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LOGISTICAL SYSTEM FORTSCHRITTZAHLEN IN THE MANAGEMENT OF THE SUPPLY CHAIN OF A MULTI-FUNCTIONAL GRAIN COOPERATIVE

Abstract. In the article features of implementing one of types of "pulling" logistical system Fortschrittzahlen in management of a cooperative grain chain have been provided. The status of the cooperative elevator has been identified as a focus line of this chain in accordance with parameters of SCOR-model. Author's methodology of realization FZ concept in multifunctional grain cooperative based on linear programming method has been processed. Differentiated system of qualitative-quantitative variables in the context of agro-technical periods, agricultural crops and farming enterprises has been suggested. A complex of author's limitations for the economical-mathematical model of the task has been developed. Formulas for describing limitations concerning costs on cooperative elevator services, number of orders for daily processing, time of produce storing without drying, probability of a high demand and selling price of produce have been introduced. Typical model of logistical management in multifunctional grain cooperative has been grounded. The processed model at developing the program of supplying produce by farms to an elevator in conditions of a certain cooperative has been approved.

Key words: logistics, cooperative elevator, Fortschrittzahlen-System, methodology, linear programming

JEL Classification: ***C61,*** M19, Q12, Q13

Introduction

In the world the most widespread forms of carrying out agrarian entrepreneurship are a private-corporate and farm-cooperative. On their basis two main models of logistical organization of the agrarian business are formed: corporate and cooperative.

An example of the latter is a multi-functional agricultural grain cooperative. Within this cooperative, which is created by its members-farming enterprise as a rule there is an elevator which is used by many farmers. A cooperative elevator unlike a commercial elevator is a comparatively complex in interrelation management with its users and it is less economically stable commercial object. In the work of such a serving cooperative a set of limiting factors ("narrow places") is evident and members of a cooperative have either to take them for granted or as target objects for influence to reduce its activity (Frederico et al., 2011; Henderson, Executive, 2008; Hines, 2014; Krueger et al., 2000; Stone et al., 2000).

Moreover, a cooperative elevator has such main downsides in its activity as: critical dependence on price competitiveness of a cooperative elevator from the volume of factually ordered services by members of a cooperative, which retain the right of economic freedom concerning decision-making; necessity and complexity of coordinating intra-economic activity of farming members-enterprises with technological possibilities of a cooperative elevator; limitations in selection of crops for storing due to the high capital intensity of grain silos; comparatively lower possibilities for simultaneous acceptance on processing and storing grain of different crops and of one crop with different qualitative indices; absence as in many commercial elevators of reserve on covering technological expenses and expenses from profit deficiency due to formation of excess grain by increasing indices of its factual dockage and moisture; limitations in actions for many potential participants of a cooperation – customers of services which is such a great competitive advantage known as convenient “transport shoulder” concerning a cooperative elevator versus its commercial analogues and so on.

Nevertheless, the model of organizing services for retailing agricultural producers itself makes possible to protect their economic interests in the most favorable way and creates condition for performing a competitive business activity.

At that for decreasing certain downsides in the management system of management over a multi-functional grain cooperative it is worth using effective systems for coordinating intra-economic activity of farming enterprises-members with technological possibilities of a cooperative elevator.

One of the most effective systems for realizing this purpose can be a logistically-organized “pulling” operational system Fortschrittzahlen.

Nowadays different logistically-organized operational systems are used in the world practice with focus on coordinative activity of subgroups in time to make necessary amounts of produce and at a certain period of time. At that within the system the “pushing” initiative belongs to lower links of the supply chain, which push objects in the material flow, at the same time the initiative of placing orders in the “pull” system is shown by higher links.

The former system implies “pushing” of the early planned party of material objects on the following operations (processes) and it cannot be predicted in what quantity (amount) these objects are necessary at each specific period of time. The latter system is built on the directly opposite approach. If in the “pushing” system on the “output” we receive what was at the “input”, in the “pulling” system in business processes in the “input” we have what is needed at the “output”. In practice it means that in the latter example objects in the material flow come in the corresponding amount at the exact necessary moment

Fortschrittzahlen-System (FZ) is a system which develops the connection “quantity-time” in correspondence of planned and factual parameters. The feature of this system is the direction at managing the whole material flow in coordinates of the quantitative-timely transformation. The conditions for applying the FZ operation system in the logistical management over the supply chain are the following: 1) series-produced or mass type of production; 2) logistical integration of suppliers in the supply chain; 3) integration of informational systems in the supply chain (Hernández, 2003; Ostertag, 2008; Pohl, 2002).

State of the art

The issues of logistical management over the supply chain have been studied by such scientists as J. Blackburn (2012), M. Chakkol (2014), M. Christopher (2011), L. Haak (2010), A. Harrison (2011), S. Sohn (2012), M.A. Souza (2013), D.H. Taylor (2009) and others.

At that the study of the logistical system Fortschrittzahlen has been carried out since the 80s of the XX century and it has caught the attention of R. Hernández (2003), R. Ostertag (2008), K. Pohl (2002) and others.

General issues of modeling and linear programming of managerial decisions in logistics have been studied by W. Dangelmaier (2013), Y.H. Hsieh (2010), N.R. Sanders (2005), D. Schweiger (2010), F. Soliman (2011), P. Stingl (2002) and others.

Logistical management and modeling in the management of the supply chain directly in the agricultural cooperatives and grain elevators have been the main focus of studies carried out by F.C. Coléno (2015), C. Hines (2014), Z. Huang (2013), D.S. Lobo (2011), G.A. Mosher (2012), A.A. Rentizelas (2009), L. Ruiz-Garcia (2010), M. Thakur (2009), H. Zhang (2009) and others.

For most contemporary researches the object of studying logistics is focused within the material flow. Thus M. Chakkol (2014), M. Christopher (2011), A. Harrison (2011), M.A. Souza (2013) equate entrepreneurial logistics with integrated logistics or with the theory of management over flows. Moreover the principle of systemic integration is considered by them as the main fundamental principle of the economical logistics and SCM concept.

At that T. Pizzuti et al. (2012) in the system of management over the supply chain of the agricultural produce paid attention to the fact that the model of the process and flow in general must be obligatory integrated with the data model.

S. Sokhansanj et al. (2006) developed a complex logistical model of supplying biomass into total networks of the material flow. To major extent this model is oriented at quantitative-timely indices of the concept FZ and makes possible to imitate the process of gathering, storing and transportation of agricultural produce. The component of this development is a system of managing lines in the process of mass servicing. Moreover this model considers factors of different weather conditions, expected qualitative indices of produce as well as possible harvest losses.

Sh.M. Schlecht et al. (2004) worked on the model of managing grain flow in the supply chain using systems MRP based on the concept "pushing".

M. Thakur et al. (2011) developed a model of internal management at the elevator which might simultaneously support both "pushing" and "pulling" operational systems. The model is oriented at optimization in using limited resources and minimization of elevator costs.

Risk management over qualitative-quantitative parameters of the process of storing grain at elevators by estimating different scenarios of the research was studied by G. Mosher et al. (2013).

A. Krueger et al. (2000) studied on cooperative elevators ways of introducing a method of imitating modeling of quantitative-timely parameters in the system of grain dockage and drying.

F.C. Coléno and M. Hannachi (2015) developed the imitating model of management over the supply chain of grain traders when they use common infrastructure.

Z. Huang et al. (2013) defined the processes of integration and coordination as key factors for enhancing the performance of business activity of the service cooperative.

G.E. Ifenkwe (2012) and S. Thompson et al. (2014) while carrying out their own research on agricultural cooperation used separate components of the "pulling" logistical concept.

Herewith in most scientific works the introduction of the "pulling" system Fortschrittzahlen into supply chain management mainly occurs at industrial enterprises. Thus R. Ostertag (2008) developed based on principles of system FZ a model of coordinating and planning the supply chain in the automobile industry. Linear optimization of quantitative-timely parameters is of great importance in the methodology of this approach.

Unsolved parts of the issue

At the same time possibilities of applying in the sully chain management of "pulling" logistically organized operational systems in the field of agricultural cooperatives remain insufficiently studied. Mainly it concerns their types such as system FZ which is oriented at mass type of agrarian and particularly grain production.

Moreover there is no clear identification of the status of links in cooperative grain chains by parameter of the SCOR-model.

Besides discussion is still going on concerning key means (instruments) of rationalistic logistics in managing certain business process in multifunctional grain cooperatives (Velychko, 2014).

The existing models of management in such cooperatives are not directly focused on realization of principles (philosophy) of Fortschrittzahlen and they are insufficiently integrated with logistical methods in general.

The method of linear programming is management studied better in modeling internal processes of grain elevators. At the same time it is less studied at optimization of quantitative-timely parameters of cooperative interaction of the elevator with the customer of services.

Purpose, materials and methodology of the research. The purpose of the research is to process the author's model of planning managerial decisions in a multifunctional grain cooperative based on principles of the logistical system FZ, as well as approval in practical conditions.

Such a model implies the development of certain methodology; its application will provide the possibility to receive specific quantitative-time parameters for rational organization of grain supply to the cooperative elevator.

For appraisal of such a methodology materials of agricultural service cooperative "Zernovuy" which is located in Ukraine on the territory of the Dnipropetrovsk region, have been used. Moreover data from 32 grain member-producers of this cooperative have been considered. Mainly those data are predicting indices based on previous experience and expected trends of their changes in 2016.

Moreover the empiric date included information about farming enterprises and cooperative elevator concerning sown areas, yield productivity at different agro-technical periods of gathering harvest, prices for services of commercial elevators at a certain radius of servicing, content of vehicle fleet of farming companies, amount and effectiveness of equipment on the elevator, expected demand and prices for selling the produce at the market based on analytical researches and marketing predictions, amounts of economical compensations (penalties) of the cooperative for failures in providing ordered services, requests considering ratio between processing and storing different crop yields on the cooperative elevator, potential producing capacities of the cooperative, minimal volumes of producing certain crops in accordance with orders of farmers in the cooperative and so on.

In the process of developing the author's methodology on realizing FZ system in management of multifunctional grain cooperatives the following generally accepted methods have been used: analysis and synthesis; special research methods: linear programming and theory of mass servicing. At that the main applied method was linear programming and the theory of mass servicing was an additional method in defining limitation parameters for economical-mathematical models of the task.

Methodology

Interaction between farmers and cooperatives must be sophisticatedly planned. Such a cooperative is a so-called "pulling" complex logistical system in which plans of producing by independent farmers should be arranged based on the program of loading their cooperative elevator (the highest link). At that in the system of "pushing" the initiative belongs to lover links in the supply chain which push objects in the material flow, while in the "pulling" system the initiative of orders is shown only by highest links.

The purpose is to develop the optimal program for a cooperative elevator. Then it will be the base for arranged (coordinated) recommended production plans for farming enterprises-members of a cooperative but not on the contrary as it traditionally happens in the work of commercial elevators.

The realization of the logistical concept FZ in the supply chain management of a multifunctional grain cooperative may be provided using the method of linear programming. At that variables in this economic-mathematical task have only quantitative-timely parameters of the system FZ, and limitations – consider and regulate the most essential starting conditions of the efficient functioning of this supply chain.

Setting a task. The members of the grain cooperative are *N* number of farming enterprises. The enterprises specialize in producing produce *M* of agricultural crops and an elevator is used for storing it.

As variables we took amounts of produce supply on the cooperative elevator in the specific time from particular farming enterprisers-members of the cooperative. At that the supply rime was differentiated in the context of three agro-technical periods of harvesting works: optimal, possible and unfavorable.

Such differentiation of timely periods makes possible to set a wide range of estimating alternatives with the existence of a major set of limitations in the organization of the cooperative elevator activity. At the same time the number (amount) of produce supply by the optimal plan of the elevator loading is the starting point for processing producing programs of independent workers-members of the servicing company.

At that the systems of variables (possible quantitative-timely parameters) itself with significant number of small members of the cooperative and high level of diversification in their production manufacturing is quite numeral. However it does not influence the methodological process of describing and solving such a task and practical importance of its results.

While describing quantitative-timely parameters of the logistical system FZ of a multifunctional grain cooperative are grouped at three levels: I – by farming enterprises; II – by agricultural crops; III – by agro-technical period to perform harvesting works.

Hence harvesting works for each *M* crop are carried out at a certain agro-technical period which can be optimal, possible and unfavorable.

The number of days for carrying out harvesting works during the optimal agro-technical terms for *i*-crop will be denoted as $n_i \ (i = \overline{1,\ M})$. Analogically the number of days of carrying out harvesting works in possible and unfavorable agro-technical terms will be denoted as $k_i \ (i = \overline{1,\ M})$ and $l_i \ (i = \overline{1,\ M})$ correspondingly. Hence the total term to perform harvesting works in days in total consists of three periods and equals

$$L_i = n_i + k_i + l_i \ (i = \overline{1,\ M}) \tag{1}$$

To more convenience of denoting variables and limitations we will use the following denomination

$$K_i = k_i + n_i \ (i = \overline{1,\ M}) \tag{2}$$

Formation of variables in the task

The desired quantities will be denoted as:

$x_{ij}^{(s)}$ $(i = \overline{1,\ M};\ j = \overline{1,\ N};\ s = \overline{1,\ n_i})$ - amount of supply to a cooperative elevator of *i*-crop by *j*-farming enterprise on the *s*-day of optimal agro-technical terms of carrying out harvesting works, t;

$x_{ij}^{(s)}$ $(i = \overline{1,\ M};\ j = \overline{1,\ N};\ s = \overline{n_i + 1,\ K_i})$ - amount of supply to a cooperative elevator of *i*-crop by *j*-farming enterprise on the *s*-day of possible agro-technical terms of carrying out harvesting works, t;

$x_{ij}^{(s)}$ $(i = \overline{1,\ M};\ j = \overline{1,\ N};\ s = \overline{K_i + 1,\ L_i})$ - amount of supply to a cooperative elevator of *i*-crop by *j*-farming enterprise on the *s*-day of unfavorable agro-technical terms of carrying out harvesting works, t;

Besides we will introduce *M* additional variables. Variable y_i will denote the total general amount of the harvested produce of *i*-crop in all farming enterprises.

System of limitations in the task

Correlation between main and introduced additional variables make the first group of *M* limitations

$$\sum_{j=1}^{N}\sum_{s=1}^{L_i} x_{ij}^{(s)} = y_i \ \ (i=\overline{1,M}) \tag{3}$$

The second limitation considering the amount of costs on services of the cooperative elevator for a separate farming enterprise (considering losses while carrying out harvesting works in post-optimal agro-technical terms)

To provide price competitiveness of the cooperative elevator compared to services of commercial elevators in the area it is necessary to predict volume limitations on costs on its services. Factual variable expenses per one weight unit of *i*-crop produce of *j*-farming enterprise with processing and storing on the cooperative elevator will be denoted as λ_{ij} $(i = \overline{1,\ M};\ j = \overline{1,\ N})$. It also includes possible harvest losses caused by harvesting works in post-optimal agro-technical period.

Constant total costs that are total costs for processing and storing of one weight unit of *i*-crop produce on the cooperative elevator in total will be denoted as $\Lambda_i \ (i = \overline{1,\ M})$. Minimal price for services of the commercial elevator in money units for *i*-culture will be denoted as $\mu_i \ (i = \overline{1,\ M})$. So we have *M* limitations

$$\frac{\sum_{j=1}^{N}\lambda_{ij}\sum_{s=1}^{L_i} x_{ij}^{(s)} + \Lambda_i}{\sum_{j=1}^{N}\sum_{s=1}^{L_i} x_{ij}^{(s)}} \le \mu_i \ (i = \overline{1,\ M}) \tag{4}$$

The third limitation considers the number of vehicles necessary for servicing on the cooperative elevator per one day.

The total number of vehicle trips for servicing on the cooperative elevator per one day must not exceed *Z*. Average carrying capacity of *j*-vehicle of the farming enterprise will be denoted as $w_j\,(j=\overline{1,N})$, and total mass of the produce which must be transported to the elevator will be denoted as $B_i(i=\overline{1,N})$. Then $\frac{B_i}{w_i}$ equals the number of vehicle trips for transporting a daily amount of grain harvesting from *j*-farming enterprise to the elevator, units. The limitation has the following form

$$\sum_{i=1}^{N}\frac{B_i}{w_i}\le Z \tag{5}$$

Limiting parameter *Z* in this limitation is defined on the base of the known methods of queueing theory concerning preparing decisions on managing queues in the cooperative elevator:

Intensity of the order flow (number of trips of vehicles with grain to the elevator from the farmers) is:

$$\lambda = Z\,/\,\mathrm{t}, \tag{6}$$

where *Z* – number of orders (trips of vehicles with grain to the elevator from the farmers) per day; t – length of the working day, hours.

Stress ratio coefficient for one channel of servicing orders equals:

$$\rho=\lambda\,/\,\mu\,, \tag{7}$$

where μ - intensity of servicing orders per one hour.

Additional value which indicates the part of the time of the downtime of the queueing system:

$$p_0 = 1(\,1+\frac{\rho^1}{1!}+\frac{\rho^2}{2!}+\frac{\rho^{k+1}}{k!(k-\rho)}), \tag{8}$$

where k - number of servicing stations.

Probability of the downtime of the servicing station without clients is defined by the following formula:

$$P_{downtime}=1-\rho\,/\,k\,, \tag{9}$$

Probability of customer queueing on the base is:

$$P_{queueing}=\frac{p_0\rho^{k+1}}{k!(k-\rho)}, \tag{10}$$

Average queue length is:

$$Z_{queueing} = \frac{k \cdot P_{queueing}}{k - \rho}, \tag{11}$$

Average time of vehicle's staying on the cooperative elevator including downtime and servicing is defined by the formula:

$$T = Z_{queueing} / \lambda + 1/\mu \tag{12}$$

Control index for setting the limiting level (number of orders (trips of vehicles with grain per day to the elevator from the farmers) per day) is the average time of vehicle's staying on the cooperative elevator considering downtime and servicing time (to be able to return to the enterprise and deliver the grain planned for harvesting to the elevator).

Correspondingly the necessity for the limited level of time for downtime and servicing a vehicle on the elevator makes possible to use the methodology of the queueing theory as the imitation model (by the way of substitutions) to define the limiting level for task limitations as number of orders (trips of vehicles with grain to the elevator from the farmers) per day.

The fourth limitation concerning the transportation of the total amount of plant produce grown in all farming enterprises and included in the plan of ordering services on processing and storing tзамовлення послуг з доробки і зберігання, to the cooperative elevator.

F_i will be denoted as the minimal amount of plant produce of *i*-crop grown in all farming enterprises and included into the plan of servicing orders on processing and storing to the cooperative elevator.

Then to keep the transportation conditions for total amount of plant produce by separate crops we have the group of *M* limitations:

$$y_i \geq F_i \quad (i = \overline{1,\ M}) \tag{13}$$

The fifth limitation concerning the maximal time of staying (storing) the harvested produce without drying:

$$\frac{K_V * y_i - \frac{F_z - B_z}{100 - B_z} * 100 * y_i}{S_E(\sum\limits_{i-1}^{M} y_i + 0{,}001)} + T \leq D \quad (i = \overline{1,\ M}) \tag{14}$$

where $\sum\limits_{i=1}^{M} y_i$ - total amount of produce supply from farmers to the cooperative elevator for the period of harvesting, t.

$\frac{F_z - B_z}{100 - B_z} * 100$ - Duval's formula, using which we define sizes of grain waste products after cleaning on the elevator before drying;

F_z - factual level of grain dockage, %;

B_z - basic level of grain dockage, %;

K_V – coefficient of maximal variation of the average size of food supply from the farmers to the cooperative elevator per day;
0.001 – artificial additional item which will make impossible situation with dividing per zero and at that minimally influence the precision of calculations;
S_E – productivity of equipment on the cooperative elevator on grain drying, t/day;
T – average time for transporting from the field, internal transportation in the joined group on the elevator by temporarily current-technological lines, storage on asphalt areas at not-mechanized or partly-mechanized warehouses and shelters as well as grain cleaning on a separator, days
D – maximally acceptable time for produce harvesting without drying.

The sixth limitation concerning the amounts of simultaneous storing of all crops for short-term, middle-term and log-term storing in the cooperative elevator.

The number of silos on the cooperative elevator for storing different crops is limited. At that during the marketing year, corn or sunflower may be for example moved to silos for short-term of middle-term storing which were freed from wheat and barley. All that to a certain extent will influence the solving of the task and correspondingly – processing of the recommended production plan for farming enterprises.

While planning volumes of placing grain for storing in the limitation Duval's formula was also used for more precise considering a potential level of simultaneous storing the produce grown in the farming enterprises-members of the cooperative.

Depletion of volumes of simultaneous placing all types of crops for short-term, middle-term and long-term storing in the cooperative elevator provides the following limitations:

$$\sum_{i=1}^{M} y_i - \frac{F_z - B_z}{100 - B_z} * 100 * \sum_{i=1}^{M} y_i \le V_z \tag{15}$$

The seventh limitation concerning the probability of a high demand and possibility for significant volume of sales of different crops.

In the methodology separate elements of the "decision tree" model which are connected with probable estimations of realizing possible ideas. The limiting level for such estimation is defined by management of the cooperative based on agreement with heads of farming enterprises. The essence of limitations is in defining weight-average probable estimation by the expected market conjuncture concerning each type of the produce, which can be produced and stored by farming enterprises on the cooperative elevator.

Thus, for example, predicting probabilities of estimating potential demand for corresponding produce in the following marketing year can be described.

Probabilities are defined based on observing analytical researches and marketological prognosis of the grain servicing cooperative by all crops which are used for growing in farming enterprises for the next commercial year.

In order to provide the probability of a high demand and possibility to sell major amounts of different crops in group we build the corresponding limitation.

The predicted probabilities of a high demand and possibility to sell major amounts of crops are defined based on examination of analytical and marketological examinations of the grain servicing cooperative by all crops which are planned to be planted in the farming enterprise s in the following commercial year. We will denote as p_i the probability of a high demand

and possibilities of selling major amounts of produce for *i*-crop, and ass P^* - the lower limit of the mentioned probability. Then we have the following inequality

$$\frac{\sum_{i=1}^{M} p_i * y_i}{\sum_{i=1}^{M} y_i} \geq P^* \tag{16}$$

The eighth limitation concerning the probability to get a big margin for sales of the produce via the cooperative (for all crops) by the farming enterprise.

To a major extent the profitability of the farming business will depend on low prime cost of production and favorable situation at the market. Therefore in the limitations of the task the predicted probabilities are considered, these probabilities are connected with the derivation from the first and second index from margin of futuristic sales.

The probability to receive a high margin by farming enterprises through sales of *i*-crop produce via the cooperative will be denoted as r_i, and R^* - lower limitation of the mentioned probability.

$$\frac{\sum_{i=1}^{M} r_i * y_i}{\sum_{i=1}^{M} y_i} \geq R^* \ (17)$$

The ninth limitation concerning agro-technical requirements is in the square of technical crops for each separate farming enterprise.

The amount of plant produce of technical crops is limited by agro-technical requirements by square of each separate farming enterprise. Total area under crop of *j*-farming enterprise will be denoted as $S_j (j = \overline{1,N})$, and average crop capacity of *i*-crop in this enterprise – as U_{ij}. Then the total area of technical crops in *j*-enterprise can be calculated using the following formula $\sum_{i \in Q_j} \frac{\sum_{s=1}^{L_i} x_{ij}^{(s)}}{U_{ij}}$ and the limitation is:

$$\sum_{i \in Q_j} \frac{\sum_{s=1}^{L_i} x_{ij}^{(s)}}{U_{ij}} \leq \rho_j S \tag{18}$$

where S – value of percentage area of technical crops.

The tenth limitation concerning the possible payment of penalties by the farming enterprise for the unrealized commitment on processing (cleaning and drying) grain in the cooperative elevator.

As $g_i^{(1)}$ we will denote the size of the penalty per weight unit of *i*-crop $(i = \overline{1, M})$, and $G_i^{(1)}$ - maximally possible sum of sanctions for all farming enterprises in total. Hence the size of production of i-crop in j-enterprise is $\sum_{s=1}^{L_i} x_{ij}^{(s)}\ (i=\overline{1,M})$, corresponding to the number of crops we will receive the following limitations

$$\sum_{j=1}^{N} g_j^{(1)} \sum_{s=1}^{L_i} x_{ij}^{(s)} \le G_i^{(1)}\ (i=\overline{1,M}) \tag{19}$$

The eleventh limitation concerning the possible payment of penalty sanctions by the farming enterprise for the not kept commitment on grain storing on the cooperative elevator.

Besides economical compensations of the cooperative can be connected with failure to comply with orders on grain storing on the elevator. Then the following limitation of the task can be formulated.

As $g_i^{(2)}$ we will denote the size of the penalty sanction per weight unit of i-crop $(i=\overline{1,\ M})$, and as $G_i^{(2)}$ - maximally possible sum of such sanctions for all farming enterprises in total. Then we have the group of limitations which are similar to the previous ones

$$\sum_{j=1}^{N} g_j^{(2)} \sum_{s=1}^{L_i} x_{ij}^{(s)} \le G_i^{(2)}\ (i=\overline{1,M}) \tag{20}$$

The twelfth limitation concerning the ratio between volumes of processing and storing of different crops on the cooperative elevator.

As H_1 we will denote the multiplicity, elements of which are indices of those crops which are included in the first group and multiplicity H_2 analogically includes indexes of crops of a different group. If the ratio between amounts of processing and storing of different groups of cultures on the cooperative elevator has the form $\gamma \div 1$, then we have the limitation:

$$\sum_{i \in H_1} y_i \le \gamma \sum_{i \in H_2} y_i \tag{21}$$

The thirteenth limitation concerns minimal amounts of loading capacities of the elevator for possible payments of fine sanctions to the members of the cooperative from failure to comply with the stated provision of services.

The possibility to change the use of the elevator service by monetary compensation of a farming enterprise as a rule is limited and diverse by different crops.

Based on the previously indicated features of co-working between farmers and servicing cooperative concerning regulation of possibility to change the use of technological or logistical services per monetary reimbursement limitations may take the form and a certain weight-average percent from the amount of the ordered services or a specific fixated amount in quantity. It is described by the corresponding limitation in the context of separate crops.

We will denote q_{ij} as a percentage index for possible substitute of using elevator services by the monetary compensation for i-crop in j-farming enterprise, and as Q_{ij} - minimally possible amount of produce supply of the crop to load elevator capacity per possible payments of penalties by members of the cooperative from the not provided but ordered services. We have the following limitations:

$$(1-q_{ij})\sum_{s=1}^{L_i} x_{ij}^{(s)} \le Q_{ij}\,(i=\overline{1,M};\, j=\overline{1,\,N}) \tag{22}$$

The fourteenth limitation concerning potential (maximal) productive capacities of the members of the cooperative by each culture according to favorable conditions.

Potentially average multi-year volumes of aggregated production of the crop which can be in the elevator are included in limitations. At that the limiting maximal amount must be defined by each separate crop and it should be the sum of data on all farming enterprises. But certain increases of average potential capacities are possible in the optimal plan by one crop or another in each specific enterprise they could be partially corrected after solving the task by two means: 1) increase in the planned level of ratio of commodity and length of the sales period by separate types of produce; 2) partial correction of the previous project in the structure of areas under crop.

We will denote it as $R_i\ (i=\overline{1,M})$. We receive *M* of such limitations:

$$\sum_{j-1}^{N}\sum_{s=1}^{L_i} x_{ij}^{(s)} \le R_i\ (i=\overline{1,M}) \tag{23}$$

The fifteenth limitation considers fixated (minimal) volumes of production in agricultural crops in separate farming enterprises (by notes approved by members of the cooperative).

We will denote N^* as a multiplicity with elements – indices of those enterprises which have contracts with elevators considering granted supplies of certain types of crops.

M_j^* - Multiplicity which elements are indices of those crops of *j*-farming enterprise, concerning them, fixated (minimal) volume of production (agreed by applications of farmers with the cooperative).

We receive the following group of limitations

$$\sum_{s=1}^{L_i} x_{ij}^{(s)} \ge E_{ij}\ (j\in N^*; i\in M_j^*) \tag{24}$$

where E_{ij} - caused by contracts minimal amount of supply to the *i*-crop produce by the *j*-farming enterprise.

The sixteenth limitation concerns daily harvesting produce by each crop.

For each enterprise it is necessary to carry out prognosis concerning daily maximal possible volumes of harvesting produce by each crop. We will denote as $W_{ij}^{(s)}\ \ (i\ =\ \overline{1,\,M};\, j=\overline{1,\,N};\, s=\overline{1,\,L_i}\,)$ the upper limit of the amount of the harvested produce of *i*-crop in *j*-farming enterprise on the *s*-day of optimal agro-technical terms for harvesting works.

Then this value for possible terms of carrying out harvesting works equals $\sigma_1 W_{ij}^{(s)}$, and for unfavorable terms– $\sigma_2 W_{ij}^{(s)}$, де σ_1 та σ_2 - some coefficients which corrugate the value $W_{ij}^{(s)}\ \ (i\ =\ \overline{1,\,M};\, j=\overline{1,\,N};\, s=\overline{1,\,L_i}\,)$.

Then we will have 3 groups by M limitations in each one which consider upper limits of volumes of produce supply to the cooperative elevator depending on optimal, possible and unfavorable terms of supply.

$$x_{ij}^{(s)} \leq W_{ij}^{(s)} (i = \overline{1, M}; j = \overline{1, N}; s = \overline{1, n_i}) \quad (25)$$

$$x_{ij}^{(s)} \leq \sigma_1 W_{ij}^{(s)} (i = \overline{1, M}; j = \overline{1, N}; s = \overline{n_i + 1, K_i}) \quad (26)$$

$$x_{ij}^{(s)} \leq \sigma_2 W_{ij}^{(s)} (i = \overline{1, M}; j = \overline{1, N}; s = \overline{K_i + 1, L_i}) \quad (27)$$

The seventeenth limitation concerning non-negative character of variables.

The last limitation will be of a technical character and provide non-negative character of the received data or quantitative-timely parameters of the system FZ.

So, this group of trivial limitations which correspond to the non-negative character of variables:

$$x_{ij}^{(s)} \geq 0 \; (i = \overline{1, M}; j = \overline{1, N}; s = \overline{1, L_i}) \quad (28)$$

Formation of the objective function

Considering that the cooperative elevator in the supply chain in a multifunctional grain cooperative is a focus link and the concept FZ is a "pulling" logistically organized operational system, the objective function of the task must be focused on maximal loading of capacities of such an elevator. Considering the content of many suggested limitations it completely corresponds to the idea of building an effective logistical cooperative in general as well as individual interests of its members.

As an optimization criterion the maximal value of loaded capacities of a cooperative elevator during the whole commercial (marketing) year is taken.

By y_i we denote the volume of loaded capacities of the cooperative elevator by production of i-crop, gathered from all farming enterprises $(i = \overline{1, M})$. Total loading of elevator capacities is a sum of possible values of those indices.

The objective function has the form:

$$\sum_{j=1}^{M} y_j \rightarrow max \quad (29)$$

Maximal loading of capacities with processing and storing n the cooperative elevator provides minimization of service costs for farmers-members of the cooperative (saving on constant costs). At that the model considers may other significant interests of farming enterprises (potential incomes, structure of areas under crops, and so on). Therefore such maximization will completely correlate with the interests of those who created the cooperative and used its services.

Results and discussions

Application of the processed methodology for implementation of the logistical system FZ should be carried out concerning separate processes in the links of the supply chain in the multifunctional grain serving cooperative (Fig. 1).

Hence the concept Fortschrittzahlen as a type of the "pulling" system can perform starting with the process of cleaning, drying and storing of the grown grain and other produce on the cooperative elevator and ending up with the final stages of purchasing, storing and supplying material resources to the manufacturing process of the members of the cooperative.

At the same time unfavorable agro-technical terms unlike other separate crops, by wheat were not included in the solution of the purpose.

The applied author's methodology is primarily focused on the chain "processing and storing produce on the elevator" and "approval by cooperative-members of production programs".

Moreover it was used to realize the logistical system FZ under conditions of managing the supply chain of the agricultural servicing cooperative "Zernovuy". Members of that multifunctional grain cooperative are over 30 farming enterprises with total arable area from 50 to 1000 ha. The elevator with maximal capacity 36,000 tons was designed in the cooperative. Carrying capacity of the elevator per day is about 2,000 tons.

Calculation of economical-mathematical model with corresponding system of variables and limitations enabled authors to receive optimal quantitative-time parameters of FZ system in the form of graphs and amounts of the providing produce by members of the cooperative to their own elevator. For that purpose as variables we defined the planned amounts of certain type of produce from a certain farming enterprise on the appointed day of gathering harvest (optimal, possible, and unfavorable). Thus, for example, X1 – amount of providing winter wheat to the cooperative elevator by farming enterprise "Zorya" on the first day of optimal agro-technical conditions for gathering works. The planned structure of arable lands of all members of the cooperative "Zernovuy" for 2016 includes such cultures as winter wheat, spring barley, turnip, corn for grain and sun flower.

Based on that fact 4088 variables have been formed which were placed into the matrix of linear programing tasks. Moreover 384 limitations have been described which were included into 17 groups according to the methodology suggested by authors. The limitations have been formed using variables and a large array of empiric output data in conditions of activity of farming enterprises and cooperative "Zernovuy". Objective function of the task was determined as maximal loading on capacities (amounts of processing and storing) for the elevator of cooperative "Zernovuy" during the marketing year.

The solution of the formed matrix of linear programming was carried out in software Excel. The example of the received results in the form of distributing matrix on one of the farming enterprises demonstrates the fact that the range of variables (X1-X126) before the solution included only 26 of them and the rest had zero values (Table 1).

At that daily volumes of wheat supply vary significantly during the calendar year. It is connected with different expectations about level of crop yield by agro-technical approaches, as well as with the partial shift in time of harvesting winter wheat, barley, rape. Therefore during the days of such shifting in wheat supply to the elevator, even optimal agro-technical period is limited. Specific calendar data can be in fact corrected depending on weather conditions.

In total the efficiency function enables us to maximize loading of capacities of the elevator "Zernovuy" casued by requests from its own members at the level of 84%.

The received optimal schedules of supply by all crops in the future may become the basis for developing individually-approved production programs by members of the cooperative for a certain marketing year and then plans of purchasing material-technical resources through the cooperative. Hence supply chain management in the cooperative "Zernovuy" effectively performs by principles "pulling" logistical system FZ.

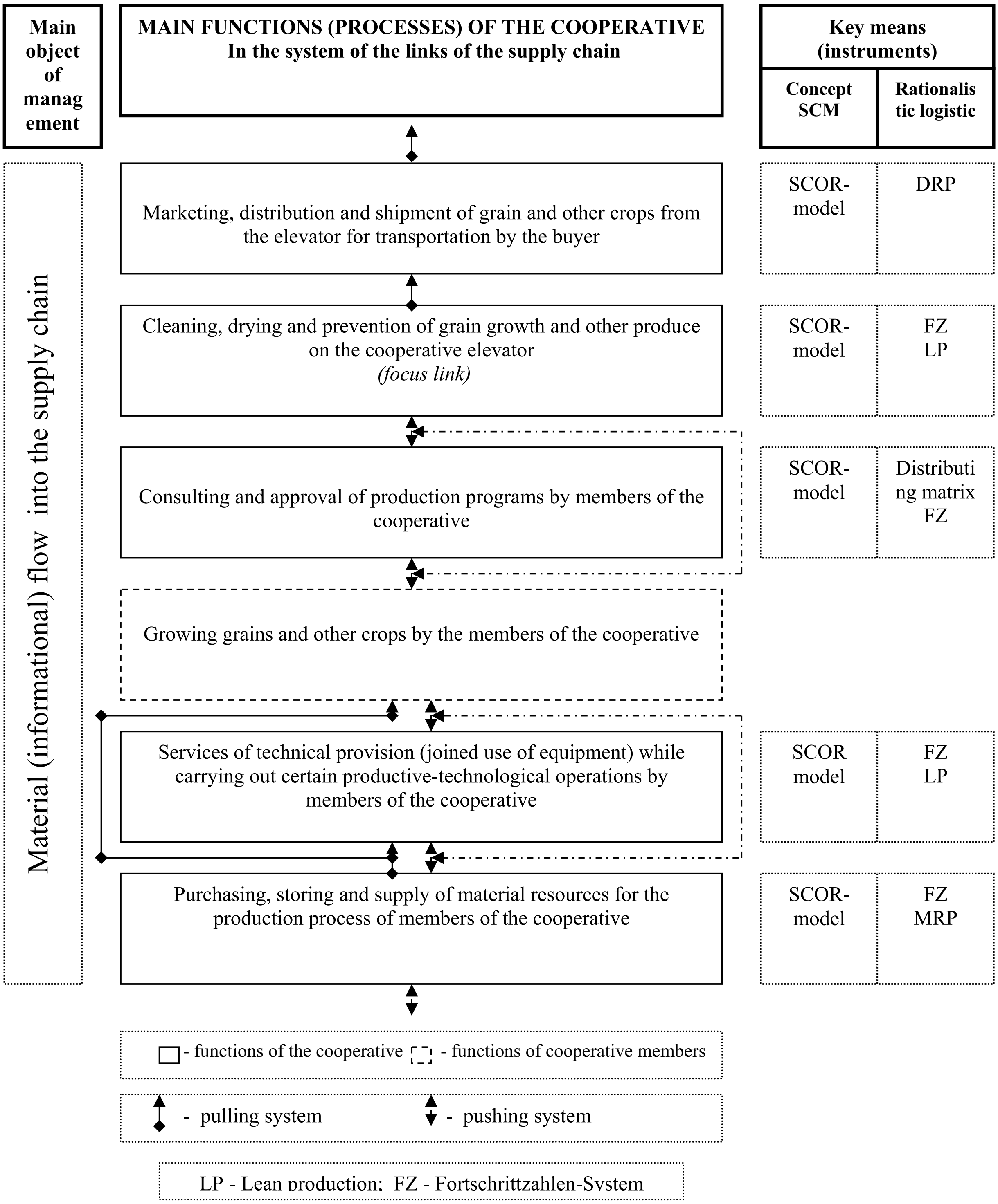

Fig. 1. Model of logistical management in multifunctional grain processing cooperative «Zernovuy»

Source: author's development

Table 1. Quantitative-time parameters of FZ concerning produce supply by farming enterprise "Zorya" (№ 1) to the elevator of cooperative "Zernovuy" in 2016 (according to the results of solving the models of linear programming)

Culture	Agro-technical terms	Variables	Values, tons	Culture	Agro-technical terms	Variables	Values, tons
WINTER WHEAT	optimal	X1	48,1	TURNIP	possible	X64	0,0
		X2	38,2			X65	0,0
		X3	0,0			X66	2,3
		X4	0,0			X67	0,0
		X5	94,3		unfavorable	X68	0,0
		X6	0,0			X69	0,0
		X7	0,0			X70	0,0
		X8	0,0			X71	0,0
		X9	78,1			X72	0,0
	possible	X10	0,0			X73	0,0
		X11	0,0			X74	0,0
		X12	0,0			X75	0,0
		X13	0,0	CORN FOR GRAIN	optimal	X76	0,0
		X14	0,0			X77	24,2
		X15	0,0			X78	38,4
		X16	0,0			X79	0,0
		X17	70,3			X80	23,5
	unfavorable	X18	0,0			X81	0,0
		X19	0,0			X82	0,0
		X20	0,0			X83	0,0
		X21	0,0			X84	0,0
		X22	0,0		possible	X85	0,0
		X23	0,0			X86	0,0
		X24	0,0			X87	0,0
		X25	0,0			X88	24,5
SPRING BARLEY	optimal	X26	0,0			X89	0,0
		X27	0,0			X90	0,0
		X28	0,0			X91	0,0
		X29	24,2			X92	0,0
		X30	0,0		unfavorable	X93	18,7
		X31	12,5			X94	0,0
		X32	0,0			X95	0,0
		X33	0,0			X96	0,0
		X34	0,0			X97	0,0
	possible	X35	0,0			X98	0,0
		X36	0,0			X99	0,0
		X37	11,2			X100	0,0
		X38	9,8	SUN FLOWERS	optimal	X101	0,0
		X39	0,0			X102	0,0
		X40	0,0			X103	25,2
		X41	0,0			X104	18,7
		X42	0,0			X105	14,2
	unfavorable	X43	0,0			X106	0,0
		X44	0,0			X107	10,2
		X45	5,6			X108	0,0
		X46	0,0			X109	0,0
		X47	0,0		possible	X110	0,0
		X48	0,0			X111	0,0
		X49	0,0			X112	15,4
		X50	0,0			X113	0,0
TURNIP	optimal	X51	0,0			X114	0,0
		X52	0,0			X115	21,5
		X53	3,2			X116	0,0
		X54	5,4			X117	0,0
		X55	0,0		unfavorable	X118	0,0
		X56	0,0			X119	0,0
		X57	0,0			X120	12,4
		X58	0,0			X121	0,0
		X59	0,0			X122	0,0
	possible	X60	0,0			X123	0,0
		X61	4,5			X124	0,0
		X62	0,0			X125	0,0
		X63	0,0			X126	0,0

Source: author's development.

Based on such distributing matrixes by each farming enterprise the optimal schedule-plan on food supply to the cooperative elevator by all cultures was drawn.

Hence, for example, the optimal schedule for winter wheat from farming enterprises completely involves both optimal and possible agro-technical terms of harvesting works (Fig. 2).

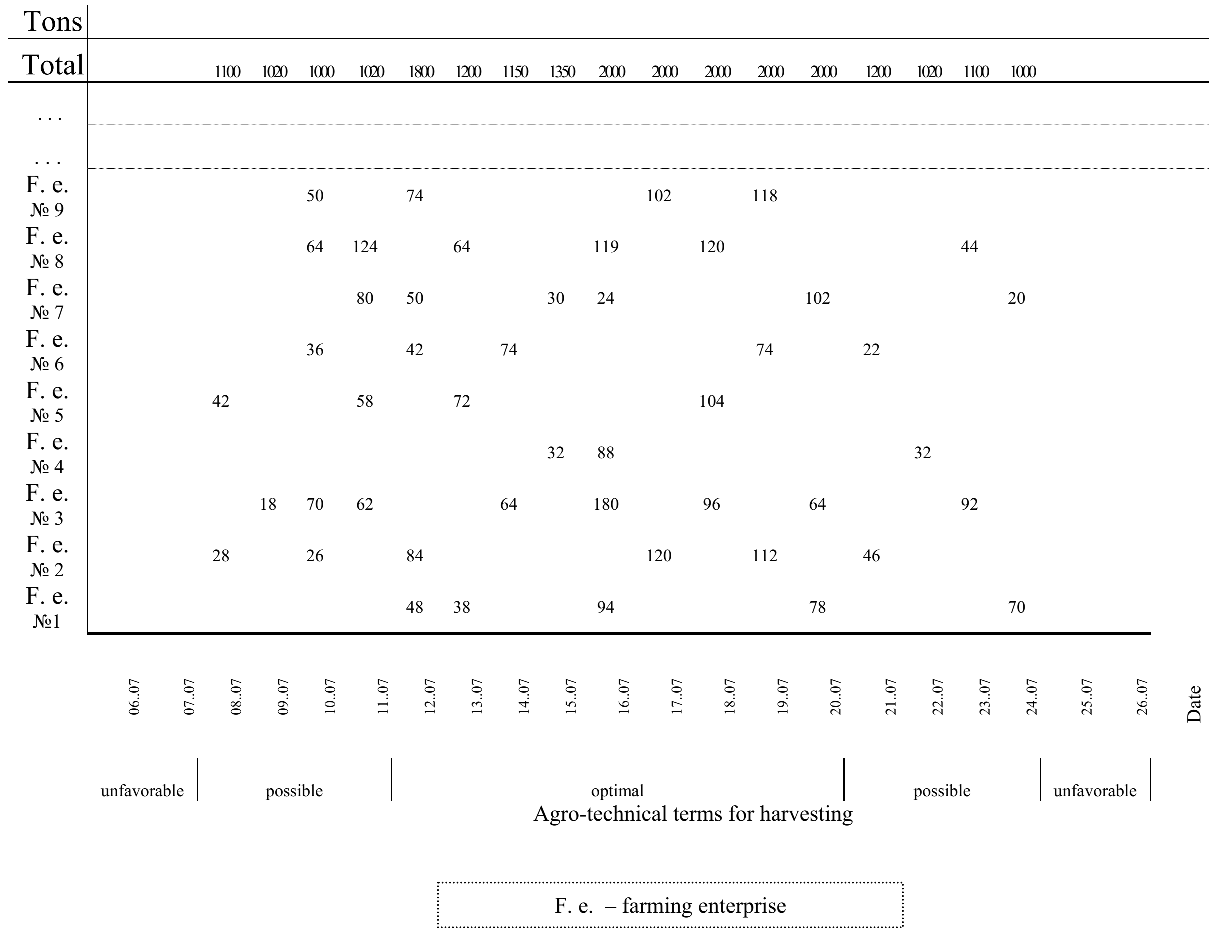

Fig. 2. Fragment of the optimal supply schedule of winter wheat to the cooperative elevator by members of the cooperative "Zernovuy", year – 2016 (project)

Source: author's development

At that the existing methods of organizing management over cooperative elevator are grounded on principles "pushing" logistical systems (MRP, DRP and others) but the method of linear programming is used at optimization of mainly internal business processes on elevators or agrarian enterprises. The advantages of the author's methodology are that it is focused on realization of the "pulling" logistical system FZ through integration with the method of linear programming. Despite certain heavy efforts at formation of the model task matrix such inverse approach enables authors to develop the clear and precise plan to supply produce to the cooperative elevator, provide maximal loading of its capacities and consequently to minimize expenses of farmers-members of the cooperative on using services of such an elevator.

Conclusions

In business processes management in the grain cooperative it is reasonable to use such a type of the "pulling" logistical system as Fortschrittzahlen. It provides efficient logistical integration of information system links in the cooperative supply chain. At that the cooperative elevator should be considered as a focus line for this chain.

Effective realization of quantitative-timely parameters of the concept FZ in management of the cooperative may be carried out using the method of linear programming. The methodology of this process requires identification of the system of variables, limitations and efficiency function of the task. Herewith variables must include quantitative-timely parameters of the system FZ and be the volumes of the production supply to farming enterprises-members of the cooperative to their own elevator at a strictly assigned time. The time of the production supply must be considered in the context of three agro-technical periods with different influence on crop yield and total yield.

The suggested limitations consider such indices as price competitiveness of the elevator services, capability of simultaneous serving customers, grain placing for storing, probability of a high demand and prices for produce selling, agro-technical requirements, possibility to pay penalty sanctions by the members of the cooperative and so on.

Considering the purposes of the FZ, as “pulling” logistical system, the efficiency function should be focused on maximal loading of capacities of the cooperative elevator.

Significance for theory: the methodology of applying principles of the FZ system found further development in the multifunctional grain cooperative based on means of linear programming.

Significance for practice: the received with the help of this methodology optimal program to supply produce to the elevator based on principles of FZ may become the basis for coordinated production plans of the members of the cooperative.

Further researches are reasonable to be focused on methodological means of realizing other “pulling” systems in the logistical supply management chain.

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