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CONSULTING SUPPORT OF LOGISTIC TECHNOLOGIES OF GRAIN TRANSPORTATION BASED ON INDUCTIVE TECHNOLOGY OF SIAR

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Designing of effective technologies of grain harvesting transportation in large farms considered from the standpoint of inductive technologies of system information-analytical research and mathematical modeling of complex systems. Approach, tools and the obtained results are suggested to apply in modeling units of computerized advisory (consulting) systems in such directions.
Keywords: Logistics technology, combine-harvesters, system-analytic research, inductive approach, modeling.

Конструювання ефективних технологій транспортування зерна від комбайнів у крупних фермерських господарствах розглянуто з позицій індуктивних технологій системних інформаційно-аналітичних досліджень і математичного моделювання складних систем. Підхід, інструментарій та отримані результати пропонується застосовувати в моделюючих блоках комп'ютеризованих консалтингових систем даного напрямку.
Ключові слова: Логістична технологія, зернозбиральний комбайн, системно-аналітичне дослідження, індуктивний підхід, моделювання.

Конструирование эффективных технологий транспортировки зерна от комбайнов в крупных фермерских хозяйствах рассмотрено с позиций индуктивных технологий системных информационно-аналитических исследований и математического моделирования сложных систем. Подход, инструментарий и полученные результаты предлагается применять в моделирующих блоках компьютеризованных консалтинговых систем данного направления.
Ключевые слова: Логистическая технология, зерноуборочный комбайн, системно-аналитическое исследование, индуктивный подход, моделирование.

INTRODUCTION

Analysis of the traditional model of grain transportation on direct transport indicates the presence of high labor costs and capital costs associated with increased time to change expectations loading vehicles. This is especially true when using a vehicle carrying high when one bunker combine traditional enough to fill dump trucks. To reduce costs, especially for high-duty vehicles, transshipment technology is used to transport grain shoulders “combine-reception center”, which involves the use of assembly-transport complex consisting of: combine harvesters, trailer-reloaders as equalizers interoperable and highly automobile transportation tools [1].

Therefore the problem of optimizing the processes of collection and transportation of grain harvesting by identifying patterns influence the composition, structure and parameters of complex technical means to minimize costs, is relevant.

PURPOSE OF WORK

It is necessary to create the information base for the development of the document that would be simple and at the same time sufficient for the decision making process of synthesis the flexible logistics technologies for gathering and transporting grain from combines to granaries. Such technologies should be maximally adapted to the specific industrial, economic, technical and other conditions during harvesting. The such document, as an innovative product, under submitted approach may be a concept of so-called consulting package.

RESULTS AND DISCUSSION

Formation sufficient to develop of consulting package information basis was carried out by inductive technology of system information-analytical research (IT SIAR) [1], [2]. The procedure could be represented as follows.

Stage one. Initial information basis formally has been described as:

$$I_b^1 = (N_{gh};\, N_{tr};\, N_{veh};\, S_{nat};\, P_{tec}^*), \tag{1}$$

where: N_{gh} – grain-combine harvester with the specification features; N_{tr} – trailer-reloader with the specification features; N_{veh} – vehicle with the specification features; S_{nat} – natural and production conditions specified and zoned in places; P_{tec}^* – profitability of constructed final flexible logistics technology.

Stage two. Experts in this task advocated the transportation technologies specialists that did not take direct participation in this research problem. The formalized portrait of Consulting Package (CP) was formally described by experts in such matrix of benchmark result [2] (fragment):

$E(R^0(I_b^0)) =$

9	9	7	8	8	5	4	0
7	8	7	8	7	5	0	0
6	8	8	8	5	6	0	0
9	7	5	6	8	6	7	8
9	8	7	8	9	9	7	8
8	7	8	9	8	7	8	0
9	8	7	9	9	8	8	0
3	3	2	2	1	1	1	0

In the first column of the matrix shown the concerted assessment of section importance of the final consulting document. The following columns reflect expert assessments concerning the relevant parameters of the group optimal information basis [1]. The first four rows of this matrix to a certain extent overlap with initial information basis I_b^1 (see *Table 1*).

Starting from the 5th row and to 8th - reflected a higher level of requirements experts doubt regarding the required processing of the final sections of the document, including (in rows):

5 – circuit synthesis of harvesting and transport processes;

6 – technical and economic analysis of optimal assembly-transport technology transportation (ATTT);

7 – forecasting of economic efficiency of selected ATTT;

8 – applications (graphics, additional tables, numerical data, etc.).

Table 1

Initial information basis on project synthesis of flexible ATTT

No.	Group (№, name)	No.parameter in group	Symbol	Parameter name and unit of measure
1	**I. Grain-combine harvester**	1	W_k	nominal performance, t / h
2		2	N_k	engine power, kW
3		3	G_k	consumption, kg / kW. h
4		4	C_k	combine cost, UAH
5		5	V_k	grain hopper capacity, m^3
6		6	$W_{шк}$	performance grain auger of harvester, t / h
7	**II. Trailer - reloader**	1	$V_б$	capacity of trailer-reloader, m^3
8		2	$N_{пп}$	claims tractor engine power, kW
9		3	$g_{тр}$	specific fuel consumption, kg / kWh
10		4	$C_{пп}$	trailer-reloader cost, UAH
11		5	$W_{шп}$	performance grain auger of trailer-reloader, t / h
12	**III. Vehicle**	1	g_a	carrying capacity of car, t
13		2	$Q_н$	normative fuel consumption, l / 100 km
14		3	C_a	cost car, USD
15		4	v_a	technical vehicle speed, km / h
16		5	$D_{пал}$	type of fuel (diesel, gasoline, gas)
17	**IV. Natural and production conditions**	1	$K_{пр}$	complex factor of natural-production conditions
18		2	$K_{пог}$	coefficient of a suitable weather
19		3	$T_{агр}$	agro-terms (during of harvest) days
20		4	U	productivity, t / ha

21		5	*S*	field area, ha
22		6	*L*	rut length L, m
23		7	*l*	distance (shoulder) of carriage, km

IT SIAR for create the final information basis gave the necessary for the accepted statistical criteria informational material to constructing the models of effective technologies and logistic chains of moving grain from harvesting to collection points in time in large grain farms.

It should be noted that in the final description of logistics processes through the use of IT SIAR was also took into account the effect of factors that affect the cost and process modes (varying size at harvest parcel of ground, road conditions, the reliability of the machines, technical and operational performances and economic parameters of machines as well, etc.).

On the third stage of the research was formed the set factors, numeric values are later used as input data for econometric modeling. These numerical values were obtained during of field research during the harvest grain handling using technology in farms Mykolaiv, Kyiv and Chernigiv regions [3].

With this set of conditions, typing overall functioning of harvesting and transport processes in the course of the study was divided into several classes, each of which has its own laws were the relations of elements, baseline characteristics and so on.

This basis has been proposed by two independent performers groups (analysts) and agreed by all experts with almost identical estimates. That is why the approval procedure of expert estimates was practically redundant, but for the sake of completeness the technology IT SIAR was performed.

The criterion of consulting efficiency at choosing of best solution (variant of technological transportation), expedient and natural to select an integrated economic indicator. Logically, such integral indicator was adopted aggregate level cost of a variant of logistics technology from harvesting grain transportation to destinations in farming in UAH per 1 ton of grain during collection and transport (ISO 4397: 2005).

This synthesized information base for econometric models of the common type:

$$I^*_{b,s} = \{W_k / x_1,\ Q_n / x_2,\ Q_a / x_3,\ V_a / x_4,\ T_{pa} / x_5,\ U / x_6,\ S / x_7,\ T / x_8,\ L / x_9\}, \qquad (2)$$

where:

W_k / x_1 – performance combine harvester, t / h;

Q_n / x_2 – load capacity of the trailer-conveyors, t;

Q_a / x_3 – load capacity of the vehicle, t;

V_a / x_4 – technical vehicle speed, km / h;

T_{pa} / x_5 – length of the vehicle stay on the elevator, h;

U / x_6 – grain crop capacity, t / ha;

S / x_7 – area of harvesting crops, ha;

T / x_8 – duration of the combine per day, h;

$L\ /\ x_9$ – transportation distance of grain from the field to the elevator, km.

Numeric input data for modeling (fragment) are presented in *Table 2*. The penultimate column of Table 2 shows the modeled value of the output value $E_{пм}$.

Stage four. The modeling. Were built the regression models in the environment of professional package IBM.SPSS.Statistics [5]. It was supposed to build a model that would best identify formed as a result of technological research logistics chain.

Table 2

Initial data for modeling and output (Epm) (fragment) [3, 4]

E_{nf} /Y	W_k /x_1	Q_n /x_2	Q_a /x_3	V_a/x_4	T_{pa}/x_5	U /x_6	S /x_7	T/x_8	L/x_9	$E_{пм}$	δ
1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
239,79	7	15,0	14	30	0,1	3	500	10	5	237,19	2,60
162,99	12	22,3	20	40	0,3	5	1500	12	10	184,54	-21,55
149,74	17	30,0	24,5	50	0,5	7	2500	14	15	133,91	15,83
247,36	7	22,3	14	30	0,1	3	500	10	5	244,80	2,56
259,23	7	30,0	14	30	0,1	3	500	10	5	252,82	6,41
171,30	12	14,0	20	40	0,3	5	1500	12	10	175,89	-4,59
167,72	12	30,0	20	40	0,3	5	1500	12	10	192,56	-24,84
240,64	7	15,0	20	30	0,1	3	500	10	5	230,77	9,87
240,87	7	15,0	24,5	30	0,1	3	500	10	5	225,95	14,92
163,71	12	22,3	24,5	40	0,3	5	1500	12	10	179,72	-16,01
239,28	7	15,0	14	40	0,1	3	500	10	5	231,74	7,55
238,98	7	15,0	14	50	0,1	3	500	10	5	226,28	12,70
163,63	12	22,3	20	30	0,3	5	1500	12	10	189,99	-26,36
162,61	12	22,3	20	50	0,3	5	1500	12	10	179,08	-16,48
159,16	17	30,0	24,5	30	0,5	7	2500	14	15	144,82	14,34
150,12	17	30,0	24,5	40	0,5	7	2500	14	15	139,36	10,76
240,20	7	15,0	14	50	0,3	3	500	10	5	227,17	13,03
241,42	7	15,0	14	50	0,5	3	500	10	5	228,06	13,36
161,85	12	22,3	20	50	0,1	5	1500	12	10	178,19	-16,34
163,37	12	22,3	20	50	0,5	5	1500	12	10	179,97	-16,61
140,32	17	30,0	24,5	50	0,1	7	2500	14	15	132,13	8,19

140,82	17	30,0	24,5	50	0,3	7	2500	14	15	133,02	7,80
232,02	7	15,0	14	50	0,1	5	500	10	5	223,03	8,99
213,64	7	15,0	14	50	0,1	7	500	10	5	219,77	-6,13
156,22	12	22,3	20	50	0,1	3	1500	12	10	181,45	-25,23
163,89	12	22,3	20	50	0,1	7	1500	12	10	174,94	-11,05

The simulation results for selecting of existing or constructing new variants of effective transportation technologies from harvesting grain to the elevator during harvest were as follows.

Model 1(M1). In view of the significant difficulties in obtaining relevant information, the obvious is to build and practical use of the most simple models. Studies such opportunities was also in sight of this work.

Structure information basis for constructing the model M1 was very simple:

$$I_b^*(M1) = \{W_k / \text{x}_1, V_a / x_4, U / x_6, \ S / x_7\}. \tag{3}$$

But it is worth noting that such simple model (see *Table 3*), while showing high predictive properties have significant drawbacks: small changes in the information may seriously impair basis such as predictive models.

The relative error of approximation models determined by the formula:

$$\Delta_j = \frac{1}{n}\sqrt{\sum_{i=1}^{n}(E_{пф}^i - E_{пм}^i)^2} \times 100\% = \frac{1}{n}\sqrt{\sum_{i=1}^{n}\delta_i^2} \times 100\%. \tag{4}$$

where: n – number of options logistics technologies, which are included in the training model, δ_i^2 – squared deviations of model outputs $E_{пм}^i$ and actual data $E_{пф}^i$ for the i-th logistics option.

Model 2 (M2). This variant also foresaw the application of coercive regime of include all variables in the model. From the other words, simulation was carried out at the level of parametric identification without busting structures. Baseline data were taken from the results of the previous system information-analytical research of problem, which was conducted to the stage of modeling. Structure information basis for constructing the model M2:

$$I_b^*(M2) = \left\{W_k / x1; \ Q_a / x3; \ V_a / x4; \ U / x6; \ S / x7\right\}. \tag{5}$$

Model 3 (M3). Model M3 by power of ensemble of informational factors on the one hand and the number of options process (originally of many hundreds of them were selected based on the results SIAR), and on the other hand, is the most powerful due to the objective conditions the formation of optimal information basis. An important innovation point in this case is that essentially differentiates this model from many other approaches is that, in contrast to conventional requirements for the maintenance by one trailer of three combines, in model M3 this requirement not respected and the number of trailers is determined by technological need and at any time. Structure information basis for constructing the model M1 was as:

$$I^{*}_{b,s} = \{W_k / x_1,\ Q_n / x_2,\ Q_a / x_3,\ V_a / x_4,\ T_{pa} / x_5,\ U / x_6,\ S / x_7,\ T / x_8,\ L / x_9\}. \qquad (6)$$

Model 4 (M4). This model was called "The direct traffic". On power information base model M4 and the number of variants technological chain was almost the same as the model M3. That is, the optimal information basis for the synthesis of model M4 was the same ensemble as the model M3, except a trailer-loading parameter.

Obviously, the total cost of last technologies were more significant than in previous versions. Analytical models M4 is almost like a model M3, except, of course, option Q_n / x_2 (see model 4 in Table 3).

The average output error of model M4 did not exceed 9.8 UAH / tone in absolute terms, which corresponded to the value of 5.59% in relative terms. As with previous models, the relative error is defined by formula (4).

Table 3 presents all four types of models synthesized for the most typical options logistic chains with corresponding sets of factors.

Table 3

The synthesized model of harvesting and transport technology efficiency

No.	Model	Approximation accuracy
1.	$E_{пм} = 431,33 + 0,21x_1 - 0,86x_4 - 28,20x_6 - 0,01x_7$ $E_{пм} = 431,33 + 0,21W_k - 0,86V_a - 28,20U - 0,01S$	3,89%
2.	$E_{пм} = 411,548 + 0,334x_1 - 1,456x_2 - 1,136x_4 - 5,383x_6 - 0,049x_7$ $E_{пм} = 411,548 + 0,334W_k - 1,456Q_a - 1,136V_a - 5,383U - 0,049S$	5,79%
3.	$E_{пм} = 362,266 - 6,456x_1 + 1,042x_2 - 1,070x_3 - 0,545x_4 +$ $+4,451x_5 - 1,627x_6 - 0,013x_7 - 6,540x_8 + 2,396x_9$ $E_{пм} = 362,266 - 6,456W_k + 1,042Q_n - 1,070Q_a - 0,545V_a +$ $+4,451T_{pa} - 1,627U - 0,013S - 6,540T + 2,396L$	5,51%
4.	$E_{пм} = 362,266 - 6,456x_1 - 1,070x_3 - 0,545x_4 +$ $+4,451x_5 - 1,627x_6 - 0,013x_7 - 6,540x_8 + 2,396x_9$ $E_{пм} = 1022,615 + 23,320W_k - 11,964Q_a - 0,891V_a -$ $-40,102T_{pa} - 59,761U - 0,274S + 14,590T + 12,662L$	5,59%

Results of previous SIAR of logistic problems formed the creation basis of the consulting document for practical use in large agricultural grain companies.

Modern consulting services are usually regulated by the CP, which are often supplemented by the necessary software and customized information technologies. These packages are complete sets of final documents that are as result of execution of an innovative project that necessarily reflects the results of system information-analytical research facility of the customer and has usually advisory nature.

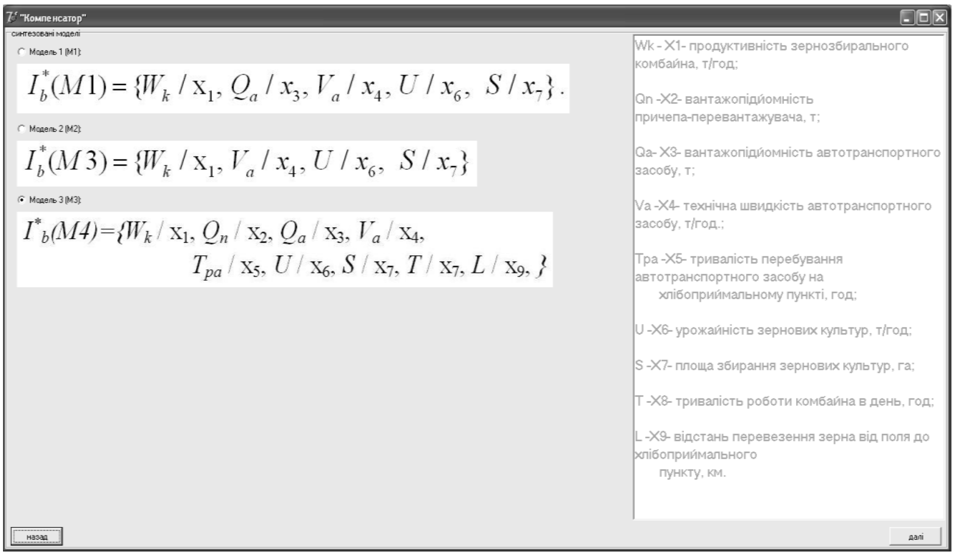
Obviously, these works belong to the class of re-engineering services [6]. Usually re-engineering as the direction of intelligent system outsourcing services are classified under three levels (on a scale increasing complexity) that define here as:

1) system analytical research of the object and (i) development of CP to optimize the client's business;

2) system analytical research of the object and (i) development of CP to optimize the client's business and (ii) mandatory implementation at customer objects for so-called scheme of "turnkey";

3) system analytical research of the object and (i) development of CP to optimize the client's business and (ii) mandatory implementation at customer objects for so-called scheme of "turnkey" and (iii) management in full volume of optimized business on customer objects.

Fig. 1 - 2 shows some basic layout blocks of consulting software system "Logistics of Harvesting " ("COMPENSATOR") realized on the algorithmic language C ++.



In the simplest case for a level 1 re-engineering consulting package (except for formal documents) consists of (1) a computer program, and (2) user manuals, which presented a detailed method of technical-economic evaluation of selected logistic scheme of moving grain from harvesting (simulation results) and described:

- procedure for gathering information of different levels of modeling;
- recommendations for the visualization and analysis of simulation results;
- recommendations for selecting of final results;
- recommendations on the feasibility of forecasting efficiency of selected of logistic scheme;
- other supporting information materials (nomograms, graphs, tables, etc.).

CONCLUSIONS

Use of system information-analytical research of a problem and his assembly-based simulation of transport processes using KS "COMPENSATOR" has allowed for scientists and experts as well as other researchers of Technical Institute of NUB&L of Ukraine to make a number of important conclusions which should be included in consulting packages as options for the practice of graining. Established, that in typical conditions steppe and forest-steppe zones are the most effective group of similar harvesting machines, thus reducing the total cost to an average at least of 50 UAH per ton.

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