to be obtained for the locations relates to the following questions:

- What is the probability that congestion will occur in the left lane on Monday morning in January?
- What is the probability of a vehicle breakdown in the left lane on Monday morning in January?
- What is the probability of a traffic incident occurring in the left lane on Monday morning in January?
- What is the probability that an accident will occur in the left lane on Monday morning in January?
- On Monday morning, in the right lane, what is the probability that maintenance repair work will take place in January?
- What is the probability that an accident notification will occur on a Wednesday morning in January, in the right lane?
- What is the probability that a vehicle breakdown in the right lane will occur at noon on a Monday in January?

In fig. 3, the vehicle density model of 59 points on the route of the D100 highway line has been created. In fig. 4, the locations of 59 points of the D100 highway are shown in detail. The points on the D100 highway line are shown on the maps in segments 1, 2, 3, and 4 respectively.

D100 Selimpaşa (1), D100 Celaliye_2 (2); D100 Celaliye_1 (3); D100 Kumburgaz_2 (4); D100 Kumburgaz_1 (5); D100 Muratbey (6); D100 Güzelce (7); D100Büyükçekmece, (8); D100 S-Rampası (9); D100 Tüyap (10); D100 Ambarlı (11); D100 Avcılar Hacı Şerif (12); D100 Küçükçekmece Gölü_2 (13); D100 Küçükçekmece Gölü_1 (14); D100 Cennet Mah. (15); D100 Florya (16); D100 Sefaköy (17); D100 Sefaköy Havaalanı (18); D100 Çobançeşme_2 (19); D100 Çobançeşme_1 (20); D100 Şirinevler (21); D100 Metroport (22); D100 Türk Böbrek Vakfı Önü (23); D100 Merter (24); D100 Topkapı Haliç Yönü (25); D100 Vatan Metrobüs (26); D100 Edirnekapı (27); D100 Haliç Köprü Çıkışı (28); D100 Okmeydanı (29); D100 Çağlayan (30); D100

Zincirlikuyu (31); D100 15 Temmuz Şehitler Köprüsü (32); D100-Altunizade (33); D100 Beylerbeyi (34); D100 Altunizade (35); D100 Acıbadem Köprüsü (36); D100 Uzunçayır (37); D100 Küçük Çamlıca_1 (38); D100 Küçük Çamlıca_2 (39); D100 Göztepe (40); D100 Kozyatağı_1 (41); D100 Kozyatağı_2 (43); D100 Altıntepe (44); D100 Küçükyalı (45); D100 Başıbüyük (46); D100 Maltepe (47); D100 Zümrüt Evler (48); D100 Gülsuyu (49); D100 Soğanlık (50); D100 Kartal Oto Sanayi (51); D100 Kartal Kavşağı (52); D100 Pendik_1 (53); D100 Pendik_2 (54); D100 Kaynarca (55); D100 Pendik Tersane 2 (56); D100 Güzelyalı (57); D100 Tuzla (58); D100 Tuzla Piyade (59).

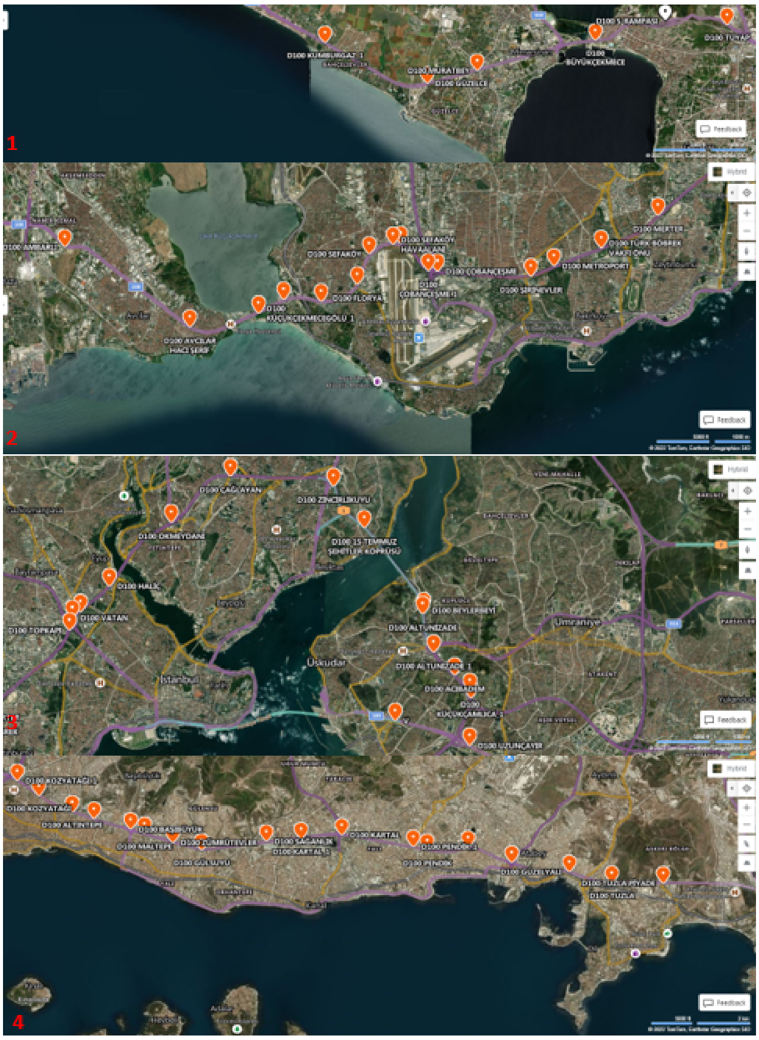

Figure 4. D100 Highway

An analysis of 36628 traffic incidents on the D100 highway line was carried out. According to the results obtained:

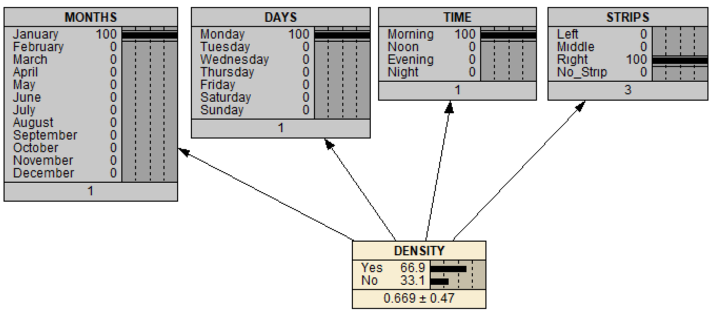

Figure 5. Bayesian Network Density Estimation Model

The density data for the traffic incidents that occurred in January, on Monday, in the morning and in the right lane are given in table 3. In January, on Monday morning, the right lane will be crowded with a probability of 66.9% (in fig.5).

P*(Density=**Yes I** Months=**January**, Days=**Monday**, Time=**Morning**, Lane=**Right)=1***

Table 3. Traffic Incidents Scenario 1

Density	Yes	No	Total	%Yes	%No
	20552	16075	36627	0.561	0,439
January	2172	1791	3963	0,106	0,111
Monday	3481	2390	5871	0,169	0,149
Morning	6849	4701	11550	0,333	0,292
Right Lane	13818	8428	22246	0,672	0,524

- *P(Density=""**Yes** " I Months=**January** ",Days= "**Monday** ",Time= "**Morning** ",Strip= "**Right** "")*=0.561*0.106*0.169*0.333*0.672=0.00225
- *P(Density=""**No** " I Months=**January** ",Days= "**Monday** ",Time= "**Morning** ",Strip= "**Right** "")*=0.439*0.111*0.149*0.292*0.524=0.001115
- *P(Density=""**Yes** " I Months=**January** ",Days= "**Monday** ",Time= "**Morning** ",Lane= "**Right** ")*=0.00225/(0.00225+0.001115 =0.669=66,9%)
- *P(Density=""**No** " I Months=**January** ",Days= "**Monday** ",Time= "**Morning** ",Strip= "**Right** "")*=0.001115/(0.00225+0.0011 =0.331=33.1%)

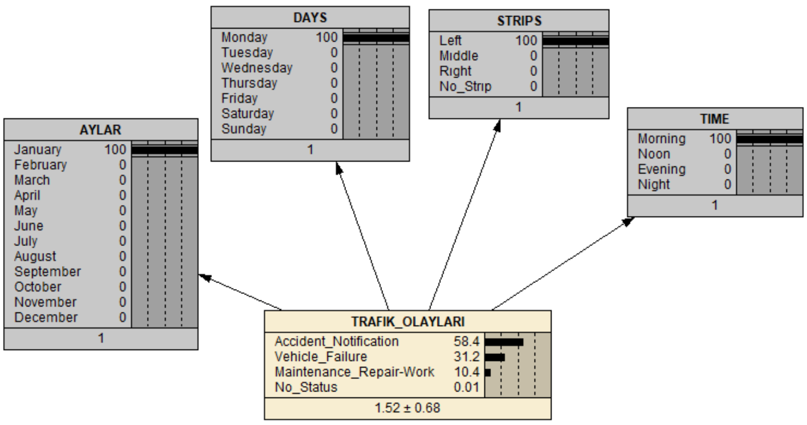

Figure 6. Bayesian Network Traffic Event-Based Prediction Model

The traffic events data for the traffic incidents that occurred in January, on Monday, in the morning and in the right lane are given in table 4. In January, on Monday morning, in the left lane, an accident report will occur with a probability of 54.8% (in fig.6).

P(**Traffic_Events=**Accident_Notification I** Months=*January, *Days=**Monday**, Time=**Morning**, Lane=**Left)=1

Table 4. Traffic Incidents Scenario 3

Traffic_ Event	Accident__ Notification	Vehicle_ failure	Maintenance_ Repair_ Study	No_ Status	Total	% Accident_ Notification	Vehicle_ failure	% Maintenance_ Repair_ Study	% No_ Status
	14927	18337	2447	916	36627	0.408	0,501	0,067	0,025
January	1605	2013	247	98	3963	0,108	0,110	0,101	0,107
Monday	2284	3175	301	111	5871	0,153	0,173	0,123	0,121
Morning	4481	5808	977	284	1155	0,300	0,317	0,399	0,310
Left Lane	4958	2170	881	0	8009	0,332	0,118	0,360	0,000

- P(***Traffic_Events=" "Accident Notification"** I Months=**"January"**,Days=**"Monday"**,Time=**"Morning"**,Strip=**"Left" ")***=0,408*0,108*0,153*0,300*0,332=0,00066885

- P(***Traffic_Events***=*" "**Vehicle_Failure**" I Months="**January**" "*,*Days="**Monday**" "*,*Time=" "**Morning**" "*,*Strip="**Left**" ")*=0,501*0,110*0,173*0,317*0,118=0,000357
- P(***Traffic_Events***=*" "**Maintenance_Repair_Study**" I Months="**January**"*,*Days="**Monday**"*,*Time="**Morning**"*,*Strip="**Left**" ")*=0,0607*0,101*0,123*0,399*0,360=0,0001192
- P(***Traffic_Events***=*" "**No_Status**" I Months="**January**"*,*Days="**Monday**"*,*Time="**Morning**"*,*Strip="**Left**" ")*=0,025*0,107*0,121*0,310*0,000=0,000
- P(***Traffic_Events***=*" "**Accident Notification**" I Months="**January**"*,*Days="**Monday**"*,*Time="**Morning**"*,*Strip="**Left**" ")*=0,0006685/(0,0006685+0,000357+0,0001192+0,000)=0,584=%58,4
- P(***Traffic_Events***=*" "**Vehicle_Failure**" I Months="**January**"*,*Days="**Monday**"*,*Time="**Morning**"*,*Strip="**Left**" ")*=0,000357/(0,0006685+0,000357+0,0001192+0,000)=0,312=%31,2
- P(***Traffic_Events***=*" "**Maintenance_Repair_Study**" I Months="**January**"*,*Days="**Monday**"*,*Time="**Morning**"*,*Strip="**Left**" ")*=0,0001192/(0,0006685+0,000357+0,0001192+0,000)=0,104=%10,4
- P(***Traffic_Events***=*" "**No_Status**" I Months="**January**"*,*Days="**Monday**"*,*Time="**Morning**"*,*Strip="**Left**" ")*= 0,000/(0,0006685+0,000357+0,0001192+0,000)=0,000=%0,00

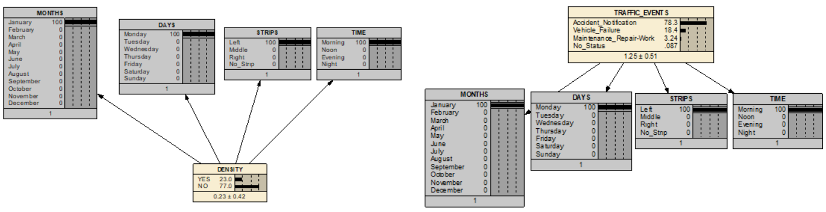

Figure 7. Maltepe Location Traffic Analysis

In Maltepe, in January, on Monday mornings, the probability of congestion in the left lane was 23.0%, and the probability of an accident notification from traffic events was 78.3% (fig.7). The probabilities of the traffic incidents that will occur on the D100 15 Temmuz Şehitler Köprüsü were calculated with the Bayesian Network by establishing month, day, time and lane scenarios. In table 5, the probabilities of traffic incidents on Monday are calculated for the 15 Temmuz Şehitler Köprüsü. According to the results, the highest probability of an accident notification on Monday in the morning will occur in the right lane with 71.29% probability, 73.57% probability that vehicle breakdown will occur in the left lane at night, and maintenance-repair work will occur with 30.00% probability in the middle lane at night.

Table 5. 15 Temmuz Şehitler Köprüsü Traffic Events On Monday Avg. Probability

Day	Time	Strips	Accident Notification	Vehicle Failure	Maintenance Repair Work
Monday	Morning	Left	62.78%	26,24%	10,81%
	Noon		23,28%	67,26%	9,40%
	Evening		68,21%	29,54%	2,01%
	Night		24,62%	73,57%	1,69%
	Morning	Right	71,29%	27,95%	0,64%
	Noon		26,82%	72,57%	0,56%
	Evening		70,87%	16,23%	12,59%
	Night		33,35%	52,03%	14,45%
	Morning	Middle	45,47%	53,68%	0,48%
	Noon		47,03%	52,85%	30,00%
	Evening		45,64%	54,13%	13,00%
	Night		67,73%	30,59%	1,59%

As a result of the sensitivity analysis of the model performed on the D100 highway line in Table 6, it was concluded that the biggest factor on traffic events and density is the lane, which has mutual info of 0.1789 and 0.1534, respectively.

Table 6. Sensitivity analysis result of the node Traffic Events and Density

Node	Mutual Info	Percent	Variance of beliefs
Traffic Events	1,2573	100,0	0,2938
Strips	0,1789	14,2	0,0308
Months	0,0103	0,8	0,0007
Time	0,0278	2,2	0,0044
Days	0,0128	1,0	0,0015
Node	Mutual Info	Percent	Variance of beliefs
Density	0,9723	100,0	0,2405
Strips	0,1534	15,8	0,0473
Months	0,0213	2,2	0,0072
Time	0,0094	1,0	0,0031
Days	0,0042	0,4	0,0014

Vehicle densities of 59 locations along the D100 Highway line were modeled. The probability of vehicle densities were calculated according to months and days for the 15 Temmuz Şehitler Köprüsü, 29 locations on the European side and 29 locations on the Anatolian side.

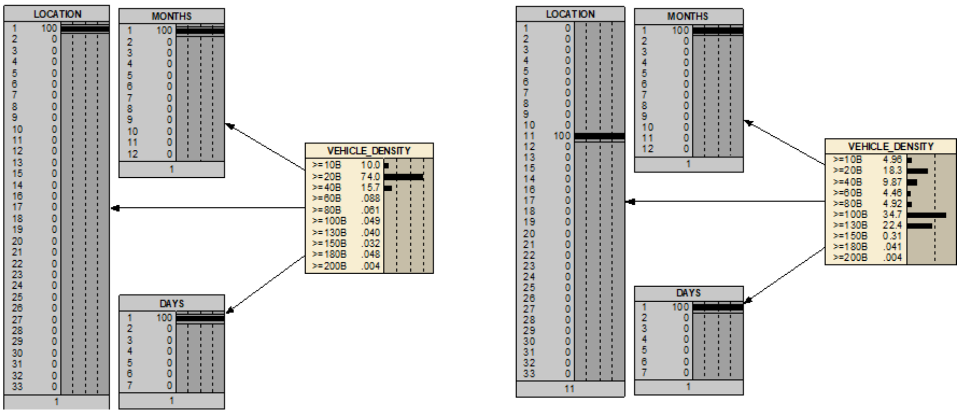

Figure 8. D100 Selimpaşa and Ambarlı Location Vehicle Density

On the D100 Highway line in January, on Monday, the vehicle density in Selimpaşa will be more than 20 thousand with a probability of 74.0%. In Küçükçekmece, there is a 34.7% probability that it will be more than 100K (fig.8).

The traffic density probability values of the European side of the D100 highway line for January and Monday are presented in the Table 7. From the places where more than 100 thousand vehicles pass Sefaköy recorded a 58.50% probability , Zincirlikuyu with 54.10% probability, and Florya with 62.00% probability. From the places where more than 130 thousand vehicles pass, Küçükçekmece had a 66.80% probability. From the places where more than 150 thousand vehicles pass, Turkish Kidney Foundation recorded a 47.40% probability. From the locations where more than 180 thousand vehicles passed, Edirnekapı had a probability of 26,60%. It is seen that the density of vehicles on the European side of the D100 highway line is higher on the Küçükçekmece-Florya-Sefaköy-Airport line in January, on Monday.

Table 7. European Side, January, Monday, Traffic Density Probability Values

D100 AVRUPA YAKASI HATTI	**>=10B**	**>=20B**	**>=40B**	**>=60B**	**>=80B**	**>=100B**	**>=130B**	**>=150B**	**>=180B**	**>=200B**
SELİMPAŞA	10,00%	74,00%	15,70%	*	*	*	*	*	*	*
CELALİYE_2	23,70%	70,60%	1,02%	*	*	*	*	*	*	*
CELALİYE_1	3,41%	88,00%	5,95%	*	*	*	*	*	*	*
KUMBURGAZ_1	6,20%	79,90%	10,90%	*	*	*	*	*	*	*
KUMBURGAZ_2	37,30%	60,70%	*	*	*	*	*	*	*	-
GÜZELCE	13,40%	37,40%	45,70%	*	*	*	*	*	*	*
MURATBEY	3,28%	18,00%	57,90%	20,00%	*	*	*	*	*	*
BÜYÜKÇEKMECE	1,22%	3,64%	72,20%	21,30%	*	*	*	*	*	*
S_RAMPASI	4,71%	12,90%	80,40%	*	*	*	*	*	*	*
TUYAP	3,71%	8,34%	21,90%	18,90%	42,60%	4,41%	*	*	*	*
AMBARLI	4,96%	18,30%	9,87%	4,46%	4,92%	34,70%	22,40%	*	*	*
HACI_ŞERİF	1,98%	1,87%	2,20%	2,61%	5,38%	13,40%	22,50%	49,50%	*	*
KÜÇÜKÇEKMECE_1	2,90%	2,69%	2,48%	2,58%	3,89%	7,62%	9,47%	66,80%	1,55%	
KÜÇÜKÇEKMECE_2	2,98%	1,79%	2,08%	3,64%	5,17%	29,70%	42,40%	12,10%	*	*
CENNET MAH.	6,58%	4,50%	4,17%	15,70%	15,40%	9,02%	23,80%	20,80%	*	*
FLORYA	1,50%	1,90%	1,19%	2,30%	3,72%	24,00%	62,00%	3,26%	*	*
SEFAKÖY	1,77%	1,85%	1,80%	4,98%	7,39%	58,50%	22,30%	1,34%	*	*
SEFAKÖY HAVAALANI	1,53%	10,70%	79,60%	*	*	*	*	*	*	*
ÇOBANÇEŞME HAVAALANI	8,05%	9,97%	79,30%	*	*	*	*	*	*	*
ÇOBANÇEŞME	4,79%	21,60%	26,60%	4,38%	11,50%	31,10%	*	*		*
ŞİRİNEVLER	12,00%	5,02%	4,05%	6,85%	8,75%	47,50%	15,40%	*	*	*
METROPORT	25,80%	2,45%	14,00%	2,99%	6,75%	27,30%	20,50%	*	*	*
TÜRK BÖBREK VAKFI	1,70%	2,13%	1,09%	2,47%	3,45%	9,18%	32,40%	47,40%		*
MERTER	0,72%	0,51%	2,73%	35,10%	30,60%	28,50%	1,76%	*	*	*
TOPKAPI	4,81%	2,43%	3,40%	8,28%	11,20%	38,30%	21,20%	*	*	*
VATAN	0,87%	2,45%	20,50%	75,60%	*	*	*	*	*	*
EDİRNEKAPI	0,98%	1,61%	1,35%	6,92%	37,90%	11,00%	1,81%	11,30%	26,60%	*
HALİÇ	1,89%	2,17%	2,08%	5,49%	7,31%	47,30%	33,00%	*	*	*
OKMEYDANI	2,56%	1,87%	2,07%	3,94%	7,88%	43,20%	37,30%	1,17%	*	*
ÇAĞLAYAN	2,10%	53,00%	43,80%	*	*	*	*	*	*	*
HÜRRİYET TEPESİ	5,01%	2,44%	5,09%	7,79%	14,20%	33,60%	27,30%	4,43%	*	*
MECİDİYEKÖY	2,59%	2,25%	2,31%	3,87%	6,28%	30,80%	40,20%	11,60%	*	*
ZİNCİRLİKUYU	3,46%	2,27%	9,45%	9,97%	11,90%	54,10%	8,53%	*	*	*

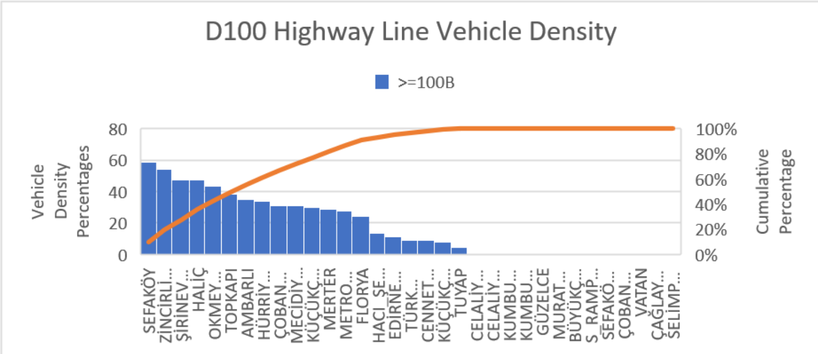

Figure 9. D100 Highway European Side Vehicle Density Pareto Analysis

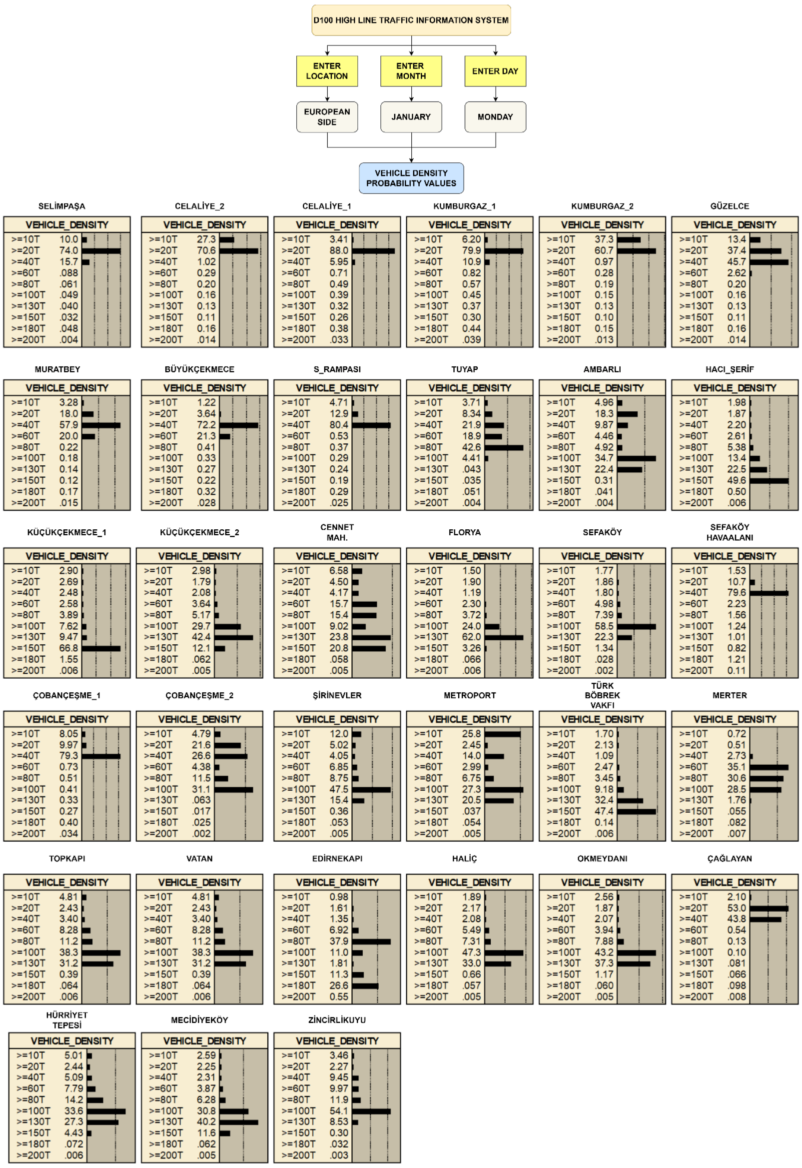

Figure 10. D100 Highway European Side Vehicle Density on Monday, January

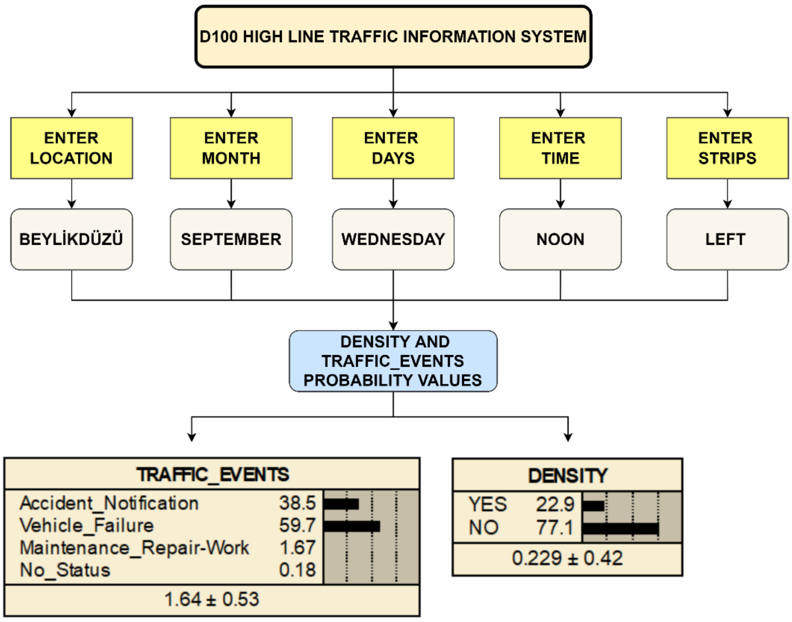

Figure 11. Beylikdüzü Location Traffic Information System

5. Discussion

It has been emphasized that the measurement and modeling performed with social media data and data mining methods in the analysis of traffic incidents are complementary to the existing methods (Wu, et al., 2022). Suat-Rojas (2022) argued that Twitter data would be effective in detecting traffic incidents and would be an important source of information in traffic management. Salazar et al., (2021) emphasized that social media tools are an important alternative that can be used to collect voluntary geographic information for streets and events taking place on the streets. Yao (2021) offers significant opportunities for transportation research in terms of integrating social media data into traffic forecasts for the detection of traffic incidents and the creation of travel demand models. It has been stated that social media networks are a promising data source for understanding and analyzing the state of metropolitan cities and events occurring in the transportation system (Sumalee and Ho, 2018). In this study, as a result of the processing of Twitter messages, location, month, day, time, lane and season data of traffic notifications were extracted. A Bayesian model was created to predict the traffic events and traffic density that may occur for each region from the traffic notifications obtained from the Twitter social media tool. The main idea of the study is to develop a model proposal on how to use this data in traffic analysis of metropolitan cities by compiling the traffic notification content created by Twitter users with text mining. With the proposed model, it is aimed to create a low-cost model in the realization of traffic analysis. This makes a significant difference to traditional traffic data collection tools, which are costly to maintain and deploy.

6. Conclusion

With the density and traffic incident models established with the Bayes Network, the probability of density and traffic incidents to occur according to months, days, time and lane conditions of 59 different locations on the D100 highway line have been obtained. By transforming the designed models into a dynamic structure, data will be transferred as a result of a traffic event that will occur, and an infrastructure will be created that will provide information about the instantaneous density and traffic events of each location. Thanks to this developed model, it is of great importance in preventing traffic congestion and ensuring traffic safety by providing more detailed information about roads to users traveling along the D100 highway.

In the D100 Highway Traffic Information System presented in fig. 10, the probability values of the vehicle density that may occur on the Anatolian and European sides, in which month and on which day, are calculated. Thanks to a dynamic system, the density data is entered every day and the probability value of the vehicle density that will occur the next day is revealed. Thanks to this information system, the vehicle density probability values unique to each region will be revealed. According to the months and days, the vehicle density of each location will be given to users before their journey.

In the D100 Highway Traffic Information System presented in fig. 11, after entering the location, month, day, time and lane, the traffic events and density probability values that may occur in that region are calculated. With this system, users can decide which lane would be more advantageous in terms of safety and cost, thanks to the information they enter into the system, before they travel. During the journey along the D100 Highway line, it provides an opportunity for them to have a better journey by accessing the data in which region bottlenecks will occur and in which regions the traffic incidents are more likely to occur.

The D100 Highway Traffic Information Service, month, day, time and lane conditions will be entered and measures will be taken according to the density situations that will occur along the highway and the probability of traffic events, and it will make a great contribution to the formation of a more reliable traffic. By integrating this system with navigation programs, informing the users about the density and traffic incidents of the location before they reach the next location will prevent traffic incidents that may occur and will naturally prevent traffic density.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

İç Entegrasyonun Lojistik Hız Ve Güvenirlik Üzerindeki Etkisi: Müşteri Entegrasyonun Aracı Rolü*

The Impact of Internal Integration on Logistics Speed and Reliability: The Mediating Role of Customer Integration

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ÖZ

Bu çalışmanın amacı firmalarda birimler arası iç entegrasyonun lojistik hız ve güvenirlik üzerine etkisinde müşteri entegrasyonunun arracı rolünü araştırmaktır. Bu kapsamda Gaziantep'de faaliyet gösteren 161 üretim firmasından anket ile veri toplanmıştır. Araştırma için gerekli analizler, SPSS ve AMOS paket programları ile yapılmıştır. Analiz sonucunda iç entegrasyonun müşteri entegrasyonunu ve müşteri entegrasyonun lojistik hız ve güvenirliğini pozitif yönde anlamlı olarak etkilediği bulgusuna ulaşılmıştır. İç entegrasyonun lojistik hız ve güvenirlik üzerindeki etkisi yapısal eşitlik modelinde bulunamazken process macro yöntemi ile bulgulanmıştır. Ayrıca process macro yöntemiyle yapılan aracılık testi neticesinde iç entegrasyonun lojistik hız ve güvenirlik üzerindeki etkisinde müşteri entegrasyonunun aracı rolünün bulunduğu ispatlanmıştır.

ABSTRACT

The objective of this research is to investigate the impact of internal integration on speed and reliability in logistics and the mediating role of customer integration. Toward this aim, the study collected data from 161 manufacturing companies operating in Gaziantep by applying the scales through questionnaires. The analysis essential to the research have been conducted using the programs SPSS and AMOS. The results prove internal integration to positively impact customer integration, and customer integration to positively impact logistics speed and reliability. Internal integration's impact on logistic speed and reliability could not be proven with the structural equation model. However, the process macro results revealed internal integration to positively impact speed and reliability in logistics. Furthermore, the results from the mediation test that was applied using the process macro method have proven customer integration to have an intermediary role in internal integration's impact on speed and reliability in logistics.

Anahtar Kelimeler: Tedarik Zinciri Entegrasyonu, İç Entegrasyon, Müşteri Entegrasyonu, Lojistik Performansı, Process Macro

Keywords: Supply Chain Integration, Customer Integration, Internal Integration, Logistics Performance, Process Macro

JEL Kodu / JEL Code: D30, L60, M11

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EXTENDED ABSTRACT

With the accelerated consumption and increased demand these days, manufacturers are expected to have quick reliable logistics services. Making deliveries where and when they are needed has been a distinctive feature for companies. The purpose of this study is to analyze how much manufacturers' speed and reliability in logistics is explained by internal integration and customer integration and whether or not customer integration mediates the relationship internal integration has with speed and reliability in logistics. As emphasized in this study, increasing speed and reliability in logistics is possible through integration. Integration is an

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accepted strategy businesses implement and involves applying key business processes from the raw material supplier to the end user in an integrated and harmonious manner throughout the supply chain (Gimenez & Ventura, 2005, p. 22). Integration starts with customers and extends throughout the entire supply chain, from the distribution of finished products to the production and sourcing of raw materials, as well as service suppliers. Therefore, integration is necessary both between departments and with customers (Stank et al., 2001, p. 29). Internal integration refers to the information sharing, harmony, and cooperation that takes place within the internal processes between departments. Through internal integration, functional units share information such as sales forecasts, production plans, and inventory with each other using digital systems (Narasimhan & Kim, 2001). Because of the very rapid changes in environmental conditions, the unpredictability of demand, and customers' high expectations for delivery, speed in logistics has become ever more important. Meanwhile, the expectation of having deliveries be made on time as promised makes reliability important. The reason why both concepts represent one dimension is that reliability is actually considered in terms of the reliability of fulfilling the promises that are made about delivery times. The aim of this study is to analyze the effect internal integration has on speed and reliability in logistics, as well as the mediating role of customer integration. The following hypotheses have also been developed:

H1. Internal integration positively impact speed and reliability in logistics.
H2. Internal integration positively impacts customer integration.
H3. Customer integration positively impacts speed and reliability in logistics.
H4. Customer integration has a mediating role in the effect internal integration has on speed and reliability in logistics.

The research has been applied to medium and large companies operating in Gaziantep, with the sample of the research consisting of 161 industrial companies. The study has applied confirmatory factor analysis (CFA), exploratory factor analysis (EFA), and reliability analyses to test the validity and reliability of the scales. The EFA results reveal the KMO values to be greater than 0.70 and the factor loads to exceed 0.50 for all scales. The reliability analysis reveals the alpha of reliability value for all scales to be greater than 0.70. Thus, the CFA has proven the scales to meet the goodness-of-fit criteria. The results from the structural equation model (SEM) show internal integration to positively affect customer integration but to not affect speed and reliability in logistics, as well as customer integration to affect speed and reliability in logistics. The process macro method was used to test the mediating role of customer integration in internal integration's impact on speed and reliability in logistics. According to the findings obtained from the analysis, internal integration affects customer integration positively and significantly (B = .5341, 95% CI [.3813, .6866], $t = 6.9149$, $p < .001$). Customer integration has been determined to significantly affect speed and reliability in logistics (B = .1602, 95% CI [.0165, .3039], $t = 2.2025$, $p < .001$). While SEM was unable to prove internal integration to have an impact on speed and reliability in logistics, the process macro method did support this (B = .2053, 95% CI [.0457, .3649], $t = 2.5404$, $p < .001$). Thus, customer integration can be said to mediate the impact internal integration has on speed and reliability in logistics (B = .0856, 95% CI [.0023, .1845], $p < .001$). The study results thus support hypotheses H1, H2, H3, and H4.

1. Giriş

Günümüz firmaları için rekabet gücünü belirleyen önemli faktörlerden bir tanesi lojistik faaliyetlerindeki hız ve güvenirliktir. Daha hızlı ve daha doğru teslimat yapabilmenin yolu entegrasyondur. İşletmeler, departmanları arasında ve müşterileriyle entegre olarak daha hızlı teslimat yapabilmektedirler (Yamak, 2001: 257; Yeung, 2006; Deepen, 2007: 125).

Bir firma stratejisi olarak kabul edilen entegrasyon, firmalar tarafından bilgi ve mamül akışını daha iyi yönetmek için uygulanmaktadır. Firmalar ve birimler arasında geliştirilen entegrasyonun teslimatlarda hız ve güvenirliği geliştireceği düşünülmektedir. Önceki çalışmalar incelendiğinde tedarik zinciri entegrasyonun tedarikçi entegrasyonu, iç entegrasyon ve müşteri entegrasyonu olmak üzere üç boyutta ele alındığı görülmektedir. Bu çalışmada ise daha çok teslimatlar dikkatte alındığından sadece iç entegrasyon ve müşteri entegrasyonu dikkate alınmıştır. Entegrasyonun faydaları birçok çalışmada ortaya koymuştur (Bowersox vd., 1999, Salvador vd., 2001; Flynn vd. 2010; Wong vd. 2011).

Son 20 yıldır gerçekleşen teknolojik gelişmeler ve verimliliği arttırmak üzere yapılan çalışmalar, üretim firmalarının verimliliklerini optimize etmelerine ve üretim hızını büyük bir oranda arttırabilmelerine yardımcı olmuştur. Üretim konusunda büyük bir hız kazanan firmalar yönünü üretim dışında kalan lojistik faaliyetlerinde çevirmiştir. Siparişlerinin en hızlı şekilde teslim edilmesini isteyen müşteriler, firmaların bu konuda yeni adımlar atmasına sebep olmuştur. İşletmelerin birimler arası entegre olarak süreçleri daha hızlı yönetmesi ve müşterileriyle entegre olarak talepleri ön görebilmesi gibi sebeplerle bu çalışmada iç entegrasyon ve müşteri entegrasyonunun lojistik hız ve güvenirliğe etkisi incelenmiştir.

1.1. İç Entegrasyon ve Müşteri Entegrasyonu

Entegrasyon, en özet haliyle hammadde tedarikçisinden son kullanıcıya kadarki tüm süreçlerin koordineli olarak ve iş birliği çerçevesinde yapılmasını anlamına gelmektedir (Gimenez ve Ventura, 2005: 22). Entegrasyon müşterilerle başlar ve firma boyunca bitmiş ürün dağıtımından üretim ve hammadde tedarikine ve ayrıca malzeme ve hizmet tedarikçilerine kadar uzanır. Bu nedenle, entegrasyon hem departmanlar arası hem de müşterilerle gereklidir (Stank, vd. 2001:29). İç entegrasyon departmanlar arasında gerçekleşen iş birliğini, bilgi paylaşımını ve uyumu ifade etmektedir. İç entegrasyon ile fonksiyonel birimler satış tahminleri, üretim planı ve envanter gibi bilgileri dijital sistemler üzerinden birbirleriyle paylaşırlar (Narasimhan ve Kim, 2001). İç entegrasyonun başarısı, fonksiyonel birimler arasında planlama, koordinasyon ve şirket veri tabanlarının paydaşlarla paylaşımına bağlıdır (Li vd., 2009: 126). Bu şekilde oluşan iş birliği sayesinde ürün tasarımı, satın alma, üretim, satış ve dağıtım gibi anahtar fonksiyonlar daha koordineli olarak sürdürülecek ve müşteri ihtiyaçları daha hızlı ve daha düşük maliyetlerle karşılanmış olacaktır (Morash vd., 1997: 46). Departmanlar arasında entegrasyonu göz ardı eden firmalarda birimler arası çatışmalar ortaya çıkabilir. Bu durum, kaliteye ve maliyete yansıyabileceği gibi kaynak israfına da sebep olabilmektedir (Pagell, 2004: 459).

Müşteri entegrasyonu ise, firmaların müşterileri ile işbirliğini ve koordinasyonu ifade etmektedir (Gimenez ve Ventura, 2005: 22). Müşteri entegrasyonu firmanın müşterileriyle bilgi paylaşımında bulunarak stratejik işbirliği, ortak planlamalar ve ortak talep tahminleri yapmasını kapsar. Müşteri entegrasyonu farklı seviyelerde sağlanabilmektedir. Entegrasyon sonucu müşterilerle performans karşılaştırması, stok, üretim planı, sipariş vb. bilgilerin paylaşılarak daha doğru satış tahminleri ve tedarik planlamalarının birlikte yapılması ve hatta gerektiğinde kaynakları, müşterileri ve siparişleri paylaşmaya kadar giden derin bir anlayış mevcuttur. Müşteri entegrasyonu, müşterilerin ihtiyaçlarını önceden anlamak ve faaliyetleri değer yaratmak üzere organize etmek için kilit müşterilerin katılımını gerektirmektedir (Koufteros vd., 2005). Müşterilerin katılımı, fikir üretmeden ürünlerin üretim ve teslimatının yönetilmesine kadar çeşitli faaliyetleri kapsamaktadır (Lau vd., 2010). Ürün tasarımı ve ortak karar alma süreçlerinde kilit müşterilerle etkileşim ve işbirliği, şirketlerin müşteri sorunlarını anlamasına ve müşteri beklentileriyle ilgili belirsizlikleri azaltmasına yardımcı olmaktadır (Koufteros vd., 2005).

1.2. Lojistik hız ve güvenirlik

Lojistik hız ve güvenirlik, literatürde anlatılan lojistik performans kriterlerinin en önemlilerinden bir tanesidir. Aslında lojistik performansı bu konuyla ilgili çalışmalar yapmış yazarlar tarafından farklı değerlendirilmiş ve üzerinde net bir ortak görüş beyan edilememiş bir performans türüdür. Bunu temel sebebi, lojistik performansın çok sayıda boyutunun olmasıdır. Lojistik faaliyetlerden beklenen sonuçlar, müşteri memnuniyetinden çevresel sorumluluğa kadar birçok alanı içermektedir (Chow vd., 1995: 296).

Tedarikçilerinden lojistik performans anlamında önemli beklentileri olan firmalar sözleşmelerle kendilerini güvence altına almaya çalışmaktadır. Örneğin perakendeciler tedarikçilerinin gecikmeli teslimatlarında, miktar veya ambalaj hatalarında yaptıkları sözleşmeler kapsamında yaptırımlar uygulayabilmektedir (Wood vd., 2002: 414).

Lojistik performansı ile ilgili yapılmış çalışmalar incelendiğinde birçok farklı ölçme aracının kullanıldığı görülmektedir. Bu çalışmalardan bazıları performansa finansal açıdan yaklaşmış ve aktif karlılığı, geri ödeme süresini vb. sayısal verilerle elde edilebilecek ölçekler kullanmıştır. Finansal ölçümlerin avantajı verilerin kolay ulaşılabilir olması, ikna ediciliğinin yüksek olması ve karşılaştırma imkânı sunmasıdır. Ancak geçmişe bağlı kalma, değişimlere hızlı cevap verememe, muhasebe kayıtlarıyla sınırlı olma ve lojistiğin birçok önemli parametrelerinin kaydını tutmama gibi bazı eksikleri bulunmaktadır. Finansal performans göstergeleri bir yanlışın olduğunu göstersede yanlışın kaynağını ve düzeltme yollarına dair bir bilgi vermez. Gerek yapılan çalışmalar, gerekse de uygulamalar göstermiştir ki, teslimat ile ilgili konularda lojistik performansı doğrudan ölçmek daha doğrudur. Doğrudan ölçüm teslim süresi, stok devir hızı, teslimat miktarları vb. lojistikle doğrudan ilişkili olguları ölçmektir (Waters, 2003: 202). Bu sebeple bu çalışmada lojistiğin hız ve güvenirlik boyutu ele alınmıştır.

Çevre şartlarının çok hızlı değiştiği, talebin tahmin edilemez olduğu ve müşterilerin hız konusunda beklentilerinin yüksek olması gibi sebepler lojistik hızı önemli kılarken, teslimat sürelerinin söz verildiği gibi zamanda yapılma beklentisi ise güvenirliği önemli kılmaktadır. Her iki kavramın tek boyutu temsil etme sebebi ise güvenirliğin aslında teslimat süreleri ile ilgili verilen sözlerin yerine getirilme konusundaki güvenirlik olarak ele alınmasından kaynaklanmaktadır.

Lojistik performans göstergesi olarak hız ve güvenirliği ele alan birçok çalışma olmuştur (Yamak, 2001: 257; Deepen, 2007: 125; Byrnes vd., 1987: 46; Chow vd., 1994: 23; Daugherty vd., 1996; Franceschini, 2000; Yeung, 2006). Bu çalışmada da lojistik hız ve güvenirlik bir lojistik performansı göstergesi olarak ele alınmıştır.

2. Literatür Taraması Ve Araştırma Hipotezlerinin Kurulması

2.1. İç Entegrasyon ve Lojistik Hız ve Güvenirlik İlişkisi

İç entegrasyon, firmanın faaliyetleri kapsamında müşteri ihtiyaçlarını yerine getirmek için kendi birimleri arasında süreçlerini ve uygulamalarını işbirlikçi ve senkronize olarak yürütme derecesi olarak ifade edilmektedir (Kahn ve Mentzer, 1996; Kingman-Brundage vd., 1995).

Daugherty vd. (2009), çalışmalarında 125 ABD firmasını araştırmış ve lojistik ve pazarlama birimleri arasındaki iş birliğinin ve etkinliğinin, genel entegrasyon üzerinde olumlu etkisi olduğunu bulmuştur. Ayrıca, çalışma genel entegrasyonun lojistik performansı etkilediğini göstermiştir. İspanyada 64 üretim firmasını analiz eden Gimenez ve Ventura (2005) üretim birimi ile lojistik arasındaki işbirliğinin lojistik performansı positif olarak etkilediğini tespit etmiştir.

Rodrigues vd. (2004), 284 ABD'li imalat firması üzerinde yaptıkları çalışmada, iç ve dış operasyonlardaki entegrasyonun, lojistik performansınını etkilemediğini bulmuştur. Benzer şekilde Johnson ve Filippini (2009:17) iç entegrasyonun zaman performansıyla doğrudan bağlantılı olmadığını bu yüzden iç entegrasyonun ürün başarısına yardımcı olabileceğini, ancak zaman performansını etkilemediğini bulmuştur.

İç entegrasyon ve lojistik performansı arasında ilişki bulan çalışmaların (Daugherty vd., 2009; Gimenez ve Ventura, 2005) olduğu gibi ilişki bulamayan çalışmalarda olmuştur (Rodrigues vd., 2004; Johnson ve Filippini, 2009:17). Bu durum dikkate alınarak iç entegrasyonun lojistik hız ve güvenirliği arttıracağı düşünülmüş ve aşağıdaki hipotez geliştirilmiştir:

H1: İç entegrasyonuun lojistik hız ve güvenirlik üzerinde pozitif yönlü anlamlı etkisi bulunmaktadır.

2.2. İç Entegrasyon ve Müşteri Entegrasyonu İlişkisi

İç entegrasyon, firma içerisindeki birimlerin, sorumluluklarını bütünleşik bir yapının bir bölümü olarak yerine getirmesi gerektiğini benimserken, dış entegrasyon olarakta bilinen müşteri entegrasyonu, müşterilerle yakın ilişkiler kurmayı ve faaliyetleri koordineli olarak yürütmeyi önemli görür. Genel anlamda tedarik zinciri entegrasyon, departmanlar ve firmalar arasında koordineli faaliyetler yürüterek, tedarik zinciri verimliliğini arttırmak amacıyla uygulanana bir stratejidir (Flynn vd. 2010). Bazı yazarlar, iç entegrasyonun, dış entegrasyon diye adlandırılan üst düzey tedarik zinciri entegrasyonu uygulamalarına ulaşmak için temel oluşturduğunu ifade etmiştir (Cheng vd., 2016; Zhao vd., 2011). Dış entegrasyon yoluyla rekabet üstünlüğü elde etmek isteyen bir firma, müşteri beklentilerine daha iyi cevap verebilmek ve müşteri ihtiyaçlarını karşılayabilmek için şirket içine de odaklanmalıdır (Stank vd., 2001:29).

İç entegrasyonun etkisine müşteri entegrasyonunun aracılık etmesi için öncelikle iç entegrasyon müşteri entegrasyonuna etkisi bulunmalıdır. Bu etki Koufteros vd. (2005:114) tarafından 244 firma üzerinde test edilmiş ve iç entegrasyonun müşteri entegrasyonuna pozitif yönde etki ettiğini bulgulamıştır. Böylelikle müşterilerle entegre olmak isteyen firmaların önce iç entegrasyon sağlamaları gerektiği ispatlanmıştır. Benzer şekilde Zhao vd. (2011) Çin'de faaliyet gösteren üretim firmaları üzerinde yaptıkları araştırmada iç entegrasyonun müşteri entegrasyonunu etkilediğini bulmuştur. Firmaların dış entegrasyondan önce iç entegrasyon sağlaması gerektiği anlaşılmıştır.

Çalışmalar iç entegrasyonunun müşteri entegrasyonuna etki ettiğini göstermiştir. Bu sebeple çalışmanın ilk hipotez şu şekilde kurulmuştur:

H2: İç entegrasyonun müşteri entegrasyonu üzerinde pozitif yönlü anlamlı etkisi bulunmaktadır.

2.3. Müşteri Entegrasyonu ve Lojistik Hız ve Güvenirlik İlişkisi

Müşteri entegrasyonu, önemli müşterilerle yapılan iş birliğinden elde edilen temel yetkinlikleri kapsamaktadır (Bowersox vd., 1999). Müşteri entegrasyonu, önceki çalışmalarda firmaların birçok farklı performans türleriyle ilişkilendirilmiştir.

Chavez vd., (2015) çalışmasında müşteri entegrasyonun firma performans türlerinden olan teslimat performansına etki ettiğini bulgulamıştır. Salvador vd. (2001), çoklu regresyon analizi ile 164 üretici firmayı analiz ettiğinde, tedarikçiler ve müşterilerin akış yönetimi ve kalite yönetimi konularında yakın ilişki içerisinde olmalarının, teslimatta operasyon hızına olumlu etki ettiğini tespit etmiştir. Johnson ve Filippini (2009:16) ise müşteri entegrasyonuda dahil eden dış entegrasyonun zaman performansını etkilediğini bulmuştur.

Önceki çalışmaların da bulguladığı üzere iç entegrasyonun lojistik hız ve güvenirlik üzerine etkisi olabilmektedir. Çalışmanın üçüncü hipotezi bu doğrultuda kurulmuştur:

H3: Müşteri entegrasyonunun lojistik hız ve güvenirlik üzerinde pozitif yönlü anlamlı etkisi bulunmaktadır.

2.4. Müşteri Entegrasyonun aracı rolü

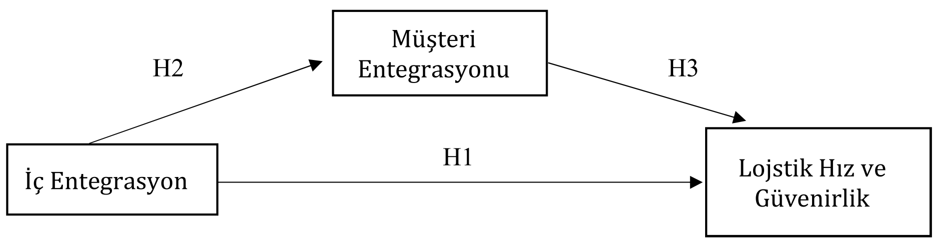
İç entegrasyonun lojistik hız ve güvenirliğe etki etmesi halinde, bu etkiye müşteri entegrasyonunun ne kadar aracılık ettiği çalışmanın bir diğer önemli katkısıdır. İç entegrasyonu sağlayan firmaların müşteri entegrasyonu sayesinde daha yüksek lojistik hız ve güvenirlik elde edecekleri düşünülmektedir.

Önceki çalışmalar incelendiğinde çalışamıza çok benzer olarak Jajja vd. (2018) 770 imalatçı firmayla yaptığı çalışmada, iç entegrasyonun çeviklik performansı üzerindeki etkisinde müşteri entegrasyonunun aracı rolünü bulmuştur. Buradaki çeviklik performansı, ölçeği itibarıyla çalışmamızdaki lojistik hız ve güvenirliğe çok benzemektedir. Benzer şekilde Feng vd., (2017) iş birliğinin firma performansı üzerindeki etkisinde tedarik zinciri entegrasyonun aracı rolünü bulmuştur.

Çalışmanın son hipotezi şu şekilde oluşturulmuştur:

H4: İç entegrasyonun lojistik hız ve güvenirliği üzerindeki etkisinde müşteri entegrasyonunun aracı rolü bulunmaktadır.

3. Araştırmnın Yöntem Ve Bulguları



Şekil 1. Araştırma Modeli

Araştırmada kullanılan iç entegrasyon ve müşteri entegrasyonu ölçekleri Wong vd. (2011)'in çalışmasından alınmıştır. Lojstik hız ve güvenirlik ölçeği Çetindaş ve Çelik (2017) tarafından geliştirilmiştir. Sorular katılımcılara 5'li likert ölçeğinde sorulmuştur. Araştırma verileri kolayda örnekleme yöntemi ile toplanmıştır. Etik kurulu onayı ise 19.11.2020'de Hasan Kalyoncu Üniversitesi'nden E-804.01.2011190012 belge numarasıyla alınmıştır.

Çalışmanın evreni, Gaziantep Sanayi Odasına (GSO) kayıtlı orta ve büyük ölçekli üretim firmalarından oluşmaktadır. Evren 320 firmadan oluşmuş ve %5'lik bir hata payı dikkate alınarak, %95 güvenilirlik sınırları içerisinde, örneklem büyüklüğü 175 kişi olarak hesaplanmıştır (Sekaran, 1992: 253). Hatalı doldurulduğundan dolayı elenen anket forumları sonrasında 161 anket formu elde edilmiştir.

Araştırmaya katılan firmaların 67'si tekstil, 36'sı gıda, 13'ü ambalaj, 11'i plastik, 4'ü sağlık ürünleri, 3'ü otomotiv, 3'ü kimya, 3'ü mobilya, 2'si çimento, 2'si kâğıt ve 1'i enerji alanında üretim yapmaktadır. 16 firma diğer seçeneğini işaretleyerek sektör belirtmemiştir. Firmaların 19'u 1-5 yıl arasında, 20'si 6-11 yıl arasında, 57'si 11-20 yıl arasında ve 64'ü 21 yıl ve üzeri süredir faaliyetlerini sürdürmektedir. Firmaların 30'u 0-51 arası, 53'ü 51-150 arası, 35'i 151-250 arası, 14'ü 251-350 arası, 5'i 351-450 arası ve 22'si 451 ve üzeri personel çalıştırmaktadır.

Araştırmada öncelikle keşfedici faktör analizi (KFA) ve doğrulayıcı faktör analizi (DFA) ile ölçeklerin yapı geçerliği ve güvenilirlik analizleri ile güvenilirliği test edilmiştir. Tedarik zinciri entegrasyonu ölçeği için KFA ve güvenilirlik analizi sonuçları Tablo 1'de verilmiştir.

KFA sonucu ölçeğin faktör yükleri 0,624 ile 0,896 arasında elde edilmiştir KMO değerinin 0,734 olarak elde edilmiş olması faktör analizi için yeterli örneklem büyüklüğüne ulaşıldığını gösterir. Ölçeğin güvenirliğini gösteren alfa katsayısı 0,798 bulunmuş ve ölçeğin oldukça güvenilir olduğu anlaşılmıştır. Ayrıca ölçeğin toplam varyansın % 63,118'sini açıkladığı tespit eidlmiştir. AVE değeri 0,5 den CR değeri ise 0,7'den büyük bulunmuştur. Ayrıca CR'nin AVE'den büyük olması şartı da sağlanmıştır. Müşteri entegrasyonu ölçeği için KFA ve güvenilirlik analizi sonuçları Tablo 2'de verilmiştir.

KFA sonucu ölçeğin faktör yükleri 0,660 ile 0,821 arasında elde edilmiştir. KMO değerinin 0,795 olarak elde edilmiş olması faktör analizi için yeterli örneklem büyüklüğüne ulaşıldığını gösterir. Ölçeğin güvenirliğini gösteren alfa katsayısı 0,796 bulunmuş ve ölçeğin oldukça güvenilir olduğu anlaşılmıştır. Ayrıca ölçeğin toplam varyansın % 55,43'ünü açıkladığı tespit eidlmiştir. AVE

Tablo 1. İç Entegrasyon Ölçeği Faktör ve Güvenilirlik Analizi

Maddeler	Faktör Yükü	Alfa	Ort.	Top. Açk. Var.	KMO	AVE CR
TZEİC3	,896	0,798	4,184	63,118	0,734	0,63 0,87
TZEİC4	,869					
TZEİC2	,759					
TZEİC1	,624					

Tablo 2. Müşteri Entegrasyonu Ölçeği Faktör ve Güvenilirlik Analizi

Maddeler	Faktör Yükü	Alfa	Ort.	Top. Açk. Var.	KMO	AVE CR
TZEMU3	,821	0,796	3,808	55,43	0,795	0,55 0,86
TZEMU1	,778					
TZEMU4	,770					
TZEMU5	,682					
TZEMU2	,660					

değeri 0,5 den CR değeri ise 0,7'den büyük bulunmuştur. Ayrıca CR'nin AVE'den büyük olması şartı da sağlanmıştır. Lojistik hız ve güvenirlik ölçeği için KFA ve güvenilirlik analizi sonuçları Tablo 3'de verilmiştir.

Tablo 3. Lojistik Hız ve Güvenirlik ölçeği Faktör ve Güvenilirlik Analizi

Maddeler	Faktör Yükü	Alfa	Ort.	Top. Açk. Var.	KMO	AVE CR
HG2	,863	0,896	4,232	61,94	0,863	0,62 0,92
HG4	,835					
HG1	,806					
HG5	,801					
HG3	,793					
HG7	,720					
HG6	,674					

KFA sonucu ölçeğin faktör yükleri 0,674 ile 0,863 arasında elde edilmiştir.

KMO değerinin 0,863 olarak elde edilmiş olması faktör analizi için yeterli örneklem büyüklüğüne ulaşıldığını gösterir. Ölçeğin güvenirliğini gösteren alfa katsayısı 0,896 bulunmuş ve ölçeğin yüksek derecede güvenilir olduğu anlaşılmıştır. Ayrıca ölçeğin toplam varyansın % 61,94'ünü açıkladığı tespit eidlmiştir. AVE değeri 0,5 den CR değeri ise 0,7'den büyük bulunmuştur. Ayrıca CR'nin AVE'den büyük olması şartı da sağlanmıştır.

KFA ile geçerlenen ölçekler için DFA yapılmıştır. Tablo 4 DFA sonucu bulgulanan uyum iyiliği değerlerini göstermektedir.

Tablo 4. Doğrulayıcı Faktör Analizi Uyum İyiliği Değerleri

Değişken	CMIN	DF	CMIN/DF	GFI	CFI	NFI	RMSEA
İç Entegrasyon	0,662	2	0,331	0,998	1	0,997	0
Müşteri Entegrasyonu	5,083	4	1,27	0,988	0,995	0,978	0,041
Lojistik Hız ve Güvenirlik	8,05	8	1,006	0,986	1	0,989	0,006

DFA sonucu ölçeklerin uyum iyiliği değerlerinin kabul edilir aralıkta olduğu görülmüştür. DFA sonucu elde edilen faktör yükleri sırasıyla iç entegrasyon için 0,46 ile 0,92 arasında, müşteri entegrasyonu için 0,56 ile 0,77 arasında, lojistik hız ve güvenirlik için ise 0,53 ile 0,95 arasında bulunmuştur.

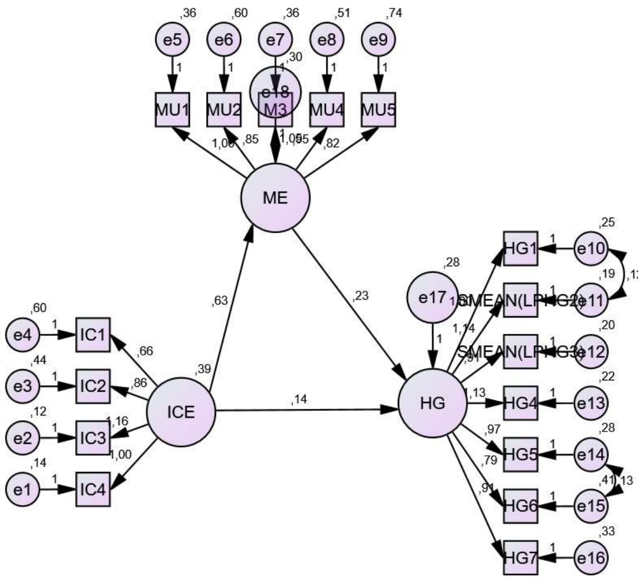
KFA, DFA ve güvenilirlik analizinden sonra çalışmanın değişkenleri arasındaki ilişkiyi inceleyebilmek için korelasyon analizi uygulanmıştır. Tablo 5 korelasyon analizine ilişkin bulguları göstermektedir

Korelasyon analizi sonucu iç entegrasyon, müşteri entegrasyonu ve lojistik hız ve güvenirlik değişkenleri arasında 0,01 anlamlılık düzeyinde pozitif yönde ilişkiler olduğu bulgulanmıştır. Değişken ortalamalarına göre ortalamalarının yüksek olduğu söylenebilmektedir.

Tablo 5. Korelasyon Analizi

	Ort.	Std. Sapma	İç Entegrasyon	Müşteri Entegrasyonu	Lojistik Hız ve Güvenirlik
İç Entegrasyon	4,1879	,64044	1		
Müşteri Entegrasyonu	3,8116	,71132	,481**	1	
Lojistik Hız ve Güvenirlik	4,2281	,62175	,295**	,293**	1

Araştırmada kurulmuş hipotezler yapısal eşitlik modeli ile test edilmiştir. Şekil 2'de yapısal eşitlik modeli, Tablo 5'de modelin uyum iyiliği değerleri ve Tablo 6'da analiz sonuçları gösterilmiştir.



Şekil 2. Araştırma Modeli

Şekil 2'de görüldüğü üzere modelde iç entegrasyonun müşteri entegrasyonu ve lojistik hız ve güvenirliğe, müşteri entegrasyonun ise lojistik hız ve güvenirliğe etkisi analiz edilmiştir.

Tablo 6. Yapısal Eşitlik Modeli Uyum İyiliği Değerleri

Değişken	CMIN	DF	CMIN/DF	GFI	CFI	NFI	RMSEA
Yapısal Eşitlik Modeli	187,649	99	1,895	0,877	0,929	0,863	0,075

Yapısal eşitlik modelinin NFI hariç kabul edilebilir uyum iyiliği değerlerini sağladığı görülmüştür. 0,90 dan büyük olması beklenen NFI gerekli aralıkta olmamasına rağmen NFI'nin serbestlik derecesinin dikkate alınarak hesaplanmış hali olan TLI (Meydan ve Şeşen, 2015: 33) 0,914 değeri ile iyi uyum göstermiştir.

Analizi sonuçları iç entegrasyonun müşteri entegrasyonuna pozitif yönde anlamlı olarak etki ettiği ancak lojistik hız ve güvenirliğe etki etmediği tespit edilmiştir. Ancak müşteri entegrasyonu lojistik hız ve güvenirliği pozitif yönde anlamlı olarak etkilemiştir. Analiz sonucunda H1 hipotezi reddedilirken H2 ve H3 hipotezleri kabul edilmiştir.

Tablo 7. Yapısal Eşitlik Modeli Analiz Sonuçları

Test Edilen Yol			B	β std.	Std. Hata	Kritik Oran	P
Müşteri Entegrasyonu	←	İç Entegrasyon	0,63	0,582	0,102	6,144	***
Lojistik Hız ve Güvenirlik	←	Müşteri Entegrasyonu	0,231	0,269	0,102	2,262	0,024
Lojistik Hız ve Güvenirlik	←	İç Entegrasyon	0,139	0,150	0,104	1,34	0,18

İç entegrasyonun lojistik hız ve güvenirliğe etkisinde müşteri entegrasyonun aracılık rolünü test etmek amacıyla Hayes (2018) tarafından geliştirilen bootstrapa dayalı Process Macro yöntemi kullanılmıştır.

Tablo 8. Aracılık Testine İlişkin Regresyon Analizi Sonuçları

Sonuç Değişkenleri						
		M (Müşteri Entegrasyonu)			Y (Lojistik HvG)	
Tahmin Değişkenleri		b	S.H.		b	S.H.
X (İç Entegrasyon)	a	.5341***	.0772	c’	.2053***	.0808
M (Müşteri Entegrasyonu)	-	-	-	b	.1602***	.0728
Sabit	İM	1.5750***	0.3272	İY	2.7564***	0.3213
		R^2=.2312			R^2=.1208	
		F(1;159)=47,8163; P<.001			F(2;158)=10,8519; P<.001	

*** p<.001

Analiz sonucu iç entegrasyonun müşteri entegrasyonu pozitif yönde anlamlı olarak etkilediğini göstermiştir (B:.5341, %95 CI [.3813, .6866], t: 6,9149, p<.001). Anlamlılık düzeyinin .001’den küçük olmasından ve güven aralığına ait değerlerin sıfır değerini kapsamamasından etkinin anlamlı olduğu görülmektedir. İç entegrasyon müşteri entegrasyonun %23,12’ünü (R2=.2312) açıklamaktadır. Böylelikle H2 hipotesi bir kez daha kabul edilmiştir.

Müşteri entegrasyonun lojistik hız ve güvenirliği positif yönde anlamlı olarak etkilediği bulgulanmıştır (B:.1602, %95 CI [.0165, .3039], t: 2,2025, p<.001). İç entegrasyon da lojistik hız ve güvenirliği anlamlı olarak etkilemiştir (B:.2053, %95 CI [.0457, .3649], t: 2,5404, p<.001). Anlamlılık düzeyinin .001’den küçük olmasından ve güven aralığına ait değerlerin sıfır değerini kapsamamasından etkinin anlamlı olduğu görülmektedir. Müşteri entegrasyonun ve iç entegrasyonun lojistik hız ve güvenirlik üzerindeki değişimin %12,08’ünü (R2=.1208) açıklamaktadır. Böylelikle yapısal model ile doğrulanamayan H1 hipotezi process macro analiz sonuçları neticesinde kabul edilmiştir.

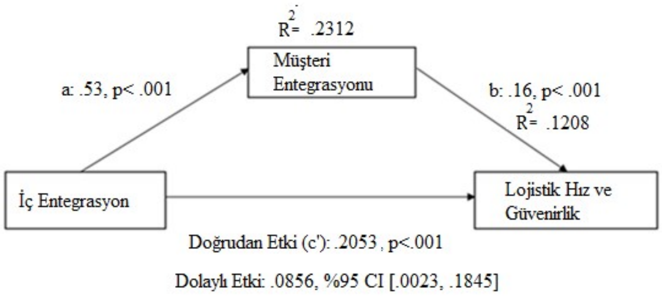
İç entegrasyonun lojistik hız ve güvenirlik üzerinde dolaylı etkisinin anlamını olduğu dolayısıyla da müşteri entegrasyonun iç entegrasyon ile lojistik hız ve güvenirlik arasındaki ilişkiye aracılık ettiği bulgusuna ulaşılmıştır (B: .0856, %95 CI [.0023, .1845, p<.001). Tam standardize etki büyüklüğünün (K^2) 0.09 olması etkinin orta düzeyde olduğunu göstermektedir (Gürbüz, 2019:64). Böylelikle H4 kabul edilmiştir.

Aracılık etkisi analizinin sonuçları ayrıca Şekil 3’de gösterilmiştir.

4. Sonuç Ve Öneriler

Tüketimin hızlandığı ve talebin arttığı günümüzde imalatçıların lojistik hizmetlerinde hızlı ve güvenilir olması beklenmektedir. Teslimatların ihtiyaç duyulan yerde ve doğru zamanda yapılması firmaların ayırt edici bir özelliği olmuştur. Bu çalışmanın amacı ise, üreticilerin lojistik hız ve güvenirliklerinin ne kadarının iç entegrasyon ve müşteri entegrasyonu tarafından açıklandığını ve müşteri entegrasyonunun iç entegrasyon ve lojistik hız ve güvenirlik arasındaki ilişkiyi aracılık edip etmediğini araştırmaktır.

Çalışmada kavramsal çerçeve ve literatür taraması sonrasın araştırma modeli analiz edilmiştir. Araştırmaya katılan firmaların 67’si tekstil, 36’sı gıda, 13’ü ambalaj, 11’i plastik, 4’ü sağlık ürünleri, 3’ü otomotiv, 3’ü kimya, 3’ü mobilya, 2’si çimento, 2’si kağıt ve 1’i enerji alanında üretim yapmaktadır. 16 firma diğer seçeneğini işaretleyerek sektör belirtmemiştir. Araştırmaya katılan firmalardan 1 ile 5 yıl arasında faaliyet gösterenlerin sayısı 19, 6 ile 11 yıl arasında faaliyet gösterenlerin sayısı 20, 11-20 yıl arasında faaliyet gösterenlerin sayısı 57 ve 21 yıl ve üzeri faaliyet gösterenlerin sayısının ise 64 olduğu görülmüştür. Çalıştırılan



Şekil 3. Aracılık Analizi Sonuçları

personel sayısına göre dağılıma bakıldığında ise 0-51 arasında personel çalıştıran firmaların sayısının 30, 51-150 arasında personel çalıştıran firmaların sayısının 53, 151-250 arasında personel çalıştıran firmaların sayısının 35, 251-350 arasında personel çalıştıran firmaların sayısının 14, 351-450 arasında personel çalıştıran firmaların sayısının 5 ve 451 üzerinde personel çalıştıran firmaların sayısının ise 22 olduğu anlaşılmıştır.

Ölçeklerin uyarlanmış olmasından dolayı KFA, DFA ve güvenirlik analizi uygulanmıştır. Böylelikle ölçeklerin yapı geçerliliği ve güvenirliği sağlanmıştır. Yapısal eşirlik modeli kurularak araştırmanın hipotestleri test edilmiştir. Analiz sonuçları iç entegrasyonun lojistik hız ve güvenirliğe etki etmediği ancak müşteri entegrasyonuna etki ettiğini göstermiştir. Ayrıca müşteri entegrasyonu lojistik hız ve güvenirliğe de etki etmiştir. Aracılık testi için ön şart olan her iki bağımsız değikenin bağımlı değişkeni etkilme şartı process macro ile tekrar analiz edildiğinde iç entegrasyonun lojistik hız ve güvenirlik etkilediği görülmüştür. Böylelikle çalışmanın birinci hipotezi (H1) yapısal eşit modeli sonuçlarına göre reddedilirken process macro analizi sonucu kabul edilmiştir. Analiz sonuçları arasında farklılık olmasının sebebinin veri sayısının azlığından kaynaklandığı tahmin edilmektedir. Process macro yöntemi ile yapılan analizlerin yapısal eşitlik modeline göre daha hassas olduğu ve analiz yapılan 161 veriyle daha doğru sonuç verdiği anlaşılmıştır. Böylelikle çalışmanın birinci hipotezi (H1) kabul edilmiştir. Bu bulgu daha önce yapılmış çalışmaların sonuçlarıyla uyumludur (Daugherty vd., 2009; Gimenez ve Ventura, 2005). Buradan frmaların birimler arası iş birliğini ve entegrasyonunu arttırdığında lojistik faaliyetlerinde daha hızlı ve güvenilir olacağı sonucu çıkmaktadır.

Çalışmanın ikinci hipotezi olan iç entegrasyonun müşetri entegrasyonu üzerindeki etkisi (H2) hem yapısal eşitlik modeli hemde proess macro yöntemi ile doğrulanmıştır. Böylelikle H2 kabul edilmiştir. Yani departmanlar arası kurulan iyi iletişim müşterilerle iletişimi arttırmakta, bu yüzden iç entegrasyon müşteri enetegrasyonu etkilemektedir. Bu bulgu önceki çalışmaların sonuçlarıyla uyumludur (Koufteros vd., 2005:114; Zhao vd., 2011). Çalışmanın üçüncü hipotezi olan müşteri entegrasyonun lojistik hız ve güvenirlik üzerinde ki etkisi (H3) kullanıln her iki yöntemle doğrulanmış, böylelikle H3 kabul edilmiştir. Bu buldu, müşterileriyle entegre olan firmaların talep planlamasını daha kolay yapabileceğinden dolayı daha yüksek lojistik hız ve güvenirlik gösterecekleri şeklinde yorumlanabilmektedir (Chavez vd., 2015; Salvador vd., 2001, Johnson ve Filippini, 2009:16).

Çalışmanın son hipotezi olan iç entegrasyonun lojistik hız ve güvenirlik üzerindeki etkisinde müşteri entegrasyonun aracı rolü (H4) process macro yöntemi ile analiz edilmiş ve doğrulanmıştır. H4 kabul edilmiştir. Böylelikle iç entegrasyonun lojistik hız ve güvenirlik üzerindeki etkiye müşteri entegrasyonun orta düzeyde aracılık ettiği ıspatlanmıştır (Jajja vd., 2018; Feng vd., 2017).

İç entegrasyon ve lojistik hız ve güvenirlik gibi lojistik performans literatürüne ait iki önemli değişkenin birlikte incelenerek aralarındaki ilişkinin ve bu ilişkide müşteri entegrasyonunun aracılık rolünün araştırılması, literatüre önemli katkıda bulunacaktır. Gelecek çalışmalarda diğer entegrasyon türlerinin de aracılık etkilerinin araştırılması konunun daha ileriye taşınmasına yardımcı olacaktır. Araştırmanın Gaziantep şehrindeki üretici firmalar üzerinde uygulanmış olması, bölgenin stratejik önemi nedeniyle birçok firmaya yol gösterecektir. Lojistik faaliyetlerini hızlandırmanın yolunun iç entegrasyon ve müşteri entegrasyonu olduğu bilgisi üretici firmalara tavsiye olarak sunulmaktadır.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Akıllı Şehir Lojistiği Kapsamında Akıllı Ulaşım Sistemleri (AUS) için Sistem Analizi *

System Analysis for Intelligent Transportation Systems (ITS) in the Scope of Smart City Logistics

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ÖZ

Şehirlerde trafik/yol, kargo/araç yoğunluğu karmaşık bir sorun alanı oluşturmaktadır. Gezi bilgisayarları, araç ve seyahat hakkında oldukça genel bir bilgi verdiği için, bu bilgilerin trafik/yol, kargo/araç konum verileri ile etkileşime girilebildiği ölçüde, anlık bir seyahat akış planı yapmak ve durum güncellemek anlık bir şekilde mümkün olacaktır. Ancak, etkileşim hızı ve veri derinliği günümüzde bile hala oldukça belirsizdir ve genellikle tek yönlü ve sınırlı bir bilgi akışı sağlanmaktadır. Bu etkileşim ise daha çok sınırlı bir bilgi edinmeye ve (kesintili) ayrık zamanlı değerlendirmeye odaklıdır. Araçların gelecekte ise artık kendi kendine yönlendirilmeye (otonom) başlayacağı bilinmektedir, örneğin insansız hava araçları (İHA). Bu beklentilerin trafik/yol, kargo/araç durumu etkileşimi ve yönetim altyapılarını izleme ve planlama eylemleri yoluyla daha etkin bir şekilde iyileştireceği görülmektedir. Çalışma, akıllı şehirlerin lojistiği kapsamında trafik/yol, kargo/araç durumunu (veya kısaca AUS etkileşimini) ön planda tutan teknolojileri araştırıyor. Ayrıca trafik/yol, kargo/araç, izleme/planlama ile ilgili diğer akıllı çözümlerdeki gelişmeleri ilişkisel ve bütünsel bir bakış açısıyla değerlendiriyor. Özellikle afet ve insani yardım lojistiğinin zorlukları ise ancak zamanla belki mikro düzeyde de olsa aşılabilir. Bu çalışmada önerilen AUS çerçevesi, tüm bu izleme ve planlama sistemlerini desteklemektedir. Ağ gecikmesi sorunu da Endüstri 5.0 ile ihmal edilebilecek şekilde artık bir sorun olmaktan çıkacaktır.

ABSTRACT

A complex problem in cities is traffic/road and cargo/vehicle density. Since trip computers provide very general information about the vehicle and the journey, it will be possible to make an instant travel flow plan and update the situation in an instant if this information can interact with the traffic/road, cargo/vehicle location data. However, the rate of interaction and depth of data between transportation systems is still unclear and consists of a limited one-way flow of information. This interaction is more focused on obtaining information and (discontinuous) discrete time evaluating it with the human factor. But it is known that vehicles will start to be self-directed (autonomous) in the future, for example unmanned aerial vehicles (UAV). Through monitoring and planning, it is evident that these expectations will improve traffic/road, cargo/vehicle situation interaction, and management infrastructures more effectively. Within the context of smart city logistics, the technologies that prioritize situations of traffic/road, cargo/vehicle—or ITS interaction for short—are the subject of the study. From a relational and comprehensive perspective, it also assesses advancements in other smart solutions about traffic/road, cargo/vehicle, tracking, and/or planning. All these tracking and planning systems are supported by the ITS framework suggested in this study. The network latency issue will no longer exist because Industry 5.0 enables it to be disregarded.

Anahtar Kelimeler: Akıllı Lojistik, Akıllı Ulaşım, Yollar ve Otoyollar, Akıllı Şehirler, Şehircilik

Keywords: Smart Logistics, Intelligent Transportation Systems, Roads and Highways, Smart Cities, Urbanism.

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EXTENDED ABSTRACT

It is known that hardware and software technologies are developing very rapidly, and artificial intelligence systems are also

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increasing rapidly in the transportation sector with telecommunications. In the new era of Industry 4.0, network technologies are also developing rapidly, creating a new network society. All these developments are also affecting tracking and planning systems. Recent developments in urban informatics, from e-government to m-government applications, show an increase in the effects of public participation on governance topics. The mobilizing strategy has been improved over the past ten years to accommodate new kinds of intelligent strategies in smart societies. In the last decade, examining problematic systems in the urban space has been a main point. In particular, the transportation sector was chosen as the focus of a lot of studies. Future applications that are structured and long-lasting are encouraged by the suggested methods. Therefore, smart city approaches should always consider interdisciplinary qualities. Traffic and road monitoring and planning, as well as cargo and vehicle density in urban areas, create a complicated road transportation issue. Trip computers provide information about vehicles and travel. It is easier to make an instant travel flow plan and update the situation, as this information can interact with other systematic information such as traffic/road conditions. However, the depth of interaction between transportation systems is still unclear and generally consists of a one-directional, limited flow of information. Information gathering and human factor evaluation are the main goals of this encounter. However, there is still uncertainty regarding the rate of interaction and depth of data sharing amongst transportation systems, and there is only a small amount of one-way information flow. This interaction is more focused on obtaining information and (discontinuous) discrete time evaluating it with the human factor. But it is known that vehicles will start to be self-directed (autonomous) in the future, for example unmanned aerial vehicles (UAV).

The technologies that prioritize traffic/road, cargo/vehicle, or ITS interaction, are the focus of the study in the context of smart city logistics. From a relational and all-encompassing perspective, it also evaluates developments in other smart solutions for traffic/road, cargo/vehicle, tracking and/or planning. The independent steps of related information systems can be covered by their structure in terms of complexity and differentiation. The road, cargo, vehicle, and traffic tracking/planning systems, as well as a futuristic advanced theoretical ITS model that has been proposed, need to be more integrated into society. Because the number of vehicles and people on the road is growing.

Human-machine interaction and decision iterations are thought to play a complementary role in inter-system relations. However, in increasingly complex processes, there will also be processes that are left entirely to robot flows. Planning and tracking are becoming increasingly more complex processes. Therefore, it is also necessary to minimize and integrate new concepts into the entire system (ITS) (for example, new protocols in telecommunication). This study also throws light on crucial issues that demand system fusions and advancements with new trends. From Industry 4.0 through 5.0, IoT (Internet of Items) will also support several things in this way. These new technologies are coming in a near future. 5.0 industry can be solved for all these issues, but it will require an increase in new technology’s capacity. The objective of this study is to help a reader to make the distinction and concepts clear.

Especially disaster and humanitarian aid logistics may have difficulties, but these problems can be overcome over time, thanks to the application of early warning systems technologies and advanced problem solutions by relevant technologies and institutions at the micro level. The ITS framework proposed in this study supports all these new generation tracking and planning systems. With Industry 5.0, network latency will also be resolved thanks to the new technologies.

The internet of things that came with the industry 4.0 revolution brings important innovations in Intelligent Transportation Systems (ITS). However, Industry 5.0 will add flexibility and functionality to communication beyond Industry 4.0. Faster communication and system integrations using standard protocols will be provided by Industry 5.0. These advancements are pushing smart systems closer to the forefront by integrating them with humans. These innovations and rapid developments in the field of transportation (wireless communication, satellite communication, sensors, and software) are referred to as Intelligent Transportation. Developments will enable logistics and transportation services to be provided more efficiently and reliably. Since the internet of things architecture allows all physical objects in our lives to stay in communication via the internet, new studies have started to emerge in the field of ITS.

This study will first reveal the basics of Internet of Things architecture. Studies on the general ITS approaches will be reviewed. By explaining the development of the topic and its significance, this article evaluates the fundamental truths about the ITS and produces recommendations. Turkey determined its national strategy for smart transportation systems (STS) (or IUS in Turkish) in 2014. The document, it is aimed to achieve the vision of "a Turkey integrated within itself and with the world, where all transportation services are managed and directed with information and communication technologies". In order to realize the vision, five strategic goals have been set for the period up until 2023, and 22 targets have been established to achieve these goals (Ulaştırma, Denizcilik ve Haberleşme Bakanlığı, Ulusal Akıllı Ulaşım Sistemleri Strateji Belgesi, 2014-2023 ve Eki Eylem Planı, 2014-2016). It covers many details about the paths to be followed with the proposed ITS framework approach in this study. The system densities and complexity levels, as well as all of the components that are connected to it, will increase excessively as the amount of data processed per unit of time increases. In today’s times of crisis, we are witnessing the breaking of supply chains. Therefore, individual logistics operations are replaced by intelligent logistics approaches, which are rapidly made safer. Advanced artificial intelligence is making itself felt more and more in all areas. Railway and maritime transport, low-emission vehicles, and alternative green fuels stand out. It is clearly understood that similar approaches should gain importance in the highways and urban logistics area as well. Everything is once again impacted by this transformation, particularly the logistics industry. I'm hoping that the issue will be under control and that any potential harm will be avoided.

Giriş

Telekomünikasyon ile ulaşım sektörlerinde donanım ve yazılım teknolojilerinin çok hızla geliştiği ve bunların içinde kullanılan yapay zekâ sistemlerinin de yine yayılarak hızlı bir şekilde arttığı bilinmektedir. Endüstri 4.0 sonrası yeni çağda ağ teknolojileri de yine benzer bir gelişim yaşıyor ve bu durum da yeni bir ağ toplumu yaratıyor. Tüm bu gelişmeler takip, izleme ve planlama sistemlerini de oldukça fazla bir şekilde etkiliyor.

E-devletten m-devlet uygulamalarına kadar kentsel bilişimde yaşanan bu son gelişmeler, kamu katılımının yönetişim konuları üzerindeki etkilerinde de artış olduğunu göstermektedir. Son on yılda, mobilize edici yaklaşımlar, akıllı toplumlarda yeni tür akıllı yaklaşımları da giderek optimize etmektedir.

Kentsel mekandaki sorunlu sistemlerin incelenmesi de güncel çalışmalarda odak noktası olmuş bir konudur. Özellikle ulaşım ve lojistik sektörleri birçok çalışmada öne çıkacak şekilde seçilmiştir. Bu çalışmalarda önerilen yöntemler ise geleceğin sistematik ve sürdürülebilir uygulamalarını desteklemektedir. Bu nedenle akıllı şehirler, her zaman disiplinler arası nitelikleri dikkate alan çağdaş yaklaşımları yansıtmak zorunda olacaktır.

Şehirlerde trafik/yol, kargo/araç yoğunluğu, takip/planlama özellikle karayolu taşımacılığında karmaşık bir sorun alanı oluşturmaktadır. Gezi bilgisayarları, araç ve seyahat hakkında bilgi verir. Bu bilgiler trafik/yol durumu ile etkileşime girebildiği ölçüde, anlık bir seyahat akışı planı yapmak ve durumu güncellemek çok daha kolay olacaktır. Ancak, etkileşim derinliği günümüzde bile hala oldukça belirsizdir. Genel olarak, tek yönlü ve sınırlı bir bilgi akışı vardır ve bu etkileşimde eşzamanlı olarak bilgi edinmeye ve sistem içinde hızlıca değerlendirmelere odaklanılmıştır.

Diğer yandan Türkiye'de kargo sektörüne bakıldığında da 35-40 yıllık genç bir sektör olmasına rağmen 25 bin araç ve 10 bin sabit merkez ve günde yedi milyon sevkiyat ile ciddi bir talebe cevap veriyor durumdadır. Aynı zamanda yaklaşık 80-90 bin kişilik bir istihdama sahip olan bu sektör, milli ekonomiye de önemli bir katma değer sağlamaktadır (Topal, & Şahin, 2019). Türkiye'de kargo sektörü özellikle pandemi döneminde büyük bir önem kazanmış ve hızla büyümüştür. Türkiye'de Taşıma Modları ile Taşınan Yük ve Yolcu Oranları (%) (2016) aşağıda sunulmuştur (Şekil 1).

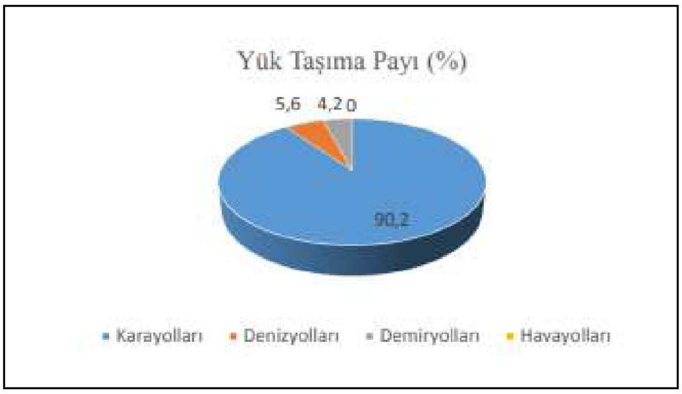

Figure 1.Türkiye'de Taşıma Modları ile Taşınan Yük ve Yolcu Oranları (%) (2016) (Taç, (2018).

Karayolu taşımacılığı şekilden de görüldüğü gibi diğerlerinden çok daha büyük bir yere sahiptir. Diğer yandan tren kontrol ve nakliye, müşteri hizmeti, acil durum kurtarma ve yönetimi üzerine uygulamalar altyapı ve üstyapının güvenli, verimli ve etkin çalışmasını sağlamaktadır (Sarıkavak, 2018). İlgili çalışmada, faaliyette ve geliştirilmekte olan akıllı sistemlerin başlıca uygulamaları araştırılmış ve ülkedeki kullanımları değerlendirilmiştir.

Karmaşık hale gelen tüm süreçlerde karar verme aşaması da önemli insan becerilerinden biri halindedir. Karar verme süreçlerinin kesin hale getirilmesinde kullanılabilecek yollardan biri de çok kriterli karar verme yöntemleridir (MCDM) (Aydın & Atak, 2020). Yapay zekâ çözümleri daha farklı yöntemleri de giderek hızlı bir şekilde gündeme getirmektedir. Karmaşık veri toplama ve analiz talepleri hızla yerine getirilme yolundadır. Nihai rapor ise istenilen veri türünde (yazı, ses, resim, video) hatta karma veriler halinde sunum formatında da kullanıcıya sunulabilmektedir.

ITS uygulamalarının ülkemizde yaygınlaşması için yapılması gereken stratejiler ve eylem planları Türkiye için önerilmiş (Tektaş, & Tektaş, 2019) tartışılmaya başlanmış ve mevzuatta da artık yerini almıştır.

Birçok karmaşık yapı içeren bu sistemlerin, insan faktörünü dışlayan yapay zekâ teknikleri ile oluşturulan uzman sistemler kullanılarak kontrolü her geçen gün giderek yaygınlaşmaktadır (Erdal, 2018). Söz konusu çalışmada yapay zekâ akıllı ulaşım sistemlerinin kontrolünde kullanılmaktadır.

Türkiye'de bir çalışmada, 30'u büyükşehir olmak üzere toplam 81 belediye trafik yönetimi, yolcu bilgilendirme, erişilebilirlik ve mobil uygulamalar konusunda değerlendirilmiş, bazı ana başlıklar altında hangi hizmetleri sunduğu incelenmiştir. Sonuçlar, belediyelerin büyük çoğunluğunun yolcu bilgilendirme ve elektronik ödeme sistemleri noktasında ciddi altyapı sahibi olduğunu ve hizmet sağladığını göstermektedir. Özellikle, erişilebilirlik ve mobil uygulamalar konularında bazı belediyelerin etkin uygulamaları olmakla beraber, genel itibari ile gelişmeye açık olduğu bulunmuştur (Özden, Akalın, Kara, 2020). Hizmet kalitesini arttırma ve oy potansiyelini yükseltmek artık belediyeler için vazgeçilemez bir hedeftir.

Firmaların Endüstri 4.0'a hazırlık ve olgunluk düzeylerinin daha iyi anlaşılıp ölçülebilmesi için, dijital tedarik zincirlerinin akıllı ve sürdürülebilir boyutta olgunluk düzeylerinin eş zamanlı ölçülebilmesine olanak sağlayan bir model önerisinde, modelin uygulandığı nümerik örnekte, her bir Endüstri 4.0 aracının sürdürülebilirlik boyutlarına ne derece uyum sağladığı belirlenmiştir. Yapay ve dikey sistem entegrasyonu sürdürülebilirliğin ekonomik, çevresel ve sosyal boyutları için yüksek olgunluk seviyesinde iken, yapay zekâ çok düşük olgunluk seviyesinde kalmıştır (Demir, Gündüz, Paksoy, 2022). Yapay zekâ uygulamalarının artış potansiyeli gelecekte her alanda yükselerek artabilir. Bu durum öncelikle tedarik zincirlerini etkileyecektir.

Çalışma, akıllı şehirlerin lojistiği kapsamında trafik/yol, kargo/araç durumunu (veya kısaca AUS etkileşimini) ön planda tutan teknolojileri araştırıyor. Ayrıca trafik/yol, kargo/araç, izleme/planlama ile ilgili diğer akıllı çözümlerdeki gelişmeleri ilişkisel ve bütünsel bir bakış açısıyla değerlendiriyor. Özellikle afet ve insani yardım lojistiğinin zorlukları da afet ülkesi olarak Türkiye'de gündemde tutulmak zorundadır. (Kocalar, 2023) Bu çalışmada önerilen AUS çerçevesi, tüm bu izleme ve planlama sistemlerini desteklemektedir. Ağ gecikmesi sorunu da Endüstri 5.0 ile ihmal edilebilecek şekilde artık bir sorun olmaktan çıkacaktır.

Malzeme ve Yöntem

Bu çalışma da ise akıllı şehirler kapsamında trafik/yol ve kargo/araç takip sistemlerinin etkileşimini önceleyen yaklaşımlar/teknolojiler araştırılmıştır. Trafik/yol ve kargo/araç takibi ile ilgili diğer akıllı çözümlerdeki gelişmeler de analitik açılardan değerlendirilmektedir.

Bu çalışmada önem verilen yaklaşımlar Trafik/Yol, Kargo/Araç, Takip/Planlama (İngilizce karşılıklarının kısaltmalarıyla T/R-V/C-T/P) olarak adlandırılmıştır. ITS ise bu çalışmanın genel çerçevesi için önerilen bir perspektif sunmaktadır. ITS gelecekte birçok alt sistemi de kapsıyor olacağı hipotezi çalışmada test edilmektedir. Bu alt sistemlerden önem verilen bazıları hiyerarşik sıralı bir numara ile aşağıda listelenerek ele alınmıştır. Çünkü burada okuyucunun izleme sistemleri ve planlama yaklaşımları ve/veya teknolojileri hakkında sahip olduğu algı karışıklığının da ileriye doğru olası gelişmeler yorumlanarak giderilmesi amaçlanmıştır.

Özellikle planlama yaklaşımları ilişkili (TTS) Trafik Takip Sistemleri de ileri karmaşık bir düzeye sahiptir. Çünkü TTS'in önce izlenmesi, daha sonra akıllı bir şekilde planlanmasına göre trafik ışıklarının değişimi için karar verir (AI tarafından veya AI olmadan) hale gelmesi söz konusu olmuştur. Bu türden akıllı yaklaşımların yapay zekâ (YZ) ile karar verme hakkında birçok yeni teknik ayrıntıya sahip olduğu görülmektedir. Bu çalışma ise genel hatlarıyla ulaşım ve lojistik sektörü ile ilişkili önem verilen birkaç örnek ayrık taşımacılık sistemini kapsamaktadır. Bu ayrık sistemlerin teknoloji isimleri genel amaçları ve hedefleri dışındaki konular bu çalışmaya dahil edilmemiştir. Örneğin ilişkili algoritmalar gibi teknik sistem analizleri ile daha ileri teknik detaylar içeren konular şimdilik kapsam dışı bırakılmıştır. Algoritmaların sadece işlevselliği bile ileri düzeyde akıllı ulaşım sistemleri ve planlanması açısından yine de ileride oldukça önemli bir hale gelmiş olacaktır.

Sistem isimlerinin kısaltmaları literatürde geçtiği gibi İngilizce karşılıklarının baş harfleri olarak alınıp, sistem bütünü ileride sunulan liste, tablo ve diyagramda basitçe görselleştirilerek anılmıştır.

Araştırma Sorusu veya Motivasyonu: Trafik/Yol, Kargo/Araç, Takip/Planlama (T/R, C/V, T/P) yaklaşımları hızla gelişmektedir, bu ilerlemeyi nasıl değerlendirmeliyiz?

Hipotez : Birbirinden ayrık olan mevcut dağınık yaklaşımlar veya sistemler tek bir çatı altında birer alt sistem olarak dönüştürülecektir (T/R, C/V, T/P) ya da bu alt sistemler eğer eski teknolojilerse, gelecekte zaten başka bir ana sistem yaklaşımı (veya ITS) altına girerek dönüştürülmüş olacaklardır.

Lojistik sektörünün afet yönetimindeki önemi gibi daha uç bir noktadan aşağıda verilmiş olan takip sistemlerine doğru bir giriş yapılarak, ileriye yönelik görülen zorluklar daha da anlaşılır kılınmaya çalışılabilir.

Afet yönetiminde lojistik

Takip sistemleri çoğunlukla yük taşımacılığı üzerinden bağlantılı olarak lojistik alanı ile ilgilidir. Özellikle afet ve insani yardım lojistiğinin zorlukları, ilgili teknoloji ve kurumlar tarafından erken uyarı sistemlerinin geliştirilmesi, ileri sorun ve çözümlerin uygulanması sayesinde mikro seviyelerde de olsa zamanla aşılabilir (Becerikliler, 2017).

Lojistik, afet yönetiminin üç aşamasında çok önemli bir rol oynar. Cozzolino buna "İnsani Lojistik Akımı" diyor. Afet Yönetim Çemberi: Hazırlık, Reaksiyon, Rekonstrüksiyon aşamaları ve aynı zamanda önlemler aşaması ile döngüsünü tamamlar (Cozzolino, 2012, s.8). İşletmelerde lojistikte yer alan bu çok adımlı dairesel anlayış, afet lojistiğinde odak noktası olan miktar, zaman ve yer olmak üzere 3 ana unsura karşı düşmektedir. Görüldüğü gibi afet yönetiminde yer alan en kritik zamanları düşünmemiz gerekmektedir.

En kritik zamanlara afet öncesinde hazır olmak için planlama ve yönetim önem kazanmaktadır. Onlar olmadan yollardaki kaosun önüne geçmekte öyle kolaylıkla mümkün olmayacaktır. Ayrıca bu sorunları çözmek konusunda da halen yeterince hazır olamadığımız bu çalışmada sunulan bulgularda da açıkça görülecektir. Bu anlamda bir afet ülkesi olan Türkiye'de kriz yönetimi kadar risk yönetimi de önemsenerek disiplinler arası boyutlarıyla güncel sorun alanları üzerinden yeni ve teknolojik çözümler sürekli geliştirilerek ayrıntılarıyla çalışılmalıdır. (Kocalar, 2023)

Bulgular

Son yıllarda AUS/ITS-Akıllı Ulaşım Sistemlerinde alttaki bulgularda da sunulduğu gibi pek çok faklı yaklaşımdan hareketle artık entegrasyon sağlanacak çatı bir oluşum aranmaktadır.

AUS/ITS-Akıllı Ulaşım Sistemleri: Trafik/Karayolu, Kargo/Araç, Takip/Planlama (T/R, C/V, T/P)

Aşağıda Trafik/Yol, Kargo/Araç, Takip/Planlama (T/R, C/V, T/P) kavramlarına yönelik yaklaşımlarda farklı sistemlere rastlanılmaktadır. Sonuç kısmında ise tüm bu sistemlerin entegre olacağı bir model olarak Akıllı Ulaşım Sistemleri (AUS/ITS) öneri bütünleşik bir yaklaşım olarak gündeme getirilmekte ve sektörel bağları üzerinden tekrar yorumlanmaktadır.

Takip sistemleri ile ilgili teknolojik gelişmeleri mevcutta görülen ayrık sistem yaklaşımları ile kısaca inceleyip tanıtarak anlayıp kavrayabiliriz. Öncelikle bu mevcut durum önemsenmek zorundadır. O yüzden bu çalışmada örnek olarak alınan bu mevcut önemli yaklaşımlar veya sistemler hiyerarşik bir şekilde numaralı olarak listelenerek kısaca amaç ve yöntemleri ile analiz edilmişlerdir. Çünkü bu noktada okuyucunun zihninde bu takip-izleme sistemleri ile bunların yanısıra planlama yaklaşımları hakkında yaygın bir yanlış anlama veya karıştırma eğilimi bulunmaktadır. Planlama yaklaşımları tüm bu sistemler için çok daha ileri düzeye sahip bir konudur ve karar verme hakkında teknik pek çok ayrıntıyı da kapsamaktadır.

Bu yazının amacı yaklaşımlar arasındaki önemli bazı ayrımları daha net bir hale getirerek okuyucuya yardımcı olmak ve olası gelişmelerle birlikte teknolojik trendi daha anlaşılır kılmaktır.

Öncelikle takip sistemi teknolojisi üç yeni teknolojinin (GPS, CBS, GPRS) entegrasyonu ile mümkün olmuştur:

1. Navigasyon teknolojileri içeren Küresel Konumlandırma Sistemi (GPS) gibi.
2. Veritabanı teknolojileri içeren Coğrafi Bilgi Sistemi (CBS) gibi. Günümüzde CBS çözümleri ile desteklenen yenilikçi akıllı şehir uygulamalarının arka planında yaşam döngüsü veri analizlerine dayalı çalışmalar da artmaktadır (Kocalar, 2018).
3. Haberleşme teknolojisi içeren Genel Paket Radyo Hizmeti (GPRS) gibi.

Ancak bu çalışmada, yukarıdaki teknolojiler de teknik ayrıntılarıyla ele alınmamaktadır, sadece adlarının anlaşılması ve sadece ana trend altında birbirileriyle ilişkili gelişmelerin takip edilmesi önemsenmiştir. Bu amaçla sayıları 10 kadar olan farklı isim veya yaklaşım aşağıda tek tek verilmektedir.

Birçok ulaşım sorununun (trafik kazaları, sıkışıklık, ulaşım süresindeki artış, yakıt ve enerji tüketimi, ulaşım yolları vb.) çözümü için akıllı ulaşım sistemlerine (AUS/ITS) ihtiyaç olmuştur (Meriç, 2018). Bu ihtiyaç altta biraz daha anlaşılır kılınmaya çalışılmış ve gelişmeler ile sektörel trendler ilişkisel yanlarıyla birlikte bir sistem analizi yaklaşımıyla çözülmeye çalışılmıştır.

Aşağıda öncelik verilen yaklaşımlar hiyerarşik bir sistematik içinde hem İngilizce kısaltmalarıyla hem de açık Türkçe isimleriyle birlikte tekrar listelenmiştir:

1. Yol Hasar Takip Sistemleri (RDDTS- Road Damage Detection Tracking Systems)

Sensörlerle yol hasarı anlık olarak takip edilmektedir. RDDTS ise henüz herhangi bir alt sisteme sahip değildir ya da yan sistemlerle ilişkilendirilmemektedir. Yani, daha fazla gelişmediği halde gelecekte bu yaklaşımda da gelişme sağlanması kaçınılmaz olacaktır.

2. Kargo Takip Sistemleri (CTS-Cargo Tracking Systems)

Kargo taşımacılığı için de artık çok daha yenilikçi hızlı teslimatlar gerçekleştirebilecek sistemler gelmektedir. Örneğin, henüz prototip denemeleri gerçekleştirilen İnsansız hava araçlarının (İHA) yakın gelecekte yük taşımaları kolaylaşacaktır. Böylece taşıma kapasiteleri ve programları ile gelecekte oldukça değişerek yayılacakları anlaşılmıştır.

3. Araç Takip Sistemleri (VTS-Vehicle Tracking Systems)

Araçlar farklı türdeki lojistik işlemler (taşımacılık ve teslim eylemleri) için merkezi bir sistemle takip edilir.

3.1. Sürdürülebilir Elektrikli Araçlar (SEV-Sustainable Electric Vehicles)

Günümüzde Sürdürülebilir Elektrikli Araç (SEV) teknolojileri ulaşım tercihlerini de değiştiriyor. Elektrikli araçlar sayesinde AB, 2020 yılına kadar "Sera Gazı Yoğunluğu"nun yüzde 10'a düşürülmesini hedefliyor. İyi bir akıllı sistem adaptasyonu için bu teknolojileri tercih etmek gelecekte giderek daha önemli bir hale gelmiştir.

3.2. Otonom Araçlar (AV-Autonomous Vehicles)

Araçların da gelecekte kendi kendine yönlendirilmeye (otonom) başladığı biliniyor. Bu beklentilerin araç-trafik-yol durum etkileşimini ve yönetim altyapılarını takip yoluyla gelişmeye zorladığı da görülmektedir. Bununla birlikte, otonom araçların teknoloji süreci ve "sürüş faaliyetlerini nasıl etkileyeceği, optimum yol mesafesi, otopark ve toplu taşıma tedariki gibi planlama kararları üzerindeki etkileri" hala tartışılıyor.

Birçok taşıyıcı ve şehir plancısı, araştırmacı ve politikacı, araç otomasyonunun teknik doğasına ve faydasına daha aşina hale gelmiştir. Ancak yine de ortaya çıkan etki veya sorumluların eylemleri konusunda henüz bir fikir birliği sağlanamadığı görülüyor (Taştan, & Kaymaz, 2021). Öte yandan, bazı sistemler de halen oldukça bağımsız işlemektedir.

İnsansız hava araçları da özellikle kargo taşımacılığında oldukça yenilikçi sistemler olarak ayrıca göze çarpmakta ve hızlı bir gelişme göstermektedir.

3.3. Şerit Takip Sistemleri (LTS-Line Tracking Systems)

Şerit takip sistemleri ise kaza önleyici bir yaklaşımdır. Şerit yardımı ayrık sistemlere genellikle güvenlik paketinin bir parçası olarak dahil edilir. Benzer çözümler diğer ek seçeneklerle birlikte yine paketlenerek ayrık sistemler gibi araçlarla birlikte ve satış fiyatları yükseltilerek pazara sunulmaktadır.

3.4. Otomatik Araç Konum Takip Sistemleri (AVLTS- Automatic Vehicle Location Tracking Systems)

AVLTS ise farklı izleme amaçları için kullanılmaktadır. AVLTS uygun fiyatlarla popüler bir hale getirilmiştir. Önerilen yazılım tasarımı 'takip sistemi', belirli bir aracın konumunu, zemin hızını ve yakıt seviyesini belirlemek için kullanılır (Aloquili, Elbanna, Al-Azizi, 2008). Bu tür sistemlerle bir araç veya araç filosunu rahatlıkla takip edebilirsiniz. Akıllı otomasyon çözümleri de gündeme gelerek sistemlere yine entegre edilmektedir.

3.5. Araç Yakıt-Yol Takip Sistemleri (VFRTS-Vehicle Fuel-Road Tracking Systems)

Filo sahiplerinde ise GPS izleme ve yakıt durumunu görüntüleme konuları arasında yanlış anlama hakimdir. Bu sistemler de yukarıdaki gibi birbirlerini entegre edilmiş olabilmektedirler. Kısacası isimleri ve farklı teknolojileri olan ayrık sistemler dahi artık birlikte çalışabilir bir donanım ve yazılıma (üst sisteme) bağlanarak aslında tek bir sistem altına alınmış olsalar dahi son kullanıcıya ayrı pazarlanır bir modül halinde sunulmaktadırlar.

4. Trafik Takip Sistemleri (TTS-Traffic Tracking Systems)

Araçlar akıştaki trafik darboğazına kadar kontrol amaçlı izlenmektedir. Araçlar ayrıca gecikme süresi (Decision Delay Time-DDT) ile karar verir ve akıştaki trafik darboğazlarına göre bekleme kuyruğuna katılırlar. Trafik darboğaz görüntüsü gerçek zamanlı değildir. Belirgin bir gecikme süresi de bulunmaktadır. Böylece, belirli dairesel kapsama alanlarında bu karar gecikme süresini (DDT) azaltmak için TTS'in güncellenmiş araç çağrılarıyla entegrasyon içinde olması gerekir. Bu nedenle de TTS'in gelecekte daha fazla geliştirilmesi söz konusudur.

Araçların trafik darboğazına göre akışa yerleştirilmesi (konumlandırma-bekleme kuyruğu), sorunun bir sistem kapsamında nasıl ele alındığına bağlı olarak aşağıdaki gibi basit bir şekilde modellenebilir (Şekil 2).

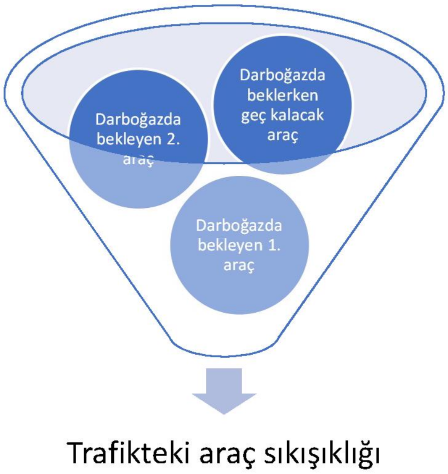

Figure 2.Trafik darboğazlarına göre araçların akıştaki yeri.

Soruna yapay zekâ bir çözüm sunabilmiştir. Bu tür yeni bir akıllı sistem (IS-AI TTS) (hiyerarşik numaralı) olarak aşağıda ayrıca listelenmiştir. Bu akıllı sistem (IS-AI TTS) (EDS) yaklaşımı da halen birçok merkezi sistem (TTS) ile paralel bütünleşik bir şekilde çalışır durumdadır.

4.1. Akıllı Sinyalizasyon - Yapay zekâ trafik takip sistemleri (IS-AI TTS-Intelligent Signaling - Artificial Intelligence Traffic Tracking Systems) (EDS)

EDS, akıştaki trafik darboğazlarına göre akıllı sinyal vermeye karar verebilmektedir.

Saha Sonuçları

Türkiye'de ulusal bir politika olarak, 2000'li yıllara kadar hızlı bir gelişme gösterilen AUS/ITS - Ulusal Akıllı Ulaşım Sistemlerinin Strateji Belgesi de 2014 yılında hazırlanmıştır. Kalkınma Bakanlığı, AUS/ITS gibi ulusal kalkınmaya katkıda bulunabilecek birçok kritik konuyu resmi olarak belirlemiştir (Ulaştırma ve Denizcilik Bakanlığı, 2014). Ancak çalışma da görüldüğü gibi özellikle afet yönetiminde kritik zamanları düşünmemiz gerektiği için, yeterli akıllı planlama ve yönetim olmadan da yollarda oluşan kaosun önüne geçmek için halen hazır olamadığımız açıktır.

Aşağıdaki tabloda (Tablo 1), Bu önemli takip sistemleri uygun odaklanmış gruplarla sıralı bir şekilde özetlenmiştir. Takip sistemleri araçlar için özellikle sayıca ve nitelikçe artmış gözükmektedir (2.sütun). Diğer sistemler (1, 3, 4) ise göreceli olarak henüz çok daha sınırlı kalmıştır. Ancak özellikle TTS trafiği düzenlemek için önemli bir husustur. RDTS ise sınırlı bölgelerde gelişme göstermektedir (örneğin, Hindistan). Diğer yandan CTS günümüzde pandemi koşullarından bu yana oldukça popüler bir hale gelmiştir. Ancak tüm bu ayrık sistemlerin de artık çok daha fazla bütünleştirici teknolojik yaklaşımlarla entegrasyon altına alınabilmiş olması gerekmektedir.

Table 1. Takip ve İzleme Sistemleri

Genel Sistemler:	**1**	**2**	**3**	**4**
İng. Kısaltılmış adı:	RDDTS	CTS	VTS	TTS
Odaklı:	Yol Hasarı	Ücret	Araç	Yol Trafik
a Alt sistem 1	Yeni alt-sistemler	*İHA*	*AV*	IS-AI TTS
b Alt sistem 2	...	Yeni alt-sistemler	*SEV*	...
c Alt sistem 3	...	...	LTS	...
d Alt sistem 4	...	...	AVLTS	...
e Alt sistem 5	...	...	VFRTS	...

Not: Yeni ve farklı teknolojiler giderek yaygınlaşıyor (AV, SEV, İHA).

Not: Yeni ve farklı teknolojiler giderek yaygınlaşıyor (AV, SEV, İHA).

Diğer kısa isimler ise sadece izleme sistemleridir

Ayrık sistemler halinde olan bu Takip ve İzleme Sistemleri (Tablo 1 ve Şekil 3'te İngilizce kısaltılmış adlarıyla görselleştirilmiş) aşağıda da benzer hiyerarşik sistematik içinde hem İngilizce kısaltmalarıyla hem de açık Türkçe isimleriyle birlikte tekrar listelenmiştir:

1. RDDTS- Yol hasar takip sistemleri
2. CTS- Kargo takip sistemleri
3. VTS- Araç takip sistemleri
   3.1 AV-Otonom Araçlar
   3.2 SEV- Sürdürülebilir Elektrikli Araçlar
   3.3 LTS- Şerit takip sistemleri
   3.4 AVLTS- Otomatik araç konum takip sistemleri
   3.5 VFRTS- Araç yakıt-yol takip sistemleri
4. TTS- Trafik takip sistemleri
   4.1. IS-AI TTS - Akıllı Sinyalizasyon - Yapay zekâ trafik takip sistemleri vb.

Yukarıdaki bu ilgili ayrık sistemleri birbirine entegre edici ana (AUS/ITS) yaklaşım çatısı altında giderek eskiyen dağıtık hiyerarşik yapıyı entegre edici yolları anlamak için aşağıda basitçe önerilen görsel bir model (Şekil 3) bu amaçlarla sunulmuştur.

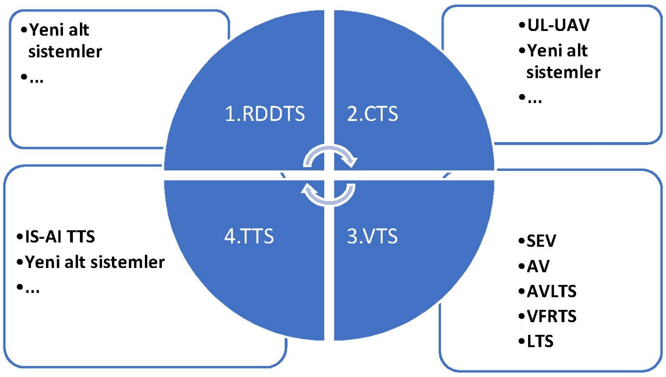

Figure 3. Ayrık Takip Sistemleri* bütünleştiren bir sistem entegrasyonu (ITS) arayışı.

* Sistemler (T/R, C/V, T/P) yukarıda kısa isimler ile ilişkisel bir sistematik yaklaşımla entegre şekilde görselleştirilmiştir.

Sistem entegrasyonu hala bu ayrık sistemler arasında önemli bir sorun alanıdır. Benzer sorunların çözümü için yeni kavram ve yaklaşımlar da önemli bir haldedir. İşte o yüzden Endüstri 5.0 bu tür teknik sorunları biraz daha hızlı bir şekilde çözmek üzere getirilen kapasite arttırıcı bir yaklaşımdır.

Tartışma

Araştırma konusunu doğuran soru ve motivasyon hatırlatılarak önerilen modelin trendle nasıl bağdaştığı ortaya konulmuştur.

Araştırma Sorusu veya Motivasyon: Gelişen Trafik/Yol, Kargo/Araç, Takip/Planlama Sistemleri (T/R, C/V, T/P)S ve akıllı şehirlerin lojistik taşımacılığındaki ilerlemeleri acaba tam olarak nasıl değerlendirebiliriz?

Bu çalışmada izleme sistemlerine yeni bir yaklaşım olarak daha esnek ve işlevsel bir model önerilmektedir: Hiyerarşik-Çevrimsel-İletişimsel/Açık-Uyumlanabilir (Hiyerarchical-Circular- Communicative/Open-Adaptable).

Sonuç

Hipotez: Birbirinden ayrık olan mevcut dağınık yaklaşımlar/teknolojiler/sistemler tek bir çatı altında birer alt sistem olarak dönüşüm geçirmektedir (T/R, C/V, T/P)S, bu alt sistemler eğer eski teknolojiler içeriyor ise, gelecekte zaten başka bir ana sistem (veya AUS/ITS) altına girerek dönüştürülmüş olacaklardır.

Hipotez doğrudur: Birbirinden bağımsız olan sistemler (T/R, C/V, T/P)S, AUS/ITS çatısı altında yani birer alt sistem olarak dönüştürülerek gelecekte entegre bir hale geleceklerdir.

Neden?

İlk olarak, bağımsız ya da ayrık pek çok sistem, önerilen yeni entegre yaklaşımlar (AUS/ITS) sayesinde hiyerarşik bir ana sistem yapısı tarafından kapsanıp, yönlendirilen teknolojik gelişmeler ışığında onun kapsamı altına alınabilir bir görünümdedir.

Toplumda gelişen ihtiyaçlar da zaten gelecek için önerilen (AUS/ITS) yaklaşımı ile ayrık sistemler (trafik /yol, kargo/araç, takip/planlama sistemleri) arasında daha fazla entegrasyona ihtiyaç duyulduğunu göstermektedir. Çünkü araç (ve insan) olarak nüfus ve onun bir sonucu olarak trafikte/yolda sayıca artmakta ve karmaşık bir sorunlar yumağı haline gelmektedir.

Dolayısıyla bu durum izleme/planlama yaklaşımlarında da giderek çok daha fazla karmaşık işlemlere sebep olmaktadır. Bu nedenle, tüm sistemin yeni (AUS/ITS) kavramlarla (telekomünikasyonda yeni protokoller, vs. ile) yeniden en aza indirgenerek yani optimize edilerek çözümlenmesine ve entegrasyonuna ihtiyaç vardır.

Nesnelerin İnterneti (IoT) Endüstri 4.0 ve 5.0 ile bu yeni yaklaşımlar desteklenebilecektir. Endüstri 5.0. ile tüm bu tür sorunlar büyük ölçüde ancak öncelikle teknolojik kapasite arttırımı yoluyla çözülebilir olacaktır. Bu çalışmanın amacı da okuyucuya var olan ayrımları ve farklı kavramları bu şekilde belirgin bir çerçevede daha net anlaşılır bir hale getirmeye yardımcı olmaktır.

Öneri

Kentleşme toplu taşıma ve yaya öncelikli ulaşım sisteminin sağlanması açısından özellikle yaya ve bisiklet güvenliğini ön planda tutmaktadır. Bu anlamda çevre ve insan dostu ulaşım sistemlerinin kullanımı da giderek yaygınlaştırılmakta olduğundan yeni akıllı ulaşım ve şehircilik tasarımlarında dönel kavşaklar daha çok uygulanmak zorundadır.

Çalışma ayrıca aşağıda bazı başka yan hipotezleri de birlikte test etmiştir. Endüstri 4.0 devrimi nesnelerin interneti, Akıllı Ulaşım Sistemlerinde (ITS) önemli yenilikler getiriyordu. Bununla birlikte, Endüstri 5.0, Endüstri 4.0'ın ötesinde iletişime esneklik ve işlevsellik katacaktır.

Bu gelişmelerle birlikte akıllı sistemler giderek insanlarla da bütünleşme içinde çalışarak daha fazla karşımıza çıkar olacaktır. Bu yenilikler ve ulaşım alanındaki hızlı gelişmeler (kablosuz iletişim, uydu iletişimi, sensörler ve yazılım) kısaca Akıllı Ulaşım olarak adlandırılmaktadır.

Söz konusu gelişmeler lojistik ve taşımacılık hizmetlerinin daha verimli ve güvenilir bir şekilde verilmesini de sağlayacaktır. Nesnelerin interneti mimarisi hayatımızdaki tüm fiziksel nesnelerin internet üzerinden iletişimde kalmasını sağladığından, AUS/ITS alanında pek çok farklı yeni çalışmalar da ortaya çıkmaya başlamıştır.

Bu çalışmada, Nesnelerin İnterneti mimarisinin temelleri de vurgulanarak, Akıllı Ulaşım ve Akıllı Lojistik anlamındaki bütünleşik yaklaşım ve sağladığı gelişmeler düşünsel teorik ve kavramsal açıdan ortaya konulmaktadır. Böylece makale, AUS/ITS ile ilgili temel bilgileri sektörel açıdan da yorumlanır kılarak genel anlamda işletme ve yönetim açısından teknik anlamda planlama açısından konunun önemine dikkat çekmektedir. Bunun yanı sıra çalışma teknik gelişmelerin seyrini de ortaya koyan teknik yapının kavranılarak gelişim trendlerine yönelik öneriler de geliştirmiştir. Özellikle ulaşım ve lojistik sektörleri geçmişe nazaran çok daha önemli bir hale gelmiş, bu alanlarda ileri düzeylerde bilişim ve iletişim teknolojileri içeren çok daha akıllı kılınan uygulamalar da giderek ön plana çıkarılmıştır. Gelecekteki bu trendler ile toplumsal bir dönüşüm de belirgin bir şekilde kaçınılmaz kılınmaktadır.

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AMAÇ VE KAPSAM

Ulaştırma ve Lojistik Dergisi (JTL), İstanbul Üniversitesi Ulaştırma ve Lojistik Fakültesi'nin çok disiplinli ve altı aylık resmi bir dergisidir. Derginin amacı, taşımacılık ve lojistik endüstrisinin küresel ekonomi için geri döndürülemez hale gelen sorunları hakkında yeni fikirleri yayınlamaktır. JTL, akademisyenlere ve saha uygulayıcılarına ulaştırma ve lojistik için yeni konuları tartışmak ve analiz etmek için dinamik bir platform sunmaktadır. JTL Dünya çapında iş yöneticileri ve araştırmacılar arasında lojistik ve tedarik zinciri yönetimi ile ilgili bilgi alışverişinin yanı sıra, lojistik ve tedarik zinciri yönetim sorunları veteknikleri hakkında yeni bir düşünce platformunda bağımsız, özgün ve özenli bir analiz olanağı sunar. Dergimize akademisyenler ve saha uygulayıcıları tarafından yapılan ulaştırma, lojistik ve tedarik zinciri yönetimi ve uygulamalarını geliştiren makaleler, araştırma çalışmaları, örnek olay analizleri ve inceleme makaleleri davet edilmektedir. Ulaştırma, lojistik veya tedarik zinciri yönetiminin herhangi bir alanındaki makaleler dergimize kabul edilmektedir. Dergimiz editörleri gelen çalışmalar ile ilgili eserlerin teorik ve yöntemsel süreçlerin uygulamalar ile ne derecede örtüştüğünü test etmektedirler. Yayınlanmak üzere gönderilen makalelerin tedarik zincirinde ulaştırma ve lojistik süreci perspektifinden uygulamalarının yapılması ve yorumlanması kabul için öncelikli tercih nedeni olmaktadır. Bu nedenle, dergimize işletmecilik, girişimcilik, yönetim, muhasebe, kurumsal yönetim müşteri ilişkileri yönetimi (CRM), pazarlama, insan kaynakları yönetimi, ekonomi, finans, işletme, imalat sanayi, lojistik, tedarik zinciri yönetimi, ulaşım endüstrileri, yeşil lojistik, ters lojistik, insani lojistik, sürdürülebilirlik, şehir lojistiği sektörleri ile ilgili çalışmalar kabul edilmektedir. Tüm makaleler, hakemler tarafından yayınlanmak üzere olarak incelenmektedir.

POLİTİKALAR

Yayın Politikası

Dergi yayın etiğinde en yüksek standartlara bağlıdır ve Committee on Publication Ethics (COPE), Directory of Open Access Journals (DOAJ), Open Access Scholarly Publishers Association (OASPA) ve World Association of Medical Editors (WAME) tarafından yayınlanan etik yayıncılık ilkelerini benimser; Principles of Transparency and Best Practice in Scholarly Publishing başlığı altında ifade edilen ilkeler için: https://publicationethics.org/resources/guidelines-new/principles-transparency-and-best-practice-scholarlypublishing

Gönderilen makaleler derginin amaç ve kapsamına uygun olmalıdır. Orijinal, yayınlanmamış ve başka bir dergide değerlendirme sürecinde olmayan, her bir yazar tarafından içeriği ve gönderimi onaylanmış yazılar değerlendirmeye kabul edilir.

Makale yayınlanmak üzere Dergiye gönderildikten sonra yazarlardan hiçbirinin ismi, tüm yazarların yazılı izni olmadan yazar listesinden silinemez ve yeni bir isim yazar olarak eklenemez ve yazar sırası değiştirilemez.

İntihal, duplikasyon, sahte yazarlık/inkar edilen yazarlık, araştrma/veri fabrikasyonu, makale dilimleme, dilimleyerek yayın, telif hakları ihlali ve çıkar çatışmasının gizlenmesi, etik dışı davranışlar olarak kabul edilir. Kabul edilen etik standartlara uygun olmayan tüm makaleler yayından çıkarılır. Buna yayından sonra tespit edilen olası kuraldışı, uygunsuzluklar içeren makaleler de dahildir.

İntihal

Ön kontrolden geçirilen makaleler, iThenticate yazılımı kullanılarak intihal için taranır. İntihal/kendi kendine intihal tespit edilirse yazarlar bilgilendirilir. Editörler, gerekli olması halinde makaleyi değerlendirme ya da üretim sürecinin çeşitli aşamalarında intihal kontrolüne tabi tutabilirler. Yüksek benzerlik oranları, bir makalenin kabul edilmeden önce ve hatta kabul edildikten sonra reddedilmesine neden olabilir. Makalenin türüne bağlı olarak, bunun oranın %15 veya %20'den az olması beklenir.

Çift Kör Hakemlik

İntihal kontrolünden sonra, uygun olan makaleler baş editör tarafından orijinallik, metodoloji, işlenen konunun önemi ve dergi kapsamı ile uyumluluğu açısından değerlendirilir. Editör, makalelerin adil bir şekilde çift taraflı kör hakemlikten geçmesini sağlar ve makale biçimsel esaslara uygun ise, gelen yazıyı yurtiçinden ve /veya yurtdışından en az iki hakemin değerlendirmesine sunar, hakemler gerek gördüğü takdirde yazıda istenen değişiklikler yazarlar tarafından yapıldıktan sonra yayınlanmasına onay verir.

Açık Erişim İlkesi

Dergi açık erişimlidir ve derginin tüm içeriği okura ya da okurun dahil olduğu kuruma ücretsiz olarak sunulur. Okurlar, ticari amaç haricinde, yayıncı ya da yazardan izin almadan dergi makalelerinin tam metnini okuyabilir, indirebilir, kopyalayabilir, arayabilir ve link sağlayabilir. Bu HYPERLINK "https://www.budapestopenaccessinitiative.org/translations/turkish-translation" BOAI açık erişim tanımıyla uyumludur.

Derginin açık erişimli makaleleri Creative Commons Atıf-GayrıTicari 4.0 Uluslararası (CC BY-NC 4.0)(https://creativecommons.org/licenses/by-nc/4.0/deed.tr) olarak lisanslıdır.

İşlemleme Ücreti

Derginin tüm giderleri İstanbul Üniversitesi tarafından karşılanmaktadır. Dergide makale yayını ve makale süreçlerinin yürütülmesi ücrete tabi değildir. Dergiye gönderilen ya da yayın için kabul edilen makaleler için işlemleme ücreti ya da gönderim ücreti alınmaz.

Telif Hakkında

Yazarlar dergide yayınlanan çalışmalarının telif hakkına sahiptirler ve çalışmaları Creative Commons Atıf-GayrıTicari 4.0 Uluslararası (CC BY-NC 4.0) https://creativecommons.org/licenses/by-nc/4.0/deed.tr olarak lisanslıdır. CC BY-NC 4.0 lisansı, eserin ticari kullanım dışında her boyut ve formatta paylaşılmasına, kopyalanmasına, çoğaltılmasına ve orijinal esere uygun şekilde atıfta bulunmak kaydıyla yeniden düzenleme, dönüştürme ve eserin üzerine inşa etme dâhil adapte edilmesine izin verir.

ETİK

Yayın Etiği Beyanı

Journal of Transportation and Logistics, yayın etiğinde en yüksek standartlara bağlıdır ve Committee on Publication Ethics (COPE), Directory of Open Access Journals (DOAJ), Open Access Scholarly Publishers Association (OASPA) ve World Association of Medical Editors (WAME) tarafından yayınlanan etik yayıncılık ilkelerini benimser; Principles of Transparency and Best Practice in Scholarly Publishing başlığı altında ifade edilen ilkeler için: https://publicationethics.org/resources/guidelines-new/principles-transparency-andbest-practice-scholarly-publishing

Gönderilen tüm makaleler orijinal, yayınlanmamış ve başka bir dergide değerlendirme sürecinde olmamalıdır. Her bir makale editörlerden biri ve en az iki hakem tarafından çift kör değerlendirmeden geçirilir. İntihal, duplikasyon, sahte yazarlık/inkar edilen yazarlık, araştrma/veri fabrikasyonu, makale dilimleme, dilimleyerek yayın, telif hakları ihlali ve çıkar çatışmasının gizlenmesi, etik dışı davranışlar olarak kabul edilir.

Kabul edilen etik standartlara uygun olmayan tüm makaleler yayından çıkarılır. Buna yayından sonra tespit edilen olası kuraldışı, uygunsuzluklar içeren makaleler de dahildir.

Araştırma Etiği

Journal of Transportation and Logistics araştırma etiğinde en yüksek standartları gözetir ve aşağıda tanımlanan uluslararası araştırma etiği ilkelerini benimser. Makalelerin etik kurallara uygunluğu yazarların sorumluluğundadır

- Araştırmanın tasarlanması, tasarımın gözden geçirilmesi ve araştırmanın yürütülmesinde, bütünlük, kalite ve şeffaflık ilkeleri sağlanmalıdır.
- Araştırma ekibi ve katılımcılar, araştırmanın amacı, yöntemleri ve öngörülen olası kullanımları;araştırmaya katılımın gerektirdikleri ve varsa riskleri hakkında tam olarak bilgilendirilmelidir.
- Araştırma katılımcılarının sağladığı bilgilerin gizliliği ve yanıt verenlerin gizliliği sağlanmalıdır. Araştırma katılımcıların özerkliğini ve saygınlığını koruyacak şekilde tasarlanmalıdır.
- Araştırma katılımcıları gönüllü olarak araştırmada yer almalı, herhangi bir zorlama altında olmamalıdırlar.
- Katılımcıların zarar görmesinden kaçınılmalıdır. Araştırma, katılımcıları riske sokmayacak şekilde planlanmalıdır.

- Araştırma bağımsızlığıyla ilgili açık ve net olunmalı; çıkar çatışması varsa belirtilmelidir.
- Deneysel çalışmalarda, araştırmaya katılmaya karar veren katılımcıların yazılı bilgilendirilmiş onayı alınmalıdır. Çocukların ve vesayet altındakilerin veya tasdiklenmiş akıl hastalığı bulunanların yasal vasisinin onayı alınmalıdır.
- Çalışma herhangi bir kurum ya da kuruluşta gerçekleştirilecekse bu kurum ya da kuruluştan çalışma yapılacağına dair onay alınmalıdır.
- İnsan öğesi bulunan çalışmalarda, "yöntem" bölümünde katılımcılardan "bilgilendirilmiş onam" alındığının ve çalışmanın yapıldığı kurumdan etik kurul onayı alındığı belirtilmesi gerekir.

Yazarların Sorumluluğu

Makalelerin bilimsel ve etik kurallara uygunluğu yazarların sorumluluğundadır. Yazar makalenin orijinal olduğu, daha önce başka bir yerde yayınlanmadığı ve başka bir yerde, başka bir dilde yayınlanmak üzere değerlendirmede olmadığı konusunda teminat sağlamalıdır. Uygulamadaki telif kanunları ve anlaşmaları gözetilmelidir. Telife bağlı materyaller (örneğin tablolar, şekiller veya büyük alıntılar) gerekli izin ve teşekkürle kullanılmalıdır. Başka yazarların, katkıda bulunanların çalışmaları ya da yararlanılan kaynaklar uygun biçimde kullanılmalı ve referanslarda belirtilmelidir.

Gönderilen makalede tüm yazarların akademik ve bilimsel olarak doğrudan katkısı olmalıdır, bu bağlamda "yazar" yayınlanan bir araştırmanın kavramsallaştırılmasına ve dizaynına, verilerin elde edilmesine, analizine ya da yorumlanmasına belirgin katkı yapan, yazının yazılması ya da bunun içerik açısından eleştirel biçimde gözden geçirilmesinde görev yapan birisi olarak görülür. Yazar olabilmenin diğer koşulları ise, makaledeki çalışmayı planlamak veya icra etmek ve / veya revize etmektir. Fon sağlanması, veri toplanması ya da araştırma grubunun genel süpervizyonu tek başına yazarlık hakkı kazandırmaz. Yazar olarak gösterilen tüm bireyler sayılan tüm ölçütleri karşılamalıdır ve yukarıdaki ölçütleri karşılayan her birey yazar olarak gösterilebilir. Yazarların isim sıralaması ortak verilen bir karar olmalıdır. Tüm yazarlar yazar sıralamasını Telif Hakkı Formunda imzalı olarak belirtmek zorundadırlar.

Yazarlık için yeterli ölçütleri karşılamayan ancak çalışmaya katkısı olan tüm bireyler "teşekkür / bilgiler" kısmında sıralanmalıdır. Bunlara örnek olarak ise sadece teknik destek sağlayan, yazıma yardımcı olan ya da sadece genel bir destek sağlayan, finansal ve materyal desteği sunan kişiler verilebilir.

Bütün yazarlar, araştırmanın sonuçlarını ya da bilimsel değerlendirmeyi etkileyebilme potansiyeli olan finansal ilişkiler, çıkar çatışması ve çıkar rekabetini beyan etmelidirler. Bir yazar kendi yayınlanmış yazısında belirgin bir hata ya da yanlışlık tespit ederse, bu yanlışlıklara ilişkin düzeltme ya da geri çekme için editör ile hemen temasa geçme ve işbirliği yapma sorumluluğunu taşır.

Editör, Hakem Sorumlulukları ve Değerlendirme Süreci

Baş editör, makaleleri, yazarların etnik kökeninden, cinsiyetinden, uyruğundan, dini inancından ve siyasi felsefesinden bağımsız olarak değerlendirir. Yayına gönderilen makalelerin adil bir şekilde çift taraflı kör hakem değerlendirmesinden geçmelerini sağlar. Gönderilen makalelere ilişkin tüm bilginin, makale yayınlanana kadar gizli kalacağını garanti eder. Baş editör içerik ve yayının toplam kalitesinden sorumludur. Gereğinde hata sayfası yayınlamalı ya da düzeltme yapmalıdır.

Baş editör; yazarlar, editörler ve hakemler arasında çıkar çatışmasına izin vermez. Hakem atama konusunda tam yetkiye sahiptir ve dergide yayınlanacak makalelerle ilgili nihai kararı vermekle yükümlüdür.

Hakemlerin araştırmayla ilgili, yazarlarla ve/veya araştırmanın finansal destekçileriyle çıkar çatışmaları olmamalıdır. Değerlendirmelerinin sonucunda tarafsız bir yargıya varmalıdırlar. Gönderilmiş yazılara ilişkin tüm bilginin gizli tutulmasını sağlamalı ve yazar tarafında herhangi bir telif hakkı ihlali ve intihal fark ederlerse editöre raporlamalıdırlar.

Hakem, makale konusu hakkında kendini vasıflı hissetmiyor ya da zamanında geri dönüş sağlaması mümkün görünmüyorsa, editöre bu durumu bildirmeli ve hakem sürecine kendisini dahil etmemesini istemelidir.

Değerlendirme sürecinde editör hakemlere gözden geçirme için gönderilen makalelerin, yazarların özel mülkü olduğunu ve bunun imtiyazlı bir iletişim olduğunu açıkça belirtir. Hakemler ve yayın kurulu üyeleri başka kişilerle makaleleri tartışamazlar. Hakemlerin kimliğinin gizli kalmasına özen gösterilmelidir. Bazı durumlarda editörün kararıyla, ilgili hakemlerin makaleye ait yorumları aynı makaleyi yorumlayan diğer hakemlere gönderilerek hakemlerin bu süreçte aydınlatılması sağlanabilir.

Hakem Süreci

Daha önce yayınlanmamış ya da yayınlanmak üzere başka bir dergide halen değerlendirmede olmayan ve her bir yazar tarafından onaylanan makaleler değerlendirilmek üzere kabul edilir. Gönderilen ve ön kontrolü geçen makaleler iThenticate yazılımı kullanılarak intihal için taranır. İntihal kontrolünden sonra, uygun olan makaleler baş editör tarafından orijinallik, metodoloji, işlenen konunun önemi ve dergi kapsamı ile uyumluluğu açısından değerlendirilir. Baş editör, makaleleri, yazarların etnik kökeninden, cinsiyetinden, uyruğundan, dini inancından ve siyasi felsefesinden bağımsız olarak değerlendirir. Yayına gönderilen makalelerin adil bir şekilde çift taraflı kör hakem değerlendirmesinden geçmelerini sağlar.

Seçilen makaleler en az iki ulusal/uluslararası hakeme değerlendirmeye gönderilir; yayın kararı, hakemlerin talepleri doğrultusunda yazarların gerçekleştirdiği düzenlemelerin ve hakem sürecinin sonrasında baş editör tarafından verilir.

Hakemlerin değerlendirmeleri objektif olmalıdır. Hakem süreci sırasında hakemlerin aşağıdaki hususları dikkate alarak değerlendirmelerini yapmaları beklenir.

- Makale yeni ve önemli bir bilgi içeriyor mu?
- Öz, makalenin içeriğini net ve düzgün bir şekilde tanımlıyor mu?
- Yöntem bütünlüklü ve anlaşılır şekilde tanımlanmış mı?
- Yapılan yorum ve varılan sonuçlar bulgularla kanıtlanıyor mu?
- Alandaki diğer çalışmalara yeterli referans verilmiş mi?
- Dil kalitesi yeterli mi?

Hakemler, gönderilen makalelere ilişkin tüm bilginin, makale yayınlanana kadar gizli kalmasını sağlamalı ve yazar tarafında herhangi bir telif hakkı ihlali ve intihal fark ederlerse editöre raporlamalıdırlar. Hakem, makale konusu hakkında kendini vasıflı hissetmiyor ya da zamanında geri dönüş sağlaması mümkün görünmüyorsa, editöre bu durumu bildirmeli ve hakem sürecine kendisini dahil etmemesini istemelidir.

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YAZILARIN HAZIRLANMASI

Dil

Dergide Türkçe ve İngilizce makaleler yayınlanır. Gönderilen makalelerde makale dilinde öz, İngilizce öz ve İngilizce geniş özet olmalıdır. Ancak makale İngilizce ise, İngilizce geniş özet istenmez.

Yazıların Hazırlanması ve Yazım Kuralları

Aksi belirtilmedikçe gönderilen yazılarla ilgili tüm yazışmalar ilk yazarla yapılacaktır. Makale gönderimi online olarak https://jtl.istanbul.edu.tr/en/_ sayfasından erişilen https://mc04.manuscriptcentral.com/jtl üzerinden yapılmalıdır. Gönderilen yazılar, makale türünü belirten ve makaleyle ilgili detayları içeren (bkz: Son Kontrol Listesi) Kapak Sayfası; yazının elektronik formunu içeren Microsoft Word 2003 ve üzerindeki versiyonları ile yazılmış elektronik dosya ve tüm yazarların imzaladığı Telif Hakkı Anlaşması Formu eklenerek gönderilmelidir.

1. Makale ana metninde, çift taraflı kör hakemlik süreci gereği, yazarın / yazarların kimlik bilgileri yer almamalıdır.
2. Yayınlanmak üzere gönderilen makale ile birlikte yazar bilgilerini içeren Kapak Sayfası gönderilmelidir. Kapak Sayfasında, makalenin başlığı, yazar veya yazarların bağlı bulundukları kurum ve unvanları, kendilerine ulaşılabilecek adresler, cep, iş ve faks numaraları, ORCID ve e-posta adresleri yer almalıdır (bkz. Son Kontrol Listesi).
3. Giriş bölümünden önce 180-200 kelimelik çalışmanın kapsamını, amacını, ulaşılan sonuçları ve kullanılan yöntemi kaydeden makale dilinde öz ve İngilizce öz ile 600-800 kelimelik İngilizce genişletilmiş özet yer almalıdır. Makale İngilizce ise Türkçe özet ve İngilizce geniş özet istenmez. Çalışmanın içeriğini temsil eden, 3'er adet anahtar kelime yer almalıdır.

4. Çalışmaların başlıca şu unsurları içermesi gerekmektedir: Makale Türkçe ise; Türkçe dilinde başlık, öz ve anahtar kelimeler; İngilizce başlık, öz ve anahtar kelimeler, İngilizce geniş özet, ana metin bölümleri, kaynaklar, tablolar ve şekiller. Makale İngilizce ise; sadece İngilizce dilinde başlık öz ve anahtar kelimeler, ana metin bölümleri, kaynaklar, tablolar ve şekiller yer almalıdır
5. **Makale Türleri:**
   Araştırma Makaleleri: Orijinal araştırma makaleleri derginin kapsamına uygun konularda önemli, özgün bilimsel sonuçlar sunan araştırmaları raporlayan yazılardır. Orijinal araştırma makaleleri, Öz, Anahtar Kelimeler, İngilizce Geniş Özet, Giriş, Yöntem, Bulgular, Tartışma, Sonuçlar, Kaynaklar bölümlerinden ve Tablo, Grafik ve Şekillerden oluşur.
   Öz: İngilizce özetler 180-200 kelime arasında olmalı ve çalışmanın amacını, yöntemini, bulgularını ve sonuçlarını belirtmelidir. Makale Türkçe ise; Türkçe ve İngilizce 180-200 kelimelik özet ve 600-800 kelimelik İngilizce genişletilmiş özet de özlerden sonra yer almalıdır.
   Giriş: Giriş bölümünde konunun önemi, tarihçe ve bugüne kadar yapılmış çalışmalar, hipotez ve çalışmanın amacından söz edilmelidir. Hem ana hem de ikincil amaçlar açıkça belirtilmelidir. Sadece gerçekten ilişkili kaynaklar gösterilmeli ve çalışmaya ait veri ya da sonuçlardan söz edilmemelidir. Giriş bölümünün sonunda çalışmanın amacı, araştırma soruları veya hipotezler yazılmalıdır.
   Yöntem: Yöntem bölümünde, veri kaynakları, çalışmaya katılanlar, ölçekler, görüşme/değerlendirmeler ve temel ölçümler, yapılan işlemler ve istatistiksel yöntemler yer almalıdır. Yöntem bölümü, sadece çalışmanın planı ya da protokolü yazılırken bilinen bilgileri içermelidir; çalışma sırasında elde edilen tüm bilgiler bulgular kısmında verilmelidir.
   Bulgular: Ana bulgular istatistiksel verilerle desteklenmiş olarak eksiksiz verilmeli ve bu bulgular uygun tablo, grafik ve şekillerle görsel olarak da belirtilmelidir. Bulgular yazıda, tablolarda ve şekillerde mantıklı bir sırayla önce en önemli sonuçlar olacak şekilde verilmelidir. Tablo ve şekillerdeki tüm veriyi yazıda vermemeli, sadece önemli noktaları vurgulanmalıdır.
   Tartışma: Tartışma bölümünde o çalışmadan elde edilen veriler, kurulan hipotez doğrultusunda hipotezi destekleyen ve desteklemeyen bulgular ve sonuçlar irdelenmeli ve bu bulgu ve sonuçlar literatürde bulunan benzeri çalışmalarla kıyaslanmalı, farklılıklar varsa açıklanmalıdır. Çalışmanın yeni ve önemli yanları ve bunlardan çıkan sonuçları vurgulanmalıdır. Giriş ya da sonuçlar kısmında verilen bilgi ve veriler tekrarlanmamalıdır.
   Sonuçlar: Çalışmadan elde edilen sonuçlar belirtilmelidir. Sonuçlar, çalışmanın amaçları ile bağlantılı olmalıdır, ancak veriler tarafından yeterince desteklenmeyen niteliksiz ifadeler ve sonuçlardan kaçınılmalıdır. Yeni hipotezler gerektiğinde belirtilmeli, ancak açıkça tanımlanmalıdır.
   Şekil, Resim, Tablo ve Grafikler: Metin içinde kullanılan fotoğraf, plân, harita vb. materyallerin ".jpg /.tiff" uzantılı kayıtları gönderilecek dokümanlara eklenmelidir. Bu tür belgelerin baskı tekniğine uygun çözünürlükte (en az 300 piksel) ve sayfa alanını aşmayacak büyüklükte olmasına dikkat edilmelidir. Fotoğraf ve levhaların 10 sayfayı aşmamasına dikkat edilmeli ve metin içinde parantezle atıfta bulunulan resim, harita veya diğer ekler makalenin sonuna eklenmelidir.
   Derleme: Yazının konusunda birikimi olan ve bu birikimleri uluslararası literatüre yayın ve atıf sayısı olarak yansımış uzmanlar tarafından hazırlanmış yazılar değerlendirmeye alınır. Yazarları dergi tarafından da davet edilebilir. Derleme yazısı, başlık, öz, anahtar kelimeler, İngilizce geniş özet (Türkçe, Almanca, Fransızca ve İtalyanca makaleler için), ana metin bölümleri ve kaynaklardan oluşmalıdır.
6. Referanslar derginin benimsediği American Psychological Association (APA) 6 stiline uygun olarak hazırlanmalıdır.
7. Kurallar dâhilinde dergimize yayınlanmak üzere gönderilen çalışmaların her türlü sorumluluğu yazar/ yazarlarına aittir.

KAYNAKLAR

Referans Stili ve Formatı

Journal of Transportation and Logistics, metin içi alıntılama ve kaynak gösterme için APA (American Psychological Association) kaynak sitilinin 6. edisyonunu benimser. APA 6.Edisyon hakkında bilgi için:

- American Psychological Association. (2010). Publication manual of the American Psychological Association (6th ed.). Washington, DC: APA.
- http://www.apastyle.org/

Kaynakların doğruluğundan yazar(lar) sorumludur. Tüm kaynaklar metinde belirtilmelidir. Kaynaklar aşağıdaki örneklerdeki gibi gösterilmelidir.

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Kaynaklar metinde parantez içinde yazarların soyadı ve yayın tarihi yazılarak belirtilmelidir.

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Örnekler:

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(Esin ve ark., 2002; Karasar 1995)
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(Akyolcu, 2007)
İki yazarlı kaynak;
(Sayıner ve Demirci, 2007, s. 72)
Üç, dört ve beş yazarlı kaynak;
Metin içinde ilk kullanımda: (Ailen, Ciambrune ve Welch, 2000, s. 12–13) Metin içinde tekrarlayan kullanımlarda: (Ailen ve ark., 2000)
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Kaynak yazımı ile ilgili örnekler aşağıda verilmiştir.

Kitap
a) Türkçe Kitap
Karasar, N. (1995). Araştırmalarda rapor hazırlama (8.bs). Ankara: 3A Eğitim Danışmanlık Ltd.
b) Türkçeye Çevrilmiş Kitap
Mucchielli, A. (1991). Zihniyetler (A. Kotil, Çev.). İstanbul: İletişim Yayınları.
c) Editörlü Kitap
Ören, T., Üney, T. ve Çölkesen, R. (Ed.). (2006). *Türkiye bilişim ansiklopedisi*. İstanbul: Papatya Yayıncılık.
d) Çok Yazarlı Türkçe Kitap
Tonta, Y., Bitirim, Y. ve Sever, H. (2002). *Türkçe arama motorlarında performans değerlendirme*. Ankara: Total Bilişim.
e) İngilizce Kitap
Kamien R., & Kamien A. (2014). *Music: An appreciation*. New York, NY: McGraw-Hill Education.
f) İngilizce Kitap İçerisinde Bölüm
Bassett, C. (2006). Cultural studies and new media. In G. Hall & C. Birchall (Eds.), *New cultural studies: Adventures in theory* (pp. 220–237). Edinburgh, UK: Edinburgh University Press
g) Türkçe Kitap İçerisinde Bölüm
Erkmen, T. (2012). Örgüt kültürü: Fonksiyonları, öğeleri, işletme yönetimi ve liderlikteki önemi. M. Zencirkıran (Ed.), *Örgüt sosyolojisi kitabı* içinde (s. 233–263). Bursa: Dora Basım Yayın.
h) Yayımcının ve Yazarın Kurum Olduğu Yayın
Türk Standartları Enstitüsü. (1974). *Adlandırma ilkeleri*. Ankara: Yazar.

Makale

a) Türkçe Makale

Mutlu, B. ve Savaşer, S. (2007). Çocuğu ameliyat sonrası yoğun bakımda olan ebeveynlerde stres nedenleri ve azaltma girişimleri. *İstanbul Üniversitesi Florence Nightingale Hemşirelik Dergisi, 15*(60), 179–182.

b) İngilizce Makale

de Cillia, R., Reisigl, M., & Wodak, R. (1999). The discursive construction of national identity. *Discourse and Society, 10*(2), 149–173. http://dx.doi.org/10.1177/0957926599010002002

c) Yediden Fazla Yazarlı Makale

Lal, H., Cunningham, A. L., Godeaux, O., Chlibek, R., Diez-Domingo, J., Hwang, S.-J. ... Heineman, T. C. (2015). Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. *New England Journal of Medicine, 372*, 2087–2096. http://dx.doi.org/10.1056/NEJMoa1501184

d) DOI'si Olmayan Online Edinilmiş Makale

Al, U. ve Doğan, G. (2012). Hacettepe Üniversitesi Bilgi ve Belge Yönetimi Bölümü tezlerinin atıf analizi. *Türk Kütüphaneciliği, 26*, 349–369. Erişim adresi: http://www.tk.org.tr/

e) DOI'si Olan Makale

Turner, S. J. (2010). Website statistics 2.0: Using Google Analytics to measure library website effectiveness. *Technical Services Quarterly, 27*, 261–278. http://dx.doi.org/10.1080/07317131003765910

f) Advance Online Olarak Yayımlanmış Makale

Smith, J. A. (2010). Citing advance online publication: A review. *Journal of Psychology*. Advance online publication. http://dx.doi.org/10.1037/a45d7867 ***g) Popüler Dergi Makalesi***

Semercioğlu, C. (2015, Haziran). Sıradanlığın rayihası. *Sabit Fikir, 52*, 38–39.

Tez, Sunum, Bildiri

a) Türkçe Tezler

Sarı, E. (2008). Kültür kimlik ve politika: *Mardin'de kültürlerarasılık*. (Doktora Tezi). Ankara Üniversitesi Sosyal Bilimler Enstitüsü, Ankara.

b)Ticari Veritabanında Yer Alan Yüksek Lisans Ya da Doktora Tezi

Van Brunt, D. (1997). *Networked consumer health information systems* (Doctoral dissertation). Available from ProQuest Dissertations and Theses. (UMI No. 9943436)

c) Kurumsal Veritabanında Yer Alan İngilizce Yüksek Lisans/Doktora Tezi

Yaylalı-Yıldız, B. (2014). *University campuses as places of potential publicness: Exploring the politicals, social and cultural practices in Ege University* (Doctoral dissertation). Retrieved from: Retrieved from http://library.iyte.edu.tr/tr/hizli-erisim/iyte-tez-portali

d) Web'de Yer Alan İngilizce Yüksek Lisans/Doktora Tezi

Tonta, Y. A. (1992). *An analysis of search failures in online library catalogs* (Doctoral dissertation, University of California, Berkeley). Retrieved from http://yunus.hacettepe.edu.tr/ tonta/yayinlar/phd/ickapak.html

e) Dissertations Abstracts International'da Yer Alan Yüksek Lisans/Doktora Tezi

Appelbaum, L. G. (2005). Three studies of human information processing: Texture amplification, motion representation, and figure-ground segregation. *Dissertation Abstracts International: Section B. Sciences and Engineering, 65*(10), 5428.

f) Sempozyum Katkısı

Krinsky-McHale, S. J., Zigman, W. B., & Silverman, W. (2012, August). Are neuropsychiatric symptoms markers of prodromal Alzheimer's disease in adults with Down syndrome? In W. B. Zigman (Chair), *Predictors of mild cognitive impairment, dementia, and mortality in adults with Down syndrome*. Symposium conducted at American Psychological Association meeting, Orlando, FL.

g) Online Olarak Erişilen Konferans Bildiri Özeti

Çınar, M., Doğan, D. ve Seferoğlu, S. S. (2015, Şubat). Eğitimde dijital araçlar: *Google sınıf uygulaması üzerine bir değerlendirme* [Öz]. Akademik Bilişim Konferansında sunulan bildiri, Anadolu Üniversitesi, Eskişehir. Erişim adresi: http://ab2015.anadolu.edu.tr /index.php?menu=5&submenu=27

h) Düzenli Olarak Online Yayımlanan Bildiriler

Herculano-Houzel, S., Collins, C. E., Wong, P., Kaas, J. H., & Lent, R. (2008). The basic nonuniformity of the cerebral cortex. *Proceedings of the National Academy of Sciences, 105*, 12593–12598. http://dx.doi.org/10.1073/pnas.0805417105

i) Kitap Şeklinde Yayımlanan Bildiriler

Schneider, R. (2013). Research data literacy. S. Kurbanoğlu ve ark. (Ed.), Communications in Computer and Information Science: Vol. 397. *Worldwide Communalities and Challenges in Information Literacy Research and Practice* içinde (s. 134–140). Cham, İsviçre: Springer. http://dx.doi.org/10.1007/978-3-319-03919-0

j) Kongre Bildirisi

Çepni, S., Bacanak A. ve Özsevgeç T. (2001, Haziran). *Fen bilgisi öğretmen adaylarının fen branşlarına karşı tutumları ile fen branşlarındaki başarılarının ilişkisi*. X. Ulusal Eğitim Bilimleri Kongresi'nde sunulan bildiri, Abant İzzet Baysal Üniversitesi, Bolu

Diğer Kaynaklar

a) Gazete Yazısı

Toker, Ç. (2015, 26 Haziran). 'Unutma' notları. *Cumhuriyet*, s. 13.

b) Online Gazete Yazısı

Tamer, M. (2015, 26 Haziran). E-ticaret hamle yapmak için tüketiciyi bekliyor. *Milliyet*. Erişim adresi: http://www.milliyet

c) Web Page/Blog Post

Bordwell, D. (2013, June 18). David Koepp: Making the world movie-sized [Web log post]. Retrieved from http://www.davidbordw

d) Online Ansiklopedi/Sözlük

Bilgi mimarisi. (2014, 20 Aralık). Vikipedi içinde. Erişim adresi: http://tr.wikipedia.org/wiki/Bilgi_mimarisi Marcoux, A. (2008). Business ethics. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*. Retrieved from http://plato.stanford.edu/entries/ethics-business/

e) Podcast

Radyo ODTÜ (Yapımcı). (2015, 13 Nisan). *Modern sabahlar* [Podcast]. Erişim adresi: http://www.radyoodtu.com.tr/

f) Bir Televizyon Dizisinden Tek Bir Bölüm

Shore, D. (Senarist), Jackson, M. (Senarist) ve Bookstaver, S. (Yönetmen). (2012). Runaways [Televizyondizisi bölümü]. D. Shore (Baş yapımcı), *House M.D.* içinde. New York, NY: Fox Broadcasting.

g) Müzik Kaydı

Say, F. (2009). Galata Kulesi. *İstanbul senfonisi* [CD] içinde. İstanbul: Ak Müzik.

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REFERENCES

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All the citations done in the text should be listed in the References section in alphabetical order of author surname without numbering. Below given examples should be considered in citing the references.

Basic Reference Types

Book
a) Turkish Book
Karasar, N. (1995). *Araştırmalarda rapor hazırlama* (8th ed.) [Preparing research reports]. Ankara, Turkey: 3A Eğitim Danışmanlık Ltd.
b) Book Translated into Turkish
Mucchielli, A. (1991). *Zihniyetler* [Mindsets] (A. Kotil, Trans.). İstanbul, Turkey: İletişim Yayınları.
c) Edited Book
Ören, T., Üney, T., & Çölkesen, R. (Eds.). (2006). *Türkiye bilişim ansiklopedisi* [Turkish Encyclopedia of Informatics].

İstanbul, Turkey: Papatya Yayıncılık.

d) Turkish Book with Multiple Authors

Tonta, Y., Bitirim, Y., & Sever, H. (2002). *Türkçe arama motorlarında performans değerlendirme* [Performance evaluation in Turkish search engines]. Ankara, Turkey: Total Bilişim.

e) Book in English

Kamien R., & Kamien A. (2014). *Music: An appreciation*. New York, NY: McGraw-Hill Education.

f) Chapter in an Edited Book

Bassett, C. (2006). Cultural studies and new media. In G. Hall & C. Birchall (Eds.), *New cultural studies: Adventures in theory* (pp. 220–237). Edinburgh, UK: Edinburgh University Press.

g) Chapter in an Edited Book in Turkish

Erkmen, T. (2012). Örgüt kültürü: Fonksiyonları, öğeleri, işletme yönetimi ve liderlikteki önemi [Organization culture: Its functions, elements and importance in leadership and business management]. In M. Zencirkıran (Ed.), *Örgüt sosyolojisi* [Organization sociology] (pp. 233–263). Bursa, Turkey: Dora Basım Yayın.

h) Book with the same organization as author and publisher

American Psychological Association. (2009). *Publication manual of the American psychological association* (6^{th} ed.). Washington, DC: Author.

Article

a) Turkish Article

Mutlu, B., & Savaşer, S. (2007). Çocuğu ameliyat sonrası yoğun bakımda olan ebeveynlerde stres nedenleri ve azaltma girişimleri [Source and intervention reduction of stress for parents whose children are in intensive care unit after surgery]. *Istanbul University Florence Nightingale Journal of Nursing, 15*(60), 179–182.

b) English Article

de Cillia, R., Reisigl, M., & Wodak, R. (1999). The discursive construction of national identity. *Discourse and Society, 10*(2), 149–173. http://dx.doi.org/10.1177/0957926599010002002

c) Journal Article with DOI and More Than Seven Authors

Lal, H., Cunningham, A. L., Godeaux, O., Chlibek, R., Diez-Domingo, J., Hwang, S.-J. ... Heineman, T. C. (2015). Efficacy of an adjuvanted herpes zoster subunit vaccine in older adults. *New England Journal of Medicine, 372*, 2087–2096. http://dx.doi.org/10.1056/NEJMoa1501184

d) Journal Article from Web, without DOI

Sidani, S. (2003). Enhancing the evaluation of nursing care effectiveness. *Canadian Journal of Nursing Research, 35*(3), 26–38. Retrieved from http://cjnr.mcgill.ca

e) Journal Article wih DOI

Turner, S. J. (2010). Website statistics 2.0: Using Google Analytics to measure library website effectiveness. *Technical Services Quarterly, 27*, 261–278. http://dx.doi.org/10.1080/07317131003765910

f) Advance Online Publication

Smith, J. A. (2010). Citing advance online publication: A review. *Journal of Psychology*. Advance online publication. http://dx.doi.org/10.1037/a45d7867

g) Article in a Magazine

Henry, W. A., III. (1990, April 9). Making the grade in today's schools. *Time, 135*, 28–31.

Doctoral Dissertation, Master's Thesis, Presentation, Proceeding

a) Dissertation/Thesis from a Commercial Database

Van Brunt, D. (1997). *Networked consumer health information systems* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 9943436)

b) Dissertation/Thesis from an Institutional Database

Yaylalı-Yıldız, B. (2014). *University campuses as places of potential publicness: Exploring the politicals, social and cultural practices in Ege University* (Doctoral dissertation). Retrieved from Retrieved from: http://library.iyte.edu.tr/tr/hizli-erisim/iyte-tez-portali

c) Dissertation/Thesis from Web

Tonta, Y. A. (1992). *An analysis of search failures in online library catalogs* (Doctoral dissertation, University of California, Berkeley). Retrieved from http://yunus.hacettepe.edu.tr/ tonta/yayinlar /phd/ickapak.html

d) Dissertation/Thesis abstracted in Dissertations Abstracts International

Appelbaum, L. G. (2005). Three studies of human information processing: Texture amplification, motion representation, and figure-ground segregation. *Dissertation Abstracts International: Section B. Sciences and Engineering, 65*(10), 5428.

e) Symposium Contribution

Krinsky-McHale, S. J., Zigman, W. B., & Silverman, W. (2012, August). Are neuropsychiatric symptoms markers of prodromal Alzheimer's disease in adults with Down syndrome? In W. B. Zigman (Chair), *Predictors of mild cognitive impairment, dementia, and mortality in adults with Down syndrome*. Symposium conducted at the meeting of the American Psychological Association, Orlando, FL.

f) Conference Paper Abstract Retrieved Online

Liu, S. (2005, May). *Defending against business crises with the help of intelligent agent based early warning solutions*. Paper presented at the Seventh International Conference on Enterprise Information Systems, Miami, FL. Abstract retrieved from http://www.iceis.org/iceis2005/abstracts_2005.htm

g) Conference Paper - In Regularly Published Proceedings and Retrieved Online

Herculano-Houzel, S., Collins, C. E., Wong, P., Kaas, J. H., & Lent, R. (2008). The basic nonuniformity of the cerebral cortex. *Proceedings of the National Academy of Sciences, 105*, 12593–12598. http://dx.doi.org/10.1073/pnas.0805417105

h) Proceeding in Book Form

Parsons, O. A., Pryzwansky, W. B., Weinstein, D. J., & Wiens, A. N. (1995). Taxonomy for psychology. In J. N. Reich, H. Sands, & A. N. Wiens (Eds.), *Education and training beyond the doctoral degree: Proceedings of the American Psychological Association National Conference on Postdoctoral Education and Training in Psychology* (pp. 45–50). Washington, DC: American Psychological Association.

i) Paper Presentation

Nguyen, C. A. (2012, August). *Humor and deception in advertising: When laughter may not be the best medicine*. Paper presented at the meeting of the American Psychological Association, Orlando, FL.

Other Sources

a) Newspaper Article

Browne, R. (2010, March 21). This brainless patient is no dummy. *Sydney Morning Herald, 45*.

b) Newspaper Article with no Author

New drug appears to sharply cut risk of death from heart failure. (1993, July 15). *The Washington Post*, p.A12.

c) Web Page/Blog Post

Bordwell, D. (2013, June 18). David Koepp: Making the world movie-sized [Web log post]. Retrieved from http://www.davidbordw

d) Online Encyclopedia/Dictionary

Ignition. (1989). In Oxford English online dictionary (2^{nd} ed.). Retrieved from http://dictionary.oed.com Marcoux, A. (2008). Business ethics. In E. N. Zalta (Ed.). *The Stanford encyclopedia of philosophy*. Retrieved from http://plato.stanford.edu/entr business/

e) Podcast

Dunning, B. (Producer). (2011, January 12). *in Fact: Conspiracy theories* [Video podcast]. Retrieved from http://itunes.apple.com/

f) Single Episode in a Television Series

Egan, D. (Writer), & Alexander, J. (Director). (2005). Failure to communicate. [Television series episode]. In D. Shore (Executive producer), *House*; New York, NY: Fox Broadcasting.

g) Music

Fuchs, G. (2004). Light the menorah. On Eight nights of *Hanukkah* [CD]. Brick, NJ: Kid Kosher.

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