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Research paper

The Principles of the Choice of Management Decisions Based on Fuzzy Logic for Cargo Delivery of Grain to the Seaport

Natalya Shramenko[1*], Dmitriy Muzylyov[2], Mykola Karnaukh[3]**

[1,2,3] Kharkiv National Technical University of Agriculture, Petro Vasilenko
Corresponding author E-mail: nshramenko@gmail.com* (murza_1@ukr.net)*

Abstract

In the article, the approach on the development of management decisions for correct selection of trucks is presented, in the conditions of uncertainty and the stochastic nature of demand for transportation of a grain on the section of a supply chain named "a grain elevator - the sea terminal". The main problems arising at delivery of grain cargoes in a supply chain with the participation of automobile and sea transports were described for justification of relevance of the research. A mathematical definition of the researching tasks was made for the search for the rational management decision at forming a rational structure of the park of the trucks transporting the agricultural products to the sea terminal. Numerous management decisions based on the principles of fuzzy logic have been developed. The values of the input factors are proved in the form of a set of linguistic variables for making a correct management decision. Cargo capacity of the ship coming to the port and amounts of grain which is in a reserve directly on the sea terminal are consider to be definite quantitative characteristics of each set of a term-number.

Keywords: *management; grain (corn); fuzzy logic; cargo; sea terminal.*

1. Introduction

Modern Ukraine is one of the leading exporters of grain on the world market. At the same time, the natural tendency to increase the export volumes of this category of agricultural production is observed every year. Growth is explained by the introduction of new smart technologies in the agro-industrial branch, which are positively displayed, on productivity [1]. First of all, an increase in the number of tons of collected wheat from one hectare.

If the volumes of deliveries are increasing, the process of transportation of corn cargoes to transport hubs from which sending agricultural production for export is carried out must be improved. The most widespread technology of delivery of grain cargoes to other countries is the option of a supply chain where transportation is carried out by means of the automobile and marine transport [2]. At the same time, the last type of transport is main in a supply chain, because makes a delivery on the big distance.

The efficiency of functioning of a supply chain "Production (warehouse) - automobile transport - the sea terminal - delivery by ship - port of destination" also consists in solving questions of making rational management decision. The greatest number of issues, from the point of view of transport technologies, arises on the part of a supply chain between the sender and a grain elevator, which is in port.

First of all, the main problem that has to be solved - to decrease costs of transportation and to decrease the unproductive time of trucks in the port. This aspect depends on several factors:

- on a level of coordination of delivery participants when vehicle is unloading in the port;
- on who is an owner of the park of trucks: is own or leased;
- on the carrying capacity of a ship which arrives for loading and from the period which it stays in port.

It is necessary to provide timeliness of arrival of loaded trucks to reduce the time of staying of the vessel in port under loading. The specified fact guarantees minimization of expenses of carriers and shipment of the grain corresponding to the export quality level.

The organization of this type of deliveries occurs in the short time of the planning period. Therefore, at the adoption of management decisions on the formation of the rational structure of the park of trucks, there is a set of uncertain situations. They generate ambiguity of the choice of the correct decision which is based on a set of alternatives for the organization and management of transportation process.

2. Analysis of Recent Studies and Publications

Using the transport technological scheme with the participation of two means of transport has the specifics. This variant creates some problems in logistics of transport and warehouse complex through which there is an overload of cargoes flows. For Ukraine, the main features of the delivery technology of grain via the sea terminal include:

- Only one of two large seaports of Ukraine can be used for loading of sea vessels. It is located in the city of Mariupol. It is explained by the fact that in the city of Chernomoskoe (Ilyichevsk) the cargo terminal has no specialized granary (elevator) and it isn't equipped with the necessary type of loading mechanisms. This moment makes impossible high-quality loading of sea ships.
- The main cargo flows which go to port are transported by railway transport from all regions of Ukraine. But the automobile transport is only used when the transportation makes in a

short distance. At the same time, different transport companies or directly rolling stock of the agro-enterprises can transportation corn. As results, it makes a considerable stochastically of the process in the moments of trucks arrivals on the terminal of port and significantly reduces the coordination in work between the point of unloading and automobiles. The big excess time of trucks waiting the turn of unloading become a reason of decline in quality of grain at his reception on the sea terminal.

- The decentralizing type of cargoes delivery causes uses of the universal vehicles, which carry out grain transportation. In most cases, he has become outdated. This is significantly displayed on grain losses in transit and directly influences physical and chemical properties of cargo. It is the main reason that agricultural products come to the port with excessive humidity or temperature and consequently, doesn't meet the standards shown by export cargoes.

There is a question of the centralized approach at the organization of transport process when an increase in flows of grain from the agro-enterprises to the port of Mariupol will be. It will give the chance of essential reduction of expenses on the organization of transportation process. Also, will decrease a uploading of the terminal of port thanks to the achievement of a rational ratio of carrying opportunities of the park of trucks to production capacities of unloading in port.

The current object of a research (the process of the movement of grain on a supply chain with the application of two means of transport) can be presented in the simplified form in the Fig.1. It characterizes possible variants of delivery of grain on a part of the supply chain "farmer producer – seaport" [3].

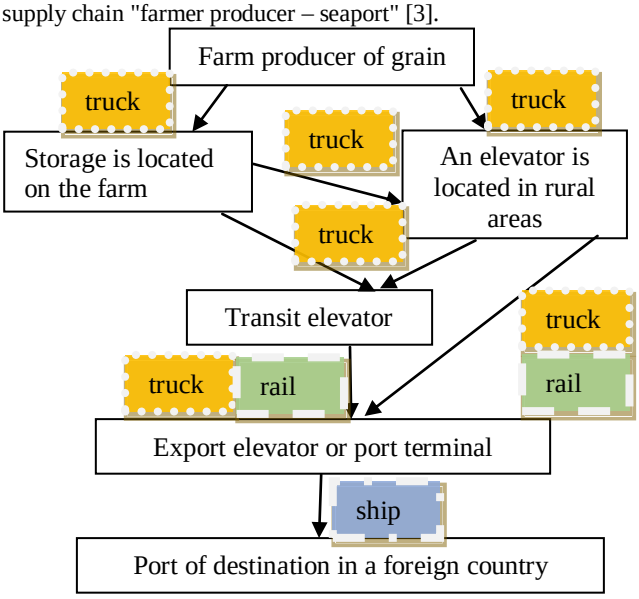

Fig. 1: A typical scheme of export in such supply chain model

The automobile transport is involved in the most part of the supply chain this fact is visible from the scheme before (Fig.1). Therefore, it contains most of the issues from the beginning of the organization of transportation and to the management of cargoes flows.

So, an important aspect of the choice of necessary truck's type is accounted with a factor of lease of the vehicle. It imposes additional illegibility on the studied object. According to the annual report [4] for delivery of grain to the port, farms have to use the hired rolling stock in the majority. This results from the fact that suppliers of high-quality export grain are about 70% of farms, that have small sowing fields and production capacities. It is inexpedient to contain the big park of the rolling stock for such type of agro-enterprises. Trucks can be used for 100% only during a certain season, and then they will not be used or must be rented.

The author in work [5] has focused attention that the expediency of application of own park of vehicles must be explained.

In a research [6] the author pays considerable attention to a solution to the problem of the effective use of vehicles in agriculture. It's the main aim to exclude idle time of grain-harvesting machines due to the lack of vehicles, which make a transportation of corn during harvesting. It is possible to avoid these problems, when works of harvester and transport are organized correctly. The number of trucks must be counted for these tasks. This work shows technology for carrying out coordination during the loading and unloading works. But it doesn't allow to make the management decision for the choice of trucks when the demand of transportation is changeable.

The research [7] is devoted to studying of features of the transport process which is carried out by main types of transport in a supply chain of grain. Authors have carried out the detailed analysis of advantages of the use of each transport group. But, the presented mathematical models don't give an opportunity to develop the management decision. That is only a resulting component which shows which variant of transportation of grain will have more priority.

From the point of view of the interaction of transport with a terminal system, such works [8, 9] are interesting. It is executed on the example of the functioning of passenger terminal systems. In this research for coordination work of the passenger terminal, the principles are used, which can be partially transferred at the creation of the management decision to control a grain cargo flows. This system is based on the forecasting models of demand for transportation.

A feature of a research [10] is a selection of the principles for effective management of transport considering a factor of demand for transportation of specific cargoes: machines, agricultural equipment, and military deliveries. At the same time approach is interesting, first of all, because of a type of the message in which cargoes are sending – international and irregularities of deliveries by analogy with the option of sending grain to the sea terminal. The models presented in work allow optimizing the time spent by the vessel in the port, which helps to calculate the best versions of schedules of the arrival of automobile transports for loading the ship. However, they are based on the heuristic principles which aren't allowed to the counting of a fuzzy factor in the studied process.

Authors of work [11] consider the efficiency of the supply chain, based on expected values of demand for transportation and based on the coordinated work of transport and mechanisms for unloading. The existence of reliable information is the main factor for next research. Due to this aspect, it is possible to develop the operating influences directed to the improvement of the process of grain transportation to the port. However, these models don't work in the period with short-time of planning when it is necessary to make quickly the correct decision considered with a fuzzy factor.

Increase in management efficiency of the system of delivery of cargoes with the use of logistic terminals and obtaining synergetic effect due to optimization of the technological and management decisions directed to resource-saving technology and synchronization of logistic flows are offered by the author in a work [12]. However, questions of research aren't considered to the problems about the correlation of trucks work and unloading point.

The presented approach of authors [13] allows rationalizing structure of the park of containers which pass through a terminal complex. The approach is based on obtaining the forecast of future volumes of transportation based on the classical probabilistic principles. The system can't be used in full when the delivery of grain cargoes is planning via the sea terminal, because doesn't allow to make quickly management decisions.

In work [14] authors, the principles of functioning of the sea terminal with the unsteady of the input and output cargo flows are considered in detail. The optimum time spent by the vessel at the mooring is defined. However, there is no decision-making technique based on several factors. In particular, taking into account parameters of work of the park of trucks.

Researches in work [15] are devoted to the representation of a technique of definition of delays of the train in comparison with

the time-table. The presented model allows developing flexible time-table of train service to avoid delays on arrival on the station. Some principles can be used for coordination of work of participants of the offered supply chain. However, this approach was applied only on the example of railway transport and doesn't consider a factor of fluctuations in demand for transportation.

According to the strategy by the ministry of Ukraine [16] the development of loading capacities in the port and of providing the transport delivery of grain and other agricultural products offered will increase. Therefore, the relevance of development of correct management decisions is increased. The first steps in this direction are taken. So, in work [17] the technique of the choice of a rational range of piggyback traffic cargo delivery in the international message is offered. It is based on the determination of equilibrium value of the distance of transportation for alternative options: deliveries by the truck in through traffic and piggyback traffic delivery. However, in work, there are no recommendations concerning the choice of rational decisions at delivery chain option "a grain elevator - the sea terminal" when freight vehicles make a transportation in this part of supply chain. It especially is relevant in connection with the start of the new sea terminal with modern capacities [18].

In works [19-22] the basic principles of synchronization of work of various categories of transport and the choice of the best options based on the principle of the minimum expenses are worked out. However, for grain transportation, the offered models will work on condition of the constant demand for cargo flow, but that in principle isn't observed. The existence of fluctuations in demand during delivery of grain to the port is caused by essential jumps in the price of this product in the world markets. That's why the producer of grain has a desire to sell products more expensively. And consequently, about the regularity of grain supply to the port of the speech doesn't go. Therefore, for planning it is necessary to use approaches which consider with the fuzzy factors.

The research [23] became one of the closest works in the context of the considered problem. In this work, the author has offered the schedule of the technological process of functioning of production and transport. This approach is directed on the coordination of technology in work of the interconnected enterprises at the organization of piggyback traffic delivery in operating conditions with a cluster of a transport and logistics. However, the chosen level of planning isn't in a short period. Therefore, the system of support of decision-making will has a glitch during delivery of grain crops to the port. At the same time, the offered development is ideal for inclusion in a supply chain of railway transport.

In researches [24, 25] authors have offered an approach to regulation of arrival of cargo land transport in the port based on the known schedule of arrival the ship to the port. As a basic model, the classical task of linear programming is used. This method can't eliminate a fuzzy factor which arises during delivery of corn to the sea terminal.

Work [26] is devoted to the maintenance of sufficient level of reliability in a chain of deliveries. The planning is made on principles based on exactly expected volumes of transportation. This approach isn't approved for cargo flows which have seasonal nature of demand, such as agricultural products.

Division of levels of management of cargo transport during delivery of goods through transit's warehouses is supposed in work [27]. However, the submitted analysis is only the recommendation for development of the models allowing to make correct management decisions.

For creating a mathematical model which would consider technological features of the process of delivery in the considered supply chain for determination of the optimum volume of simultaneous supply of grain to the terminal of port and for determining an optimum interval of supply. Introduction of technology on the basis of the received optimum parameters will allow making the increased efficiency of use of the cargo vehicles and production capacity of the port terminal [28]. Reduction of operational costs will lead to the minimum of the final export cost of agricultural goods which is transported via the sea terminal.

Thus, it is necessary to apply fuzzy logic to the elaboration of the rational list of management impacts on the considered supply chain. This mathematical apparatus allows to achieve the best results at the existence of a large number of indistinctly certain factors.

3. The Basic Part of the Study

3.1. Purpose of Research

To develop a set of management decisions for the formation of the rational park of vehicles in the conditions of the stochastic nature of demand for transportation of grain on the part of a chain, "a grain elevator - the sea terminal".

3.2. The Mathematical Model to Define a Basis for a Research Which Helps to Achieve the Main Goal

The choice of the effective management decision at short-time of planning by work of trucks, even more, becomes complicated for the considered part of a supply chain named "a grain elevator - the sea terminal". It is caused by the fact that the relations with preference between separate variants of alternative decisions are described as fuzzy. This fact is caused, first of all, by indistinctly at the set of alternatives. Therefore, mathematical apparatus of the fuzzy sets theory allows to facilitate significantly formalization and to successfully solve a problem of formation of the rational park of cargo vehicles in the conditions of the existing uncertainty.

In the role of mathematical model for planning of short-time period in the work of the trucks transporting on the part of a supply chain named by "a grain elevator - the sea terminal", is offered for use the fuzzy module of management. It will allow considering a fuzzy character of the input information based on approximate calculations. The input information is presented as inexact certain parameters, restrictions, and criteria which were got from the detailed analysis of technology of the short-time of planning by transportation.

Therefore, the set of all admissible alternatives for the creation of the most rational management decision on formation of rational structure of the park of trucks has been revealed based on the analysis and on the basis of the available information on the studied system.

It has allowed to create the system with two inputs $X_i \in \{\Delta SD; LC\}$ and one discrete output $Y_i \in \{MD_i\}$, where the discrete values $MD_i = md_1, md_2, ..., md_n$, corresponding to one of decision-making levels. For this purpose, the studied object is presented in the form of a cybernetic model of a black box (Fig.2):

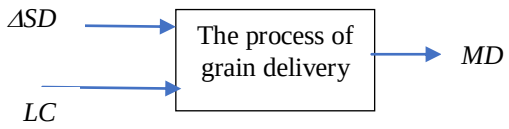

Fig. 2: The cybernetic model of a black box for the formation of the rational sizes of the park of trucks for grain transportation ΔSD - the expected rates of change in demand for transportation of agricultural cargoes during a planning period, т; LC - the optimum level of uploading of the cargo vehicles; MD_i - the management decision directed to the formation of rational structure of the park of trucks for the short-time period of planning.

At the same time object function for formation of rational structure of the park of trucks for transportation of agricultural goods to the sea terminal will have the following appearance:

$$MD_i \in \{md_1, md_2, ..., md_n\} \to rational\ . \quad (1)$$

For the effective organization of transportation of agricultural cargoes by automobile transports, timely application of the regulating measures is necessary for adjustment taken plans to the development of the potential volumes of cargo. Within a task of control, the management decisions concerning definition and preservation at the optimum level of a ratio between the nominal uploading capacity of the vehicles involved in the delivery process and the actual quantity of agricultural cargo, which are in sea terminal and between cargo capacity of the ship, are made.

Proceeding from the aim of research in a mathematical formula is realized as the problem of search of the rational management decision and it looks as follows:

$$X_i \in \{\Delta SD; LC\} \Rightarrow Y \in \left\{MD_i = md_1, ..., md_n, n = \overline{1,7}\right\} \to rational\ . \quad (2)$$

Based on the retrospective analysis about parameters of the functioning of the system on the delivery of grain to the sea terminal by the trucks was studied the formation principle of influences of the management. A possible set of alternatives consists of seven levels of decisions on management of the system of transportation of grain. They are presented in Table 1.

Table 1: Levels of management decisions

Level of management	Symbol	Describing of management decision
I	md_1	not to change quantity and the uploading capacity of the trucks which are carrying out the delivery of agricultural cargoes
II	md_2	to reduce the uploading capacity of the cars transporting agricultural cargoes
III	md_3	to increase the uploading capacity of the trucks transporting agricultural cargoes
IV	md_4	to reduce the number of trucks
V	md_5	to increase the number of trucks
VI	md_6	to reduce the number of trucks, with a simultaneous increase in uploading capacity of the vehicles which have remained for grain transportation
VII	md_7	to increase the number of trucks, with simultaneous reduction of uploading capacity of the rolling stock which is necessary for transportation of grain to the sea terminal

The technology of expeditious regulation provides carrying out forecasting of demand for the delivery of agricultural cargoes to port. This is relevant when necessary to make a forming of the qualitative structure at the park of trucks. The principle of "the remote horizon" within planning of the short-time period is applied to the adequacy of results.

The reservation of the rolling stock and formation of routes has to happen in an interval between arrival of two ships to the port before organizing the transportation of grain. Usually this period doesn't exceed seven days. Week term if necessary allows to carry out full coordination in work of all participants of a supply chain at the part "a grain elevator - the sea terminal". This reduces possible losses of grain because of idle time and reduces an expensive component. Also, the specified period of planning allows to make corrections to the schedule of work or a route of the transportation by the trucks if there is an unplanned need.

Therefore, the first entrance variable of fuzzy model is associated with the parameter of upload of object of identification, i.e. at the supply chain on the part of "a grain elevator - the sea terminal". A speed of change in demand is determined how the expected rates of change of this indicator on transportation of grain in an interval between arrivals of two ships, i.e. for the planning period:

$$\Delta SD = \frac{D_{after}^{sh2} - D_{befor}^{sh1}}{I_{sh1}^{sh2}}\ , \quad (3)$$

D_{befor}^{sh1} – the actual value of demand of the uploading capacity of trucks before the arrival of the first ship to port, i.e. for the beginning of the planning, т; D_{after}^{sh2} - forecasting value of demand for transportation of grain before arrival of the second ship in port which is defined on the basis of the loading of the terminal with grain and an uploading capacity of the ship, tons. Considers a tendency of change of demand for transportation; I_{sh1}^{sh2} - An interval between arrivals in the port of the previous and subsequent ships, days. This indicator characterizes the time horizon of planning in the transportation process.

In case the results of calculation of dependence (3) will reach the negative value then it demonstrates a necessary of the decrease in volumes of transportation. An exit, in this case, is a reduction in the number of trucks or uploading capacity of them, maybe a reduction of these two parameters at the same time. If a value stays positive, then the demand of transportation of grain is increased. This fact says about the need to increase opportunities of carrying for the park of trucks.

The second entrance factor in an object of a research characterizes a condition of profitability of work of cars. the optimum level of uploading of the park of trucks characterizes expediency of their use on the considered region of service. The optimum value of this parameter is defined by proceeding from simultaneous performance of two conditions of the presented system of inequalities:

$$LC = \begin{cases} LC_{opt}^{auto} \geq LC_{\min}^{-30\%} \\ LC_{opt}^{auto} \leq LC_{\max}^{+30\%} \end{cases}\ , \quad (4)$$

LC_{opt}^{auto} - the optimum level of uploading of a set of the trucks of the deliveries which are carrying out the delivery of grain at a supply chain on the part of "a grain elevator - the sea terminal"; $LC_{\min}^{-30\%}$ - average value of the minimum admissible level of uploading of trucks which transport agricultural cargoes; $LC_{\max}^{+30\%}$ - average value of the most admissible level of uploading of trucks which transport agricultural cargoes.

The dependence (4) makes sense if the value $LC_{\min}^{-30\%}$ isn't less than 30% of a ship cargo capacity. As the big difference can't be compensated for the account of reserves of grain which can be in a storage of the sea terminal. A similar decision is present when the second condition of the system of inequalities is relevant (4). This means that optimum level of uploading of trucks doesn't exceed $LC_{\max}^{+30\%}$ more than for 30%. т One week prior to the arrival of the following ship, that means that it is inexpedient to create an excess reserve of grain in storage in port. In this case, the goods can lose the qualitative characteristics and will not conform to standards of export delivery.

This approach allows to rationalize the process of the organization of delivery of grain at supply chain in the part of "a grain elevator - the sea terminal" and to reduce losses from the use of an excess number of the rolling stock by a full satisfaction of demand for transportation.

3.3. The Research Results

The functional method of definition of a form of representation of fuzzy terms can be used based on the continuity of a set of basic values of input variables [29, 30]. The analysis of the theory of fuzzy logic has shown that in practical applications the triangular, trapezoid and bell-shaped functions of accessory have gained the greatest distribution. Its parameters allow changing a form of function (Gaussian). Therefore, the analytical model of functions

of accessory of a variable x_k simple and convenient for control, is proposed to any fuzzy term T_k^p in next form:

$$\mu(T_k^p) = \left(\frac{x_k - b_k^m}{c_k^m} \right)^{\exp}, \quad (5)$$

b_k^m и c_k^m - settings of function of accessory; b_k^m - function maximum coordinate; c_k^m - coefficient of concentration of function.

Input parameters of the model are presented in the form of linguistic variables which values are defined on a uniform scale from five terms for all $x_k, k = \overline{1,m}$. This is proceeding from the considered restrictions and requirements.

For control of functions of accessory, it is necessary to set quantitative characteristics of the input parameters which are described by own term-number. At the same time according to classical provisions of the theory of fuzzy sets quantitative characteristics of the input parameters are presented indistinctly in the form of set of linguistic variables. They can be divided into three groups. More detailed division of terms into linguistic variables (LV), for example on five categories, is in certain cases as the next dividing:

- L – the low value of parameter;
- LA – the value of parameter is lower than an average;
- A – average value of an indicator;
- HA – the value of parameter is higher than an average;
- H – the high value of an indicator.

The set of a term-number is created from a physical sense of an indicator and the existing operating conditions of trucks in the transportation of grain (Table 2).

Table 2: linguistic variables of the entering parameters

Name of linguistic variable	Symbol	Separation of terms-number	Characteristics of terms-number
The expected rates of change in transportation demand of agricultural cargoes	$LV(\Delta SD)$	more negative	Loading of the ship happens to a delay because of the absence of reserves
		not so negative	Loading of the ship happens at the expense of the reserves of grain which are on the terminal up to 30%
		middle value	Loading of the ship happens by direct variant from the trucks to the vessel
		not so positive	A full load of the ship and creation of the greatest possible reserve of grain
		more positive	The idle time of cars because of the need of unloading of an excess of grain in the terminal
An optimal level of loads in the trucks	$LV(LC)$	below optimum	The opportunity of carrying is 30% less than cargo capacity of a vessel
		optimum	Carrying opportunities are equal to cargo capacity of a vessel
		above optimum	Carrying opportunities exceed a cargo capacity of a vessel by 30%

The submitted characteristic the terms-number will allow to carry out correct control of function of accessory and to choose the best option for formation of space of fuzzy certain input factors for search of the rational management decision at the organization of grain transportation process at a supply chain on the part of "a grain elevator - the sea terminal" during the short-time of planning.

4. Conclusion

The results of a research have proved the division of management decisions on the formation of rational structure of the park of trucks based on fuzzy nature of the input parameters. In total seven levels are allocated. Values of the input factors in the form of a set of linguistic variables are proved for the creation of the correct management decision. Under the developing set of fuzzy terms which characterize levels of uncertainty of each of the input factors, control of functions of accessory will be carried out. They will help to construct universal space on a search of the rational management decision at the organization of delivery of grain to the sea terminal. Similar approach removes a factor of fuzzy of the made decision at the short-time period of the planning of transportation process. This moment guarantees acceptance of correct management impact on the system in the conditions of a rapidly changing situation. As the further research direction, beside development of space of fuzzy certain input parameters, the forecast of demand for transportation of grain in every period based on neural networks will be performed.

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