MOTROL. Commission of Motorization and Energetics in Agriculture – 2015. Vol.17. No.7. 87-91

RESULTS OF EXPERIMENTAL STUDIES ON CHOICE OF AUTOMOBILE INTERCITY TRANSPORT DELIVERY SCHEMES FOR PACKAGED CARGO

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Summary. Experimental studies of transport and technological schemes of delivery (TTSD) for packaged cargo in the intercity by road transport using simulation have been resulted. Considering that each transport and technological schemes of delivery is the part of the logistic system of packaged cargo delivery in the intercity the analysis of the influence on the TTSD efficiency of technological and logistical parameters (TLP) has been carried out by using the regression analysis. The key request parameters and parameters, involved in the request implementation, of the freight owners, freight forwarders, carriers, terminals and external stochastic factors have been taken into account for the formalization of the initial data for the experimental studies of the model of delivery process for PC in the intercity. Principal variants of interaction between delivery process participants and the most significant TLP of TTSD for packaged cargo in the intercity by road transport have been taken into account in the obtained dependences. The conducted experimental studies using specialized software tools and regression analysis to process the experimental studies results have identifies TLPs that need to be optimized to substantiate the optimal TTSD variant for packaged cargo in the intercity by road transport for different logistic and supply chains.

Key words: delivery process, packaged cargo, intercity transportation, technological and logistical parameter, road transport.

INTRODUCTION

The chosen delivery scheme has a direct affect on the efficiency of packaged cargo (PC) intercity delivery by road transport [1-19]. If the TTSD is selected from the complete set of TTSD alternatives, such the scheme is considered to be optimal. It allows getting the maximum cumulative effect of all delivery process participants (minimum total costs of all involved in the delivery process participants) for each certain request.

Since TTSD are characterized by TLPs, the determination of the optimal transport and technological PC delivery scheme in the intercity by optimizing the TLPs of TTSD is an important problem that can be solved by determining the dependence of the efficiency criterion of TTSD operation on the main TLPs.

THE ANALYSIS OF RECENT RESEARCHES AND PUBLICATIONS

Theoretical studies towards the formation of TTSD for PC in the intercity with the detailed analysis of technological operations on a micron - level have been carried out by the authors in papers [20-22]. In [20,21] the structure of PC delivery logistic system (LS) with the specification of the transport interaction surroundings parameters has been proposed. It includes the four basic schemes of LSC describing the main types of the interaction between all participants of PC delivery in the intercity by road transport in accordance with their interests and capabilities. Wherein, the certain set of TTSD alternatives satisfies each LSC scheme [22]. To find the shortest path from the initial operation to a final operation studiers have proved the feasibility of using Dijkstra's algorithm. In this connection the using of variants of caused by processing operations events as the graph peaks and the technological operations cost as the length of the graph edges has been proposed. Thus, the developed models allow evaluating the efficiency of each delivery scheme alternative for certain request and selecting the optimum, which will minimize the total cost of all delivery process participants.

Considering that each TTSD is the part of the LS of PC delivery in the intercity the analysis of the influence on the TTSD efficiency of not just technological, but technological and logistical parameters as well defined in [23] has a great importance.

OBJECTIVES

The paper aims to determine the optimal TTSD for PC in the intercity by road transport by optimizing the technological and logistical TTSD parameters. The object of study is the process of forming of transportation technology for PC intercity delivery, and the research subject is the formation of TTSD for PC in the intercity by road transport based on logistics principles.

The following tasks have been set in order to achieve the research subject: formalization of initial data for the experimental studies, development of a full factorial experiment plan, implementing of software model of delivery process, carrying out of regression analysis of experimental results.

FORMALIZATION OF THE INITIAL DATA FOR EXPERIMENTAL STUDIES

The formalization of the initial data for the experimental studies includes the definition of ten input parameters of the model of delivery process for PC in the intercity [22] (TLPs of TTSD), the parameters of the freight owners (FO), freight forwarders (FF), carriers, terminals, that are involved in the request implementation, and external stochastic factors. Let us examine them in more detail.

The input parameters of the model are [3]:

$$IP = \{Q, L, I, Class, P\}, \quad (1)$$

where: Q – the consignment volume for the request, t; L – delivery distance, km; I – time interval between the moments of current request reception and the reception of the next request, hrs; *Class* - class of cargo; P – the vector containing the information for including in the request of additional conditions in request:

$$P = \{P_{JT}; P_{cons}; P_{return}; P_{LU\,FO}; P_{C\,FO}; P_{CPA}\}, \quad (2)$$

where: P_{JT}, P_{cons}, P_{return}, $P_{LU\,FO}$, $P_{C\,FO}$, P_{CPA} – Boolean variables characterizing the inclusion in the request of the following conditions: "just in time"; need of cargos consolidation; return shipping of empty transport containers to the FO; loading and unloading (LU) by FO without the contractors' involvement; performance of transportation using FO transport; availability of a cargo processing area respectively.

Additional FO characteristics describes the following data: availability of empty shipping tare and its technical characteristics; availability of the required vehicles and its technical and economical characteristics; information on the availability and characteristics of LU facilities; information on the availability and characteristics of equipment for packaging, labeling and documentation; data on the cost of the cargo temporary storage in FO; data on the costs associated with staff salaries, bank transfers, communication services, depreciation in the case of the independent implementation of the request.

FF characteristic includes data on the availability and characteristics of the required vehicle; data on the number of involved in request implementation workers in all required work types; data on the cost of involved workers works; data on the costs associated with the request implementation; level of profitability.

Characteristics of the terminal (-s) are the following: availability of empty shipping tare and its technical characteristics; information on the availability and characteristics of LU facilities; data on the cost of involved workers works and other activities related to the handling of cargo at the terminal; information on the availability and characteristics of equipment for packaging, labeling and documentation; the cost of temporary cargo storage; tariff for processing 1 ton of cargo.

The carry contractor (-s) characteristic includes data on the availability and performance of required vehicles; data on the components of required vehicles cost; tariff for the transportation (by 1 tkm for cargo transportation and 1 km for empty shipping tare transportation).

The LU contractor (-s) characteristic includes data on the availability and characteristics of LU facilities; data on the number and the work cost of involved for LU workers on all types of required work; tariff for 1 t cargo loading and unloading.

Parameters of TTSD participants work that characterized the simple operations implementation of participants have been defined as an external stochastic process parameters (eg., time to request place on a special logistics site, 1 t cargo loading time, etc.); vehicle speed.

DEVELOPING OF FULL FACTORIAL EXPERIMENT PLAN

To consider all the possible level combinations of TLPs of TTSD the full factorial experiment plan has been developed in a matrix consisting of a series of surveys in 2048 (detail planning matrix of full factorial experiment is shown in Table 1) in determining the optimal variant of the scheme delivery plan was developed for, and the levels of variation ten input factors (Table 2).

Table 1. A fragment of matrix of full factorial experiment planning

An experiment series	Level of input factor varying									
	X 1	*X 2*	*X 3*	*X 4*	*X 5*	*X 6*	*X 7*	*X 8*	*X 9*	*X10*
1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1
2	+1	+1	+1	+1	+1	+1	+1	+1	+1	–1
3	+1	+1	+1	+1	+1	+1	+1	+1	–1	+1
…	…	…	…	…	…	…	…	…	…	…
2046	–1	–1	–1	–1	–1	–1	–1	–1	+1	–1
2047	–1	–1	–1	–1	–1	–1	–1	–1	–1	+1
2048	–1	–1	–1	–1	–1	–1	–1	–1	–1	–1

Table 2. Levels of input factors varying

Input factor meaning	Level of factor varying	
	-1	+1
X1 - *Q*, t	0,001	30
X2 - *L*, km	50	1500
X3 - *I*, hrs.	0,2	12,2
X4 - *Class*	1	4
$X5 - P_{JT}$	1	2
$X6 - P_{cons}$	1	2
$X7 - P_{return}$	1	2
$X8 - P_{LU\,FO}$	1	2
$X9 - P_{C\,FO}$	1	2
$X10 - P_{CPA}$	1	2

SOFTWARE IMPLEMENTATION OF A DELIVERY PROCESS MODEL FOR PC IN THE INTERCITY BY ROAD TRANSPORT

The availability of alternative TTSD for PC and variety of their performance proves the necessity of applying for experimental studies to determine the optimal TTSD specialized software that contains the library of base classes that allow us to describe the subjects of the freight delivery market and the processes of their interaction within the supply chains of different levels [24].

Classes' library is developed for use in an environment Microsoft Visual Stu-dio.NET. Tools library admittance is implemented in C #. Library classes allow us to describe the received request characteristics by the random variables, and characteristics of the subjects participating LSC [25, 26].

As a result of the developed program the best TTSD variant is formed from the full set of alternatives TTSD. It is represented as a sequence of elementary technological operations [22] required for the delivery of cargo from the consignors to the consignee, in which the total costs of participants involved in the delivery of the request with its specified characteristics are minimal.

An example of a software implementation of a delivery process model for PC in the intercity by road transport is shown in Fig. 1, where "The shortest path from 0 to 1" means the optimal delivery scheme obtained by simulation for given values of request parameters for the first LSC variant.

As a result of simulation experiment on the basis of the developed plan the obtaining a data set consisting of 2,048 combinations of values of all possible variants of TLP varying levels and corresponding the total subjects delivery cost has become possible.

REGRESSION ANALYSIS OF EXPERIMENTAL STUDIES RESULTS

Implemented in MS Excel regression analysis tools have been used for processing of experimental studies results.

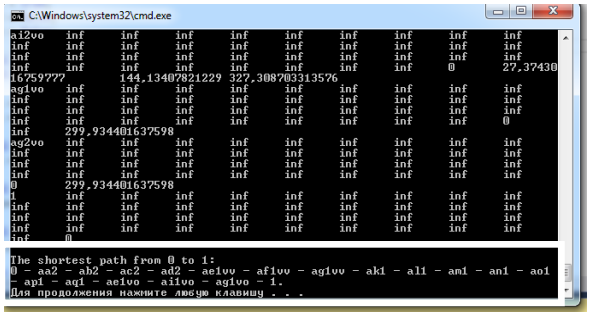

Fig. 1. An example of the optimal TTSD obtained by simulation for given values of request parameters

Determination of the functional dependence of total costs of PC delivery subjects on TLP of TTSD has been carried out for each of transport and technological structures of LSH [20] in the following order: formation of alternative hypotheses about the form of the regression model; determination of the coefficients of regression models to put forward alternative hypotheses; evaluation of the adequacy of the obtained regression models and selection of the most adequate one.

According to obtained analytical dependence for estimating of total costs of delivery participants the next variety of alternative hypotheses about the form of the functional dependence of the PC delivery total costs C_Σ on request parameters has been considered: the hypothesis of a linear dependence (3), a power (4) and an exponential (5) dependences. Function analysis package of MS Excel has been used as the main tool for determining the regression models coefficients in experimental studies results processing.

$$B^1_\Sigma = a_0 + a_1 \cdot X_1 + a_2 \cdot X_2 + a_3 \cdot X_3 + a_4 \cdot X_4 + +a_5 \cdot X_5 + a_6 \cdot X_6 + a_7 \cdot X_7 + a_8 \cdot X_8 + a_9 \cdot X_9 + a_{10} \cdot X_{10} \quad (3)$$

$$B^2_\Sigma = a_0 \cdot X_1^{a_1} \cdot X_2^{a_2} \cdot X_3^{a_3} \cdot X_4^{a_4} \cdot X_5^{a_5} \times \times X_6^{a_6} \cdot X_7^{a_7} \cdot X_8^{a_8} \cdot X_9^{a_9} \cdot X_{10}^{a_{10}} \quad (4)$$

$$B^3_\Sigma = a_0 \cdot a_1^{X_1} \cdot a_2^{X_2} \cdot a_3^{X_3} \cdot a_4^{X_4} \cdot a_5^{X_5} \times \times a_6^{X_6} \cdot a_7^{X_7} \cdot a_8^{X_8} \cdot a_9^{X_9} \cdot a_{10}^{X_{10}} \quad (5)$$

The results of the regression analysis to the first LSC variant are shown in Table. 3. Among the tested hypotheses exponential dependence is the most adequate one. Closed to one coefficient of the determination indicates almost functionality of the obtained dependence.

Table 3. The results of the regression analysis to the first LSC variant

The regression equation coefficient	Hypothesis of a regression equation		
	A linear (B^1_Σ)	A degree (B^2_Σ)	An exponential (B^3_Σ)
X1	-893,065	520,9697	3128,397
X2	619,9595	0,3464	1,1871
X3	4,5612	0,4718	1,0011
X4	0,288	0,0032	1,0012
X5	3,9542	0,0014	0,9999
X6	-4863,96	-0,0873	0,5461
X7	-576,899	-0,2026	0,8684
X8	-601,048	-1,04027	0,4866
X9	557,5883	0,0863	1,0619
X10	1593,355	-1,2753	0,413
The determination coefficient	-27,1277	-0,1617	0,8937

Similarly, the testing of hypotheses about the regression models form has been carried out for other LSC variants. The results showed that the highest values are characterized by exponential models. However, a set of the most significant factors for each LSC variant is different. The analysis results are shown in Table. 4.

Table 4. The regression equation coefficient for exponential models

The regression equation coefficient	A supply chain variant			
	LSC1	LSC 2	LSC 3	LSC 4
X1	3128,39	1242,73	204,949	227,484
X2	1,1871	1,1716	1,2078	1,2187
X3	1,0011	1,00074	1,00041	1,00047
X4	1,0012	1,03554	1,04575	1,0392
X5	0,9999	1,00025	1,04016	1,0587
X6	0,5461	0,5423	0,863	0,6093
X7	0,8684	0,9181	0,861	0,9053
X8	0,4866	0,4407	0,9925	0,9965
X9	1,0619	1,0889	1,1174	1,0882
X10	0,413	0,8391	0,7778	0,8356
The determination coefficient	0,8937	0,9305	0,9177	0,9352

Thus, obtained for the variants of logistic supply chain schemes regression models allow to take into account the effect of TLP on certain performance criteria.

CONCLUSIONS

1. The conducted experimental studies using specialized software tools and regression analysis to process the experimental studies results identifies TLPs that need to be optimized to substantiate the optimal TTSD variant for PC in the intercity by road transport for different LSCs.

2. For the first LSC variant a request consignment volume, delivery distance, "just in time" condition; the need for consolidation of cargo, return shipping of empty transport containers to the FO; performance of transportation using FO transport; availability of a cargo processing area must be optimized.

3. For the second LSC variant in addition to the included in the first LSC model parameters a time interval between the moments of current request reception and the reception of the next request and a condition of LU by FO capacity without the contractors' involvement also must be optimized.

4. For the third and fourth LSC variants among the included in the second LSC model parameters a condition of returning shipping of empty transport to the FO must not be optimized.

5. Perspective directions for further studies are determination of the optimal area of TTSD use and estimation economic efficiency of the optimal TTSD variants for the PC in the intercity by road transport.

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РЕЗУЛЬТАТЫ ЭКСПЕРИМЕНТАЛЬНЫХ ИССЛЕДОВАНИЙ ПО ВЫБОРУ ТРАНСПОРТНО-ТЕХНОЛОГИЧЕСКИХ СХЕМ ДОСТАВКИ ТАРНО-ШТУЧНЫХ ГРУЗОВ АВТОМОБИЛЬНЫМ ТРАНСПОРТОМ В МЕЖДУГОРОДНОМ СООБЩЕНИИ

Аннотация. Приведены результаты экспериментальных исследований транспортно-технологических схем доставки тарно-штучных грузов (ТШГ) автомобильным транспортом в междугородном сообщении с использованием имитационного моделирования. Формализация исходных данных для экспериментальных исследований модели процесса доставки тарно-штучных грузов в междугородном сообщении автомобильным транспортом учитывает основные параметры заказов и дополнительные параметры работы грузовладельца, экспедитора, перевозчиков и терминалов, которые привлекаются к выполнению заказа, и внешние стохастические факторы. Полученные регрессионные модели зависимости расходов на доставку от технолого-логистических параметров (ТЛП) транспортно-технологических схем доставки учитывают основные варианты взаимодействия участников процесса доставки и включают наиболее значимые ТЛП схем доставки ТШГ автомобильным транспортом в междугородном сообщении.

Ключевые слова: технологический процес доставки, тарно-штучные грузы, междугородные перевозки, технолого-логистический параметр, автомобильный транспорт.