Article

Fuzzy-logic Approach to Estimating the Fleet Efficiency of a Road Transport Company: A Case Study of Agricultural Products' Deliveries in Kazakhstan

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Abstract: The estimation of the efficiency of road transport vehicles remains a significant problem for contemporary transport companies, as the technological process is influenced by numerous stochastic impacts, such as demand stochasticity, road conditions uncertainty, transport market fluctuations, etc. To consider the uncertainty related to the estimation of the vehicles' fleet efficiency, we propose a fuzzy-logic approach, where the efficiency of a given vehicle is described by a membership function. The efficiency of the whole fleet and its rational structure in that case can be evaluated as a fuzzy set. To demonstrate the developed approach, we depict a case study of using cargo vehicles for deliveries of agricultural products in the Republic of Kazakhstan. The numeric results are presented for the selected models of vehicles that a transport company uses to service a set of clients located in Northern Kazakhstan.

Keywords: fleet structure; road transport; fuzzy logic; transport efficiency

1. Introduction

After gaining independence in 1991, Kazakhstan has started the processes of restructuring its economy and assumed a leading position in Central Asia. Due to high economic growth in 2006, the country entered the group of countries with upper-middle income. However, the unstable situation in the energy market is pushing the country's leadership to develop a strategy for transforming the economy and reducing its dependence on oil and gas [1]. Large-scale agriculture is recognized as a competitive direction for further economic development and diversification. This can be explained by the growing demand for agricultural products from high-income countries and the country's huge total agricultural area of 222 million hectares, of which about 13% (29 million hectares) is classified as arable land. However, the supply chains of agricultural products in Kazakhstan are characterized by long distances, and transport costs go up to 40% of the market price of agricultural products.

An analysis of the technical efficiency of the production of certain types of agricultural products [1] shows that small agricultural enterprises are more efficient than large agricultural holdings - which is why nowadays the agricultural policy is increasingly recognizing the potential of small farms. However, such enterprises using progressive forms of organizing agricultural production face the problem of adapting the structure of their rolling stock to operating conditions (transport, road, climatic, organizational, and technical) and external conditions: the need to transport various types and range of

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agricultural products; requirements for the material and technical equipment; the cost of fuels and lubricants, energy carriers and vehicles. The described conditions necessitate the use of an appropriate type of vehicle fleet, which allows, under given conditions, to carry out the transportation of the required amount of cargo at a minimal cost. Therefore, a well-formed structure of the vehicle fleet can significantly reduce the logistics costs associated with the transportation of agricultural goods carried out for small farms and enterprises.

This paper aims to demonstrate the approach to estimating the structure of a vehicle fleet based on the developed fuzzy-logic methodology to measure the efficiency of vehicles. The proposed method allows considering the uncertainty that appears due to a non-deterministic set of clients serviced by a transportation company. As the numeric example of using the developed approach, we consider the delivery of agricultural products for a transportation company located in Almaty that serves the producers in the northern region of Kazakhstan.

The structure of the paper is the following: in the next section we present a concise review of recent scientific literature in the field of choosing a vehicle model and fleet structure; the third section contains the description of the proposed fuzzy-logic approach to measure the efficiency of delivery vehicles; the fourth part provides a case study with the corresponding short discussion of the obtained results; and the last section offers conclusions and directions for future research.

2. Literature Review

The choice of the type of freight transport is an important part of modeling the demand for freight traffic, and the problem of forming a rational structure of the vehicles fleet is typical not only for road transport, but is relevant for rail [2, 3], water [1, 4-6] and industrial modes of transport [7-9]. That problem also occupies an important place in organizing mixed supply chains or delivery schemes with cross-docking terminals [1, 6, 10-13]. The problems of justifying the rational structure of the fleet (in terms of vehicle models) are not new, they arose in the 1950s, and considered the dependence of the carrying capacity on various indicators representing operating conditions. The existing classical methods can be conditionally divided into two groups: those that consider or do not consider the stochastic characteristics of the vehicles used for deliveries of goods. A detailed analysis of the advantages and disadvantages of classical methods is presented in the thesis [14].

The directions of research in recent scientific publications in the field of choosing a vehicle models and fleet structure are the following:

- considering the probabilistic components of the transport process [8, 10, 12, 15-20],
- considering the complex impact of technical and operational indicators [7, 8, 12, 21-27],
- optimizing of environmental [9, 28, 29], economic [7, 11, 18, 22, 19, 30] and social impacts, as well as a combination of these parameters [13, 31-34],
- determining and optimizing of truck loading schedules [4, 8, 10, 16, 35, 36],
- considering the energy efficiency of freight transportation [21, 24, 37],
- minimizing the size of the vehicles fleet [17, 20],
- ensuring the tractive effort reserves [32],
- considering the trajectory of trucks according to the global positioning system [38],
- studying parameters of demand for freight transportation [2],
- considering variations in the characteristics of the route and the vehicle [18],
- establishing complex performance criteria for transportation processes [34, 39, 40],
- using the fuel efficiency as the performance indicator [41],
- considering the risks associated with the operational activities of a transport company [13, 34, 42],
- and even using such an extraordinary performance indicator as the level of satisfaction of decision makers [43] as the element of the model of a transportation process.

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As can be noticed, the most numerous groups of criteria for choosing the structure of the vehicles (in terms of available vehicle models) are technical, operational, and economic indicators. There is no contradiction in this observation because the total carrying capacity of the fleet mainly depends on the technical and operational parameters of the vehicles: capacity, speed, and the laboriousness of maintenance and repair operations. But, on the other hand, vehicle productivity can change under the influence of factors that do not depend on the model of the vehicle, such as operating conditions, methods of organizing the transportation process, qualifications of the driver and repair personnel, supply of spare parts and materials, etc. However, in most research, special cases of choosing the structure of the vehicle fleet in specific conditions are considered, for example:

- a regular change in the volume of goods needed for transportation, in addition to the fact that trucks have various carrying capacities, differing in the cost of hiring, mileage, and speed [15],
- minimizing the costs of the life cycle of trucks [10, 44],
- uncertainties in the vehicle and crusher performance [12],
- accounting for the collection of fees depending on the time of vehicle movement [38],
- human-controlled and automated vehicles [19],
- accumulation of dump trucks in the conditions of open pit mining [9] and automated creation of rolling stock configurations [27].

In addition to the classic vehicles used in road transportation that are analyzed by most of the mentioned research, the following vehicles were considered as the vehicles under study:

- mining dump trucks [7, 9, 45],
- trucks for the transportation of heavy loads [37],
- garbage trucks [17],
- hybrid, battery, and electric trucks [32],
- trucks for concrete deliveries [40],
- hydrogen vehicles [29],
- trucks with a capacity of up to 3.5 tons [25],
- and vehicles equipped with a hybrid diesel or high-pressure gas engine [33].

At the same time, some supply chains work with perishable products [11]; soft drinks [35]; with products deteriorating over time [17]; products of the agro-industrial complex [26], and the construction industry [40].

The presence in the considered works of many variable parameters and the given formalization of the conditions for conducting research do not allow qualitative analysis of the results obtained and the development of recommendations that allow using any of the proposed methods as a universal one for choosing the optimal (rational) qualitative and quantitative vehicle models for transportation of the agro-industrial products in the conditions of Kazakhstani market. The above statement is also based on the fact that genetic algorithms and their modifications [1, 4, 10, 11, 15-17, 29], which are characterized by poor scalability to the complexity of the problem being solved, were often used to solve the optimization problems formulated in the listed above works. As other methods, the following approaches were used: hybrid Pareto optimal approaches [31], binary integer programming under uncertainty [8], fuzzy programming [12], generalized disjunctive programming [35], fuzzy-tuned models [43], and multiperiod multiplicative analysis [37], recursive logic modeling [38], binary probit and logit models [2], discrete continuum econometric models [18], agent-based modeling [32], and discrete event simulation modeling [6, 9].

Based on the analysis carried out, it is not possible to develop specific recommendations for using some chosen vehicle model as the basis for the formation of a rational structure of the vehicles' fleet, the use of which will guarantee the maximum outcome for the transport company involved in the delivery of agricultural products in the conditions of Kazakhstani market.

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3. Proposed Approach

The key concept that we use to provide a tool to measure the efficiency of vehicles under the given demand and market conditions is the idea of the areas of the efficient use of vehicles depicted in the paper [46].

By the area of effective use of a truck, we mean the range of values of the studied indicator, for which the use of a vehicle gives an acceptable value of the efficiency criterion. Since the use of a vehicle can be considered effective if the profit from the transportation has a positive value, then the area $[\xi_1, \xi_2]$ of the effective use of a vehicle for the indicator Ξ can be represented as follows:

$$\Xi \in [\xi_1, \xi_2], \text{ such that } P_{ton}(\forall \xi \in \Xi) \geq 0, \quad (1)$$

where P_{ton} is a profit per 1 ton of cargo in the consignment delivered by a vehicle, [KZT/ton].

As a parameter Ξ, any technical or operational indicator of the vehicle operation can be used (e.g., delivery distance, idle time for loading and unloading operations, vehicle speed, etc.). The most significant indicator characterizing the transport process and its cost indicators are the delivery distance and the consignment weight [47].

Let us consider the areas of effective use for some models of freight vehicles for the distance of cargo delivery, taking into account the batch nature of transportation (the cargo is delivered divided into batches – consignments that usually correspond to the vehicle capacity). A consignment of cargo can have values from the minimum allowable size of the consignment (or such a minimum amount of cargo, the transportation of which by trucks is rational) to the value of the vehicle's carrying capacity.

Let's take the following models of delivery trucks: Iveco-Magirus, DAF XF 95430, Mercedes-Benz Atego 1218, MAN TGL 8.18 BL, and Hyundai HD78. Consider consignments of 4 tons, 7 tons, and 24 tons (the maximum value of a consignment can be determined by the minimum from available values of carrying capacities). Let's calculate the profit for the delivery distance in the range $[100; 500]$ km under the assumption that the services of a transport company are paid under a per-kilometer rate. The results of such calculations for the conditions of a Kazakhstani cargo delivery market show the dependence of profit on the distance of delivery (Fig. 1-3). The horizontal dotted line in Fig. 1-3 shows the bounds of effective use of vehicles: if the graph representing the dependence of profit on the distance is located above the dotted line, the use of the corresponding model of a vehicle is considered an effective (as the profit per 1 ton of a delivered cargo in such the case is positive).

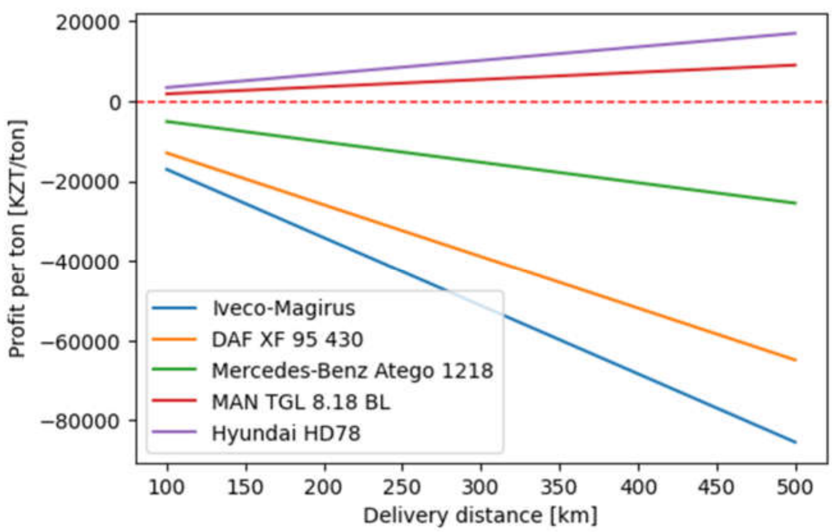

Figure 1. Dependence of the profit on the delivery distance (consignment 4 tons).

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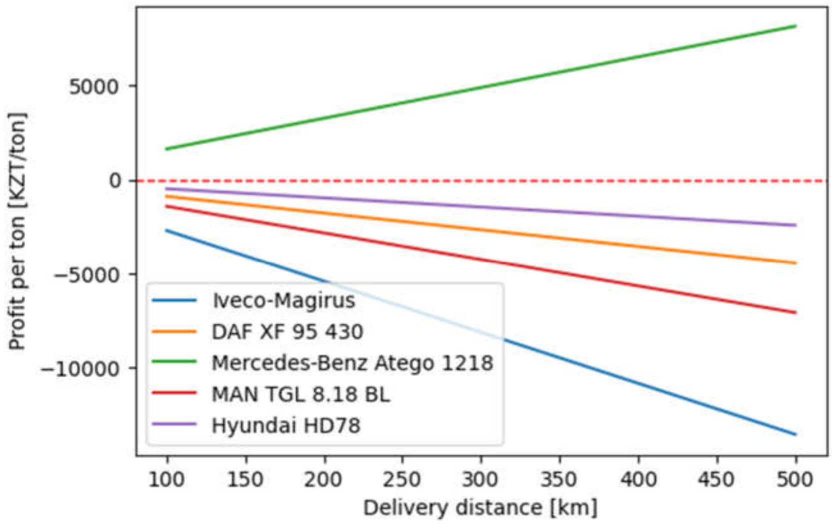

Figure 2. Dependence of the profit on the delivery distance (consignment 7 tons).

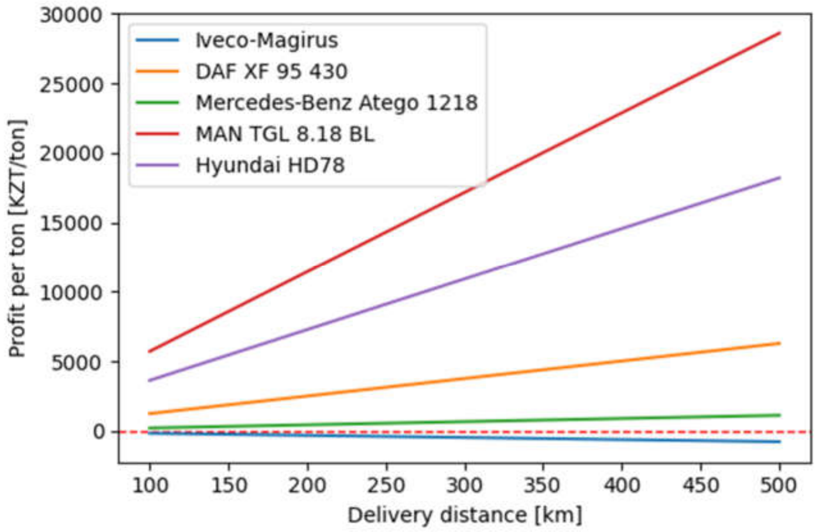

Figure 3. Dependence of the profit on the delivery distance (consignment 24 tons).

As can be observed from the graphs presented in Fig. 1-3, the weight of a consignment significantly influences the profitability of the considered vehicle models: for the consignment weight of 4 tons, MAN TGL 8.18 BL and Hyundai HD78 can be used to deliver a consignment without financial losses of a transport company, if the consignment weight equals 7 tons, only Mercedes-Benz Atego 1218 will guarantee service without losses, and for consignments of 24 tons, only the use of Iveco-Magirus will be a non-profitable solution for a transport company. As the lines representing the dependencies of a profit on the delivery distance for different truck models do not intersect in the considered range of the distance values, the most efficient solution is unambiguous – the vehicle model characterized by a graph located above all the other dependencies is the most efficient option: Hyundai HD78 for consignments weighted 4 tons (Fig. 1), Mercedes-Benz Atego 1218 for the loads with a weight equal to 7 tons (Fig. 2), and MAN TGL 8.18 BL for the consignments with the weight of 24 tons (Fig. 3).

However, the choice of the most effective vehicle model is controversial, when we consider the dependence of the transport company's profit of the consignment weight for a given delivery distance: Fig. 4 shows the dependencies for the set of truck models in the case of delivery distance equal to 100 km.

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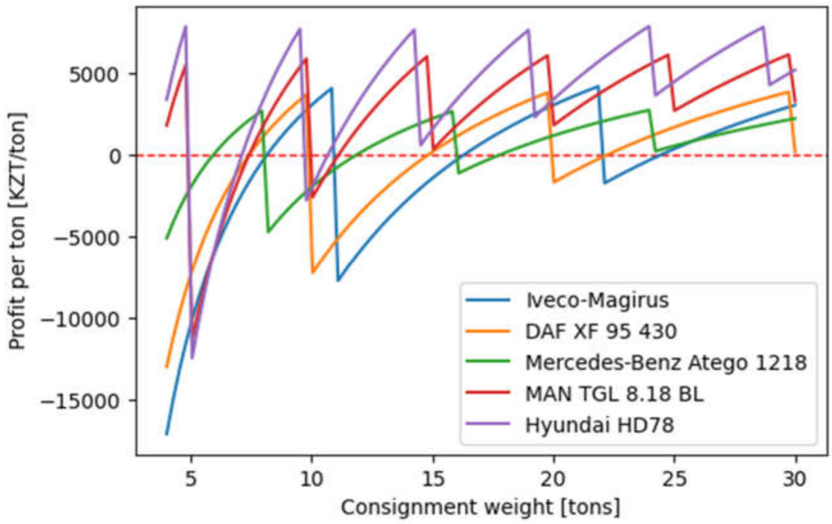

Figure 4. Dependence of the profit on the consignment weight (distance 100 km).

As can be seen from the graph in Fig. 4, the profit of a transport company does not depend on the consignment weight linearly. Furthermore, the dependencies have a stair shape which is explained by the fact that the vehicle capacity is not enough for the considered truck models to deliver the consignment in a single trip. Another important observation from the presented dependencies is that the efficient use of the vehicle models is possible for several ranges of the consignment weight: e.g., the profit from deliveries by Hyundai HD78 is non-negative when the consignments weigh less than 4.9 tons, between 7.1 and 9.7 tons, and more than 10.7 tons. It also should be mentioned, that for the weight of a consignment between 4.9 tons and 5.9 tons none of the considered truck models yield the positive profit of a transport company (i.e., the use of these vehicle models is ineffective for the consignment weight in that range of values).

The described method for choosing the most efficient models of delivery trucks can be used by contemporary transportation enterprises at the operational level – when vehicles are assigned to clients to deliver a consignment at a given distance. A truck model can be defined as the optimal one according to the criterion of maximum profit per 1 ton of a consignment, but its effective use is still possible with a positive value of this criterion (not only in cases when profit is maximum).

To determine the degree of vehicle efficiency, you can use the linguistic variable "efficiency" with the values "least efficient" + "efficient" + "most efficient" + ..., however, the value of the linguistic variable is subjective and requires additional analysis in each specific case. In addition, when using a linguistic variable to describe the efficiency of trucks, a semantic rule cannot be precisely defined for assigning values to a variable representing specific vehicle models when a transport company's clients are serviced under given operating conditions.

More specifically, the feasibility of using the specific truck models can be determined by a membership function of a given vehicle model in a fuzzy set of models that are optimal for use in specific operating conditions. The argument of the membership function should characterize the operation parameters of trucks. As noted earlier, the determining factors that characterize the operating conditions of vehicles during the transportation of goods for a particular client include the distance of delivery of the goods and the weight of a consignment. In this regard, each vehicle model can be characterized by a pair of corresponding membership functions.

The membership function $\mu_A(w)$ of the vehicle model belonging to the fuzzy set of models that are optimal for use, considering the given consignment weight w, has the following form:

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$$\mu_A(w) = \begin{cases} 0, P_{ton(w)} \le 0, \\ \dfrac{P_{ton(w)}}{\max P_{ton(w)}}, \quad P_{ton(w)} > 0, \end{cases} \tag{2}$$

where $P_{ton(w)}$ is the specific profit received as the result of the transportation of a consignment weighed w tons, [KZT/ton].

The membership function $\mu_A(d)$ of the specific vehicle model A belonging to the fuzzy set of models that are optimal for use, taking into account the delivery distance d, is defined as follows:

$$\mu_A(d) = \begin{cases} 0, P_{ton(d)} \le 0, \\ \dfrac{P_{ton(d)}}{\max P_{ton(d)}}, \quad P_{ton(d)} > 0, \end{cases} \tag{3}$$

where $P_{ton(d)}$ is the specific profit received as the result of transporting goods over a distance d km, [KZT/ton].

Let **D** be the set of values for the distance of goods delivery, and **W** be the set of values for the consignment weight. Then, using the given membership functions, each truck model can be characterized by a binary fuzzy relation on the basis sets **W** and **D**, defined as follows:

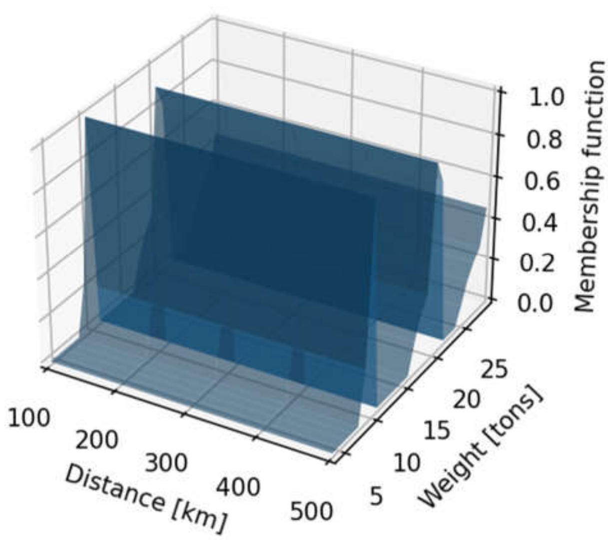
$$A = \{\langle w, d\rangle, \ \mu_A(\langle w, d\rangle)\} \tag{4}$$

where $\mu_A(\langle w, d\rangle)$ is the membership function of a binary fuzzy relation, which is defined as a mapping μ_A: $\mathbf{W}, \mathbf{D} \to [0; 1]$;

$\langle w, d\rangle$ is a tuple of elements w and d, where $w \in \mathbf{W}$ and $d \in \mathbf{D}$.

The feasibility of using a particular truck model can be determined by the obtained values of the binary fuzzy ratio using the surface plot (Fig. 5-7), where for each tuple representing the demand parameters per a single request (delivery distance and consignment weight) the value of the membership function is assigned.

As can be seen from the graphs of binary relations, in the range of distances from 100 km to 500 km and the range of the consignment weight from 4 tons to 30 tons the efficiency of the vehicle models is dissimilar for the considered truck models and significantly vary in regard to the consignment size. The biggest chance to be chosen as the optimal one, has the Hyundai HD78 truck, as the membership function for this vehicle model equals 1 in a wide range of the considered values of a consignment weight.



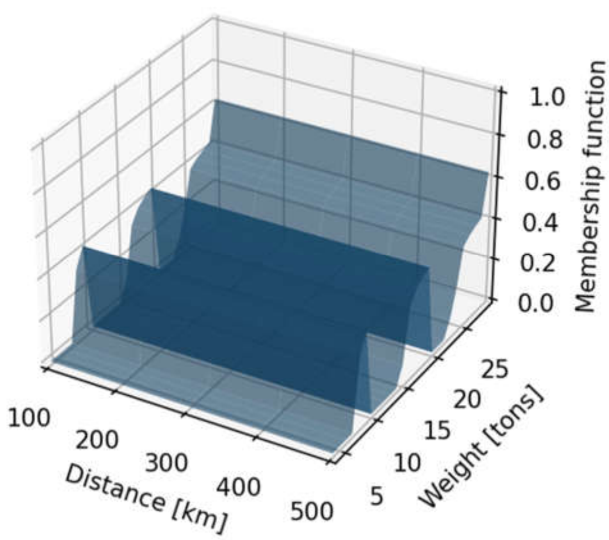


Figure 5. Binary relation of the membership function for Iveco-Magirus and DAF XF 95 430.

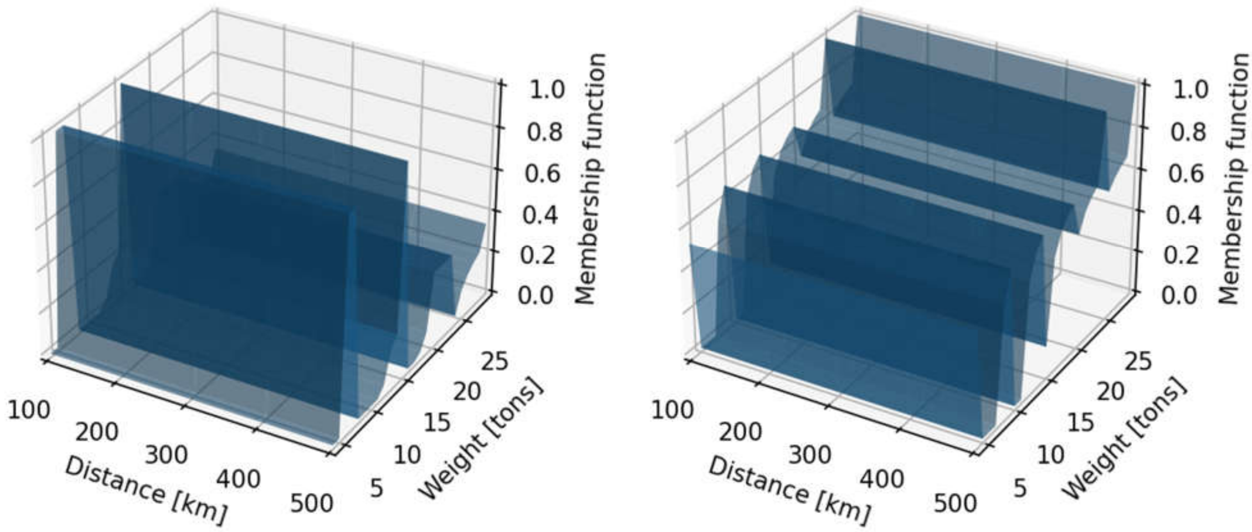


Figure 6. Binary relation of the membership function for Mercedes-Benz Atego 1218 and MAN TGL 8.18 BL.

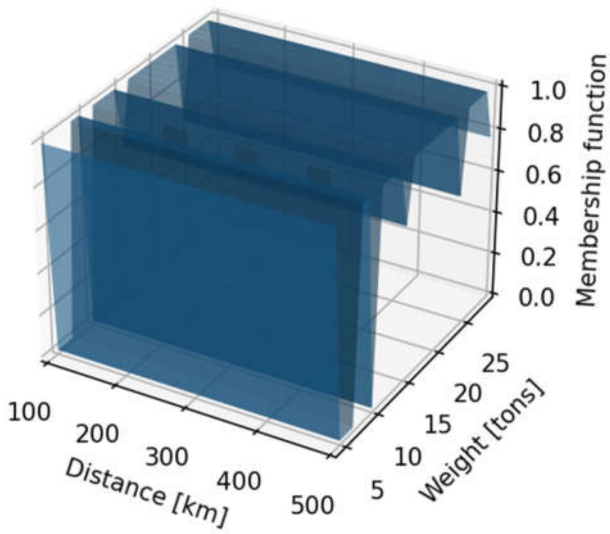


Figure 7. Binary relation of the membership function for Hyundai HD78

If the operating conditions for each of n customers and the preference functions $\mu_A(w)$ and $\mu_A(d)$ for each of m truck models are known, then the fleet of vehicles for the transportation of goods to the i-th customer can be represented as a fuzzy set $A_{f(i)}$:

$$A_{f(i)} = A_1|\mu_{i1} + A_2|\mu_{i2} + \cdots + A_m|\mu_{im}, \quad (5)$$

where $A_1, A_2, \ldots, A_m$ are available vehicle models that could be used (are available) to service the clients,

μ_{ij} is the preference level of the j-th vehicle model when servicing the i-th client.

The set defined according to (5) is an S-fuzzy set, since it is linearly ordered (vehicle models are most obviously ordered by their carrying capacity), but there is no way to determine the distance between the elements of such the set.

Since the operating conditions for a particular client are determined by the tuple $\langle w_i, d_i \rangle$, then the level of preference for the j-th vehicle model for the i-th client corresponds to the value of the membership function of the fuzzy binary relation A:

$$\mu_{ij} = \mu_{A(j)}(\langle w_i, d_i \rangle), \quad (6)$$

where w_i and d_i are the size of the consignment in tons and the delivery distance in kilometers for the i-th client.

Having a group of fuzzy sets $A_{f(i)}$, $i = 1 \dots m$, it is possible to determine the qualitative structure of the truck fleet for a transport company in the form of a fuzzy set A_{VF} in a following way:

$$A_{VF} = \cap_{i=1}^{m} A_{f(i)}. \quad (7)$$

It should be noted that the value of the level of preference μ_{ij} makes it possible to determine not only the feasibility but also the priority of using different models of trucks: the bigger the level of preference, the higher priority of the corresponding vehicle model when a request with the given demand parameters should be serviced.

The described method for determining the qualitative structure of the vehicle fleet allows us to consider, in addition to the delivery distance, the batch nature of transportation and, therefore, allows us to assess the feasibility of using specific models of trucks in a more accurate way. In addition, the representation of the fleet structure of a transport company in the form of a fuzzy set makes it possible to assess the risk of using a fleet with a given structure by constructing the corresponding risk functions.

4. Case Study and Discussion

The qualitative structure of the vehicle fleet is determined by the range of goods transported and the corresponding operating conditions. The range of goods and, to a certain extent, operating conditions (considered above delivery distance and batch size of transportation) are determined by the clientele of trucking companies. Thus, the rational structure of the transport company's fleet should be estimated based on the demand parameters that characterize the set of the company's clients.

As an example demonstrating the proposed approach, let us consider the transport company that operates in the transportation market for deliveries of agricultural products in Northern Kazakhstan. The main company's clients are listed in the first column of Table 1. As the alternative models of trucks to be used for servicing the company's clients, we consider the list of vehicle models used as a demonstration set in the previous section: Iveco-Magirus, DAF XF 95430, Mercedes-Benz Atego 1218, MAN TGL 8.18 BL, and Hyundai HD78.

The membership functions for the vehicle models taken under consideration are determined according to dependencies (2) and (3). So, for the MAN TGL 8.18 BL truck, the value of the function $\mu_A(w)$ of the vehicle belonging to the fuzzy set of models that are optimal for use for a consignment weight of 4 tons with a delivery distance of 100 km is calculated as follows:

$$\mu_A(4) = \frac{1800}{\max\{-17091; -12279; -5107; 1800; 3393\}} = 0.53.$$

Similarly, the values of the membership functions are calculated for each of the considered (or available under the given operation conditions) vehicle models.

Based on the results of the membership functions' evaluation, the fleet of trucks required for the transportation of goods to the Atameken-Agro client (with an average delivery distance of 656 km and mean consignment weight of 15 tons) in the form of a fuzzy set according to (5) and the obtained values of the membership function as the following fuzzy set:

$$A_{f(1)} = A_1|0.000 + A_2|0.084 + A_3|1.000 + A_4|0.135 + A_5|0.711,$$

wherein A_1 – the Iveco-Magirus model, A_2 – the DAF XF 95430 model, A_3 – the Mercedes-Benz Atego 1218 model, A_4 – the MAN TGL 8.18 BL model, A_5 – the Hyundai HD78 model.

Each vehicle model corresponds to the value of the membership function for the mean weight of the shipment and the average distance of delivery that characterize the considered transport company's client. Similarly, we represent the fleet of trucks for other customers and summarize the results in Table 1.

Table 1. Vehicle models within the transport company's fleet as fuzzy sets

Client	A fuzzy set of the vehicle fleet
Atameken-Agro	$A_{f(1)} = A_1\|0.000 + A_2\|0.084 + A_3\|1.000 + A_4\|0.135 + A_5\|0.711$
Dihan Plyus	$A_{f(2)} = A_1\|0.900 + A_2\|0.000 + A_3\|0.347 + A_4\|0.531 + A_5\|1.000$
Sagat SK	$A_{f(3)} = A_1\|0.000 + A_2\|0.000 + A_3\|0.039 + A_4\|0.531 + A_5\|1.000$
Altyin Biday 2000	$A_{f(4)} = A_1\|0.000 + A_2\|0.000 + A_3\|0.224 + A_4\|0.690 + A_5\|1.000$
ASG Holding	$A_{f(5)} = A_1\|0.243 + A_2\|0.421 + A_3\|0.020 + A_4\|0.671 + A_5\|1.000$
Agrotehnika-Zhambyil	$A_{f(6)} = A_1\|0.137 + A_2\|0.393 + A_3\|0.000 + A_4\|0.626 + A_5\|1.000$
Karauyil	$A_{f(7)} = A_1\|0.900 + A_2\|0.000 + A_3\|0.347 + A_4\|0.531 + A_5\|1.000$
Raimbek-Grain & Co	$A_{f(8)} = A_1\|0.000 + A_2\|0.000 + A_3\|0.039 + A_4\|0.531 + A_5\|1.000$
Olzha Astyi	$A_{f(9)} = A_1\|0.243 + A_2\|0.421 + A_3\|0.000 + A_4\|0.671 + A_5\|1.000$
Singenta Kazahstan	$A_{f(10)} = A_1\|0.900 + A_2\|0.000 + A_3\|0.347 + A_4\|0.531 + A_5\|1.000$
Tyin Zher	$A_{f(11)} = A_1\|0.000 + A_2\|0.000 + A_3\|0.224 + A_4\|0.690 + A_5\|1.000$
Agrofirma Kzyiltu-Nan	$A_{f(12)} = A_1\|0.000 + A_2\|0.333 + A_3\|0.000 + A_4\|0.531 + A_5\|1.000$
Tayyinsha-Astyik	$A_{f(13)} = A_1\|0.243 + A_2\|0.421 + A_3\|0.020 + A_4\|0.671 + A_5\|1.000$
Kaznan-Export	$A_{f(14)} = A_1\|0.243 + A_2\|0.421 + A_3\|0.000 + A_4\|0.671 + A_5\|1.000$
Kumay Esil	$A_{f(15)} = A_1\|0.900 + A_2\|0.000 + A_3\|0.347 + A_4\|0.531 + A_5\|1.000$
Zhaltyir-Tas	$A_{f(16)} = A_1\|0.000 + A_2\|0.333 + A_3\|0.000 + A_4\|0.531 + A_5\|1.000$
Altyn Astyk Group	$A_{f(17)} = A_1\|0.000 + A_2\|0.000 + A_3\|0.224 + A_4\|0.690 + A_5\|1.000$
Namyis	$A_{f(18)} = A_1\|0.900 + A_2\|0.000 + A_3\|0.347 + A_4\|0.531 + A_5\|1.000$

As can be noticed from the results presented in Table 1, the truck models A_1 and A_2 have assigned 0 values of the membership function for the majority of the transport company's clients. Such results indicate that in most cases the use of Iveco-Magirus and DAF XF 95430 will generate losses. On the other hand, the value of the membership function assigned for the A_5 vehicle model in almost all cases is 1, which means that Hyundai HD78 will be the best alternative out of the considered truck models to transport agricultural products for the company's clients.

According to expression (7), the qualitative structure of the transport company's vehicle fleet has the following form:

$$A_{VF} = \cap_{i=1}^{18} A_{f(i)},$$

or else it can be written in a transformed way as

$$A_{VF} = A_1|\max \mu_{1j} + A_2|\max \mu_{2j} + A_3|\max \mu_{3j} + A_4|\max \mu_{4j} + A_5|\max \mu_{5j}.$$

As the result of calculations based on the data presented in Table 2, we obtain the following rational qualitative composition of the transport company's truck fleet in the form of a fuzzy set:

$$A_{VF} = A_1|0.900 + A_2|0.421 + A_3|1.000 + A_4|0.690 + A_5|1.000.$$

Analyzing the composition of the obtained fuzzy set, we conclude that each of the considered truck models can be used for delivering agricultural loads for the company's clients. The vehicle models Mercedes-Benz Atego 1218 and Hyundai HD78 are the most efficient (as the maximum value of the membership function is assigned to these models), whereas the use of the truck model MAN TGL 8.18 BL to service the transport company's clients is possible (as it doesn't generate losses) when other vehicles are not available.

5. Conclusions

The structure of the transport company's vehicle fleet conditions the results of the servicing process: an inappropriate structure would increase the operating costs for the transport company and would decrease the level of clients' servicing. As transport companies operate under conditions of market uncertainty, the corresponding approaches to fleet management should be used: such approaches must consider both the transport demand variations and the profitability of the transportation process for a servicing company. The proposed approach allows researchers and practitioners to evaluate the effectiveness of the company's vehicle fleet based on the fuzzy set of vehicle models which use is optimal for the given demand parameters characterizing the set of clients.

The presented numeric results for a transport company that delivers agricultural loads in Northern Kazakhstan demonstrate the advantages of the developed methodology: the fuzzy set representing the company's vehicle fleet shows the vehicle models that guarantee the maximum profit (and, therefore, should be used while servicing the company's clients), but also proposes an indicator to evaluate the vehicle models' efficiency in the case when the optimal truck model is not available.

As the directions of future research, the following tasks are planned to be solved for developing the proposed approach: the methodology should be tested for a wider set of available vehicle models; the simulations for the non-deterministic demand parameters should be provided to assess the impact of the demand stochasticity on the parameters of membership functions in the fuzzy set representing the company's fleet; the tests for other transportation market segments (not only agricultural products delivery) should be completed to investigate the impact of the market specifics on the shape parameters of resulting fuzzy sets.

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