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Efficiency of transportation of agricultural goods in logistics container systems

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Abstract: *The article analyzes the theoretical and practical issues of the efficiency of transportation of agricultural goods in logistics container systems. The factors and features of the transportation of agricultural goods were studied. The scheme of the technological process of transporting containers (pallets, boxes) in mixed traffic, as well as possible options for the operation of vehicles for servicing the container terminal.*

Key Words: *agriculture, logistics, container, transportation, agricultural cargo, efficiency, optimization, warehouse.*

1. INTRODUCTION:

One of the most effective means of allowing complex mechanization of loading and unloading operations, to reduce downtime of automobile rolling stock under loading and unloading, to ensure maximum safety of goods during transportation, are container and package transportation. Container transportation is the modern most economical type of cargo transportation used both in domestic and in international cargo transportation carried out by various means of transport, whether it be rail transportation, trucking, etc., using removable transport containers.

Along with container transportation, the package method of transportation is increasingly being used, consisting in the fact that individual piece-packed, unpackaged goods are formed into a large batch-package on pallets.

The following factors determine the effective use of containers for the transport of goods (1):

- the exception of transshipment operations when changing modes of transport or crossing borders, maintaining product quality;
- high versatility;
- containers can be used as storage facilities, technological capacities of processing enterprises;
- international transport under customs seals imposed upon dispatch of cargo to any point on the Earth, with the intersection of any number of borders, warehousing and temporary storage of goods without immediate unloading.

However, the use of containers and, to a lesser extent, pallets has some disadvantages. The main one is the reduction in the payload of the car due to the mass of the containers themselves. The container coefficient for medium-tonnage universal containers used in mixed traffic is, for example, 0.276 ... 0.351. Reducing the own weight of the containers can be achieved by using plastics, light alloys, etc. for their manufacture.

1.1. LITERATURE REVIEW:

The theoretical foundations of production logistics have been studied in the scientific works of scientists A.U. Albekov, B.A. Anikina, A.M. Gadzhinsky, G.M. Kasymov, V.S. Lukinsky, L.B. Mirotin, V.E. Nikolaychuk, G.A.Samatova, V.F.Stukach and others. Issues of increasing the efficiency of agricultural production were studied in detail in the works of scientists of Uzbekistan's economists, such as A.M. Kodirov, Ch.M. Muratov, U.P. Umurzakov, T.F. Farmonov, R.Kh. Khusanov, N.Kh. Khushmatov, K.A. Choriev and others. At the same time, these scientific papers did not study the issues of economics, organization and optimization of transport and logistics processes in the agricultural sector of the economy.

2. METHOD:

In the research process, a systematic approach was used, economic-mathematical, expert, calculation-constructive, abstract-logical methods.

3.ANALYSIS AND RESULTS:

Features of container and package transportation allow us to determine the basic requirements for rolling stock.

Labor costs for transport and handling operations in agriculture account for up to 35% of the total labor costs for the cultivation of crops and about 17% in livestock (2). In order to determine the scope of use of containers for transporting agricultural products in the object of study, we studied the features of transportation of agricultural goods:

- significant fluctuations in cargo turnover and traffic during the year. For non-business transportation, the coefficient of unevenness of cargo turnover varies on average from 2.5 to 3.5. The distribution of annual volume of traffic by quarters looks something like this: 15% each in the first and second quarters, 45% in the third and 25% in the fourth quarter;

- short time for harvesting and its removal from the fields. As practice shows, a delay in harvesting grain for 10 days leads to losses of up to 15% of the crop, for 20 days to 30%. When harvesting agricultural products, three main methods of organizing work are applied: flow-through, when the product from the harvesting unit is fed directly to the vehicle body; separate, when the harvested product is temporarily stored in the field, and then loaded into the rolling stock; combined, combining the first two methods;
- a small distance (from 5 to 20 km) on-farm transport and a large range of distances (from 30 to 3000 km) for off-farm;
- high specific gravity of bulk and bulk cargo with low density. For example, such cargoes as hay, straw, silage, have a density of 0.25 ... 0.35 t / m3, cabbage - 0.4 ... 0.45 t / m3, raw cotton - 0.07 ... 0.15 t / m3, which leads to the incomplete use of the nominal carrying capacity of vehicles;
- among agricultural cargoes, a significant part is made up of powdered or liquid mineral fertilizers, the transportation of which has its own characteristics. Powdered ones become unusable when exposed to moisture, and liquid can have a harmful effect on the human body, cause damage to vehicles, containers;
- on-farm transportation is characterized by the predominance of dirt roads with low traffic in the spring and autumn, as well as driving on arable land, stubble. At the same time, the car must move at low speed (5 ... 10 km / h), which is why the engines overheat in the warm season;
- rocking of the body and, as a result, loosening of its base, frame when driving on uneven roads with low-density cargo (during transportation, the sides of the bodies are built up, as a result of which the center of gravity of the car increases);
- agricultural goods are subject to significant damage during transportation (vegetables, fruits, etc.). The losses of some goods, especially cereals, are also great during transportation due to spillage through body leaks (grain can “leak” even through small cracks), and also as a result of blowing out of the body by swirling air flows.

Containers and pallets are increasingly being used to deliver potatoes, vegetables and other products to fruit and vegetable bases. At the same time, the adaptability of the rolling stock to the transport of containers, which contributes to the maximum use of load capacity, convenience and efficiency of loading and unloading, is important. To ensure the economic reliability of the functional processes of the container system, the product and empty containers should be delivered to consumers with the lowest total material and labor costs. To characterize this requirement, we introduce indicators (1):

$$Z_{pl}(T) = \frac{R_{pl}(T)}{Q_{pl}^{k}(T)} \quad (1)$$

$$Z_{f}(T) = \frac{R_{f}(T)}{Q_{f}^{k}(T)} \quad (2)$$

where Z_{pl} (T) and Z_f (T) are the planned and actual specific indicators of the reduced costs per unit of product delivered in containers, respectively; R_{pl} and R_f - respectively, the planned and actual reduced costs for the delivery of the physical volume of products.

Evaluation of the economic efficiency of container services for logistics work in the agro-industrial complex should be based on a comparison of the costs of delivering products prior to the implementation of the container system and the results obtained by the serviced system after the introduction of the container system. In accordance with the above aggregated results of the implementation of the container system are the reduction of material and labor costs for the delivery of fruits, as well as the reduction of material and labor losses of the agro-industrial complex, provided by improving the quality and shortening the execution time of the process of moving fruits.

Profitability and reliability are the most important requirements for industrial and commercial activities, which are currently attracting the closest attention of various specialists. This is natural, since both requirements are generated by the most important need of society to increase the efficiency of the functioning of economic sectors in the conditions of commodity-money and market relations, and, naturally, competition. The aforesaid fully applies to logistics systems that ensure the processes of moving agricultural products. This is because these processes, including warehouse, freight, picking, transport, commercial and other technological and managerial operations, are the basis for the effective functioning of all without exception, including various forms of ownership, economic systems. At the same time, as practice shows, they are often carried out in unsatisfactory terms, involving significant material and financial resources and require large expenditures of low-skilled labor. All this predetermines the search for ways to improve logistics systems that can improve the reliability of customer service, reduce or rationalize the delivery of products to consumers and the necessary material, financial and labor costs. In addition, the search for such paths is of fundamental social importance at the current stage of the formation of new production and commercial structures. The work highlights the most progressive and promising, from the perspective of a logistics strategy, ways of moving agricultural products using containers.

The analysis showed that one of the most common principles in the world practice of the formation of regional agricultural goods movement systems is the creation of terminal complexes around large urban agglomerations in suburban areas.

The formation of an integrated terminal service system is based on the following principles (3):

- the use of progressive terminal technology for the transportation process of agricultural goods at points of interaction of transport for transportation of goods to customers;
- organization of an integrated system of forwarding services for clients, providing customers with warehouse services for the storage of their products, allowing the use of warehouseless technology for the production of agricultural and commercial enterprises, as well as commercial structures of small businesses aimed at reducing transportation and storage costs and improving the quality of customer service;
- creation of a unified system of economic and legal relations between participants in the logistics service system based on the coordination of economic interests of all participants in cargo movement and the introduction of mutual liability of the parties.

A distinctive feature of the logistics system is the emphasis on the coordination of actions in the acquisition, movement, storage and sale of agricultural goods. In this case, the criterion of the effectiveness of the functioning of the logistics system is the value of the total costs of transport and distribution operations.

As you know, the inconsistency in the actions of counterparties in the movement of agricultural products leads to increased costs in each of their areas and reduced product quality. This is due to overstatement of stocks in the sphere of sales of products and in production, with technological "inconsistencies" (associated with packaging, features of loading and unloading and storage, requirements for transportation), inconsistencies of authorities and management methods, etc.

The basis of the mechanism of economic regulation should be based on the following economic principles:

- full satisfaction of the objective needs of the population and the agro-industrial complex of the region in freight traffic;
- equal economic benefits to vehicle owners and serviced clients;
- mutual financial responsibility for the final results of product distribution;
- direct dependence of the economic situation of participants in the process of moving material flows from the final results of the work;
- equal cooperation of vehicle owners with the clientele served on the basis of contractual relations;
- the maximum convenience of using transport, the provision of a wide range of services, the exemption of clients from unusual functions.

The process of interaction of automobile, container and document flows in time proceeds differently. The optimal case is when, at the time of delivery of the cars with containers to the site for their unloading, the process of processing transportation documents was completed and a car arrived to transport the container. Schematically, this can be represented in the following form (Fig. 1).

The practice of organizing the transportation of agricultural goods shows that when operating vehicles to maintain a consolidated terminal, the most common are pendulum and circular triangular routes.

We list the main conditions, in one of which there may be a container on the territory of the consolidated agricultural terminal:

x_1 - at the checkpoint when delivered to the terminal by road;
x_2 - at the container site awaiting departure;
x_3 - on the transfer platform awaiting departure;
x_4 - on a railway platform at the container site awaiting departure;
x_5 - on driveways awaiting departure.

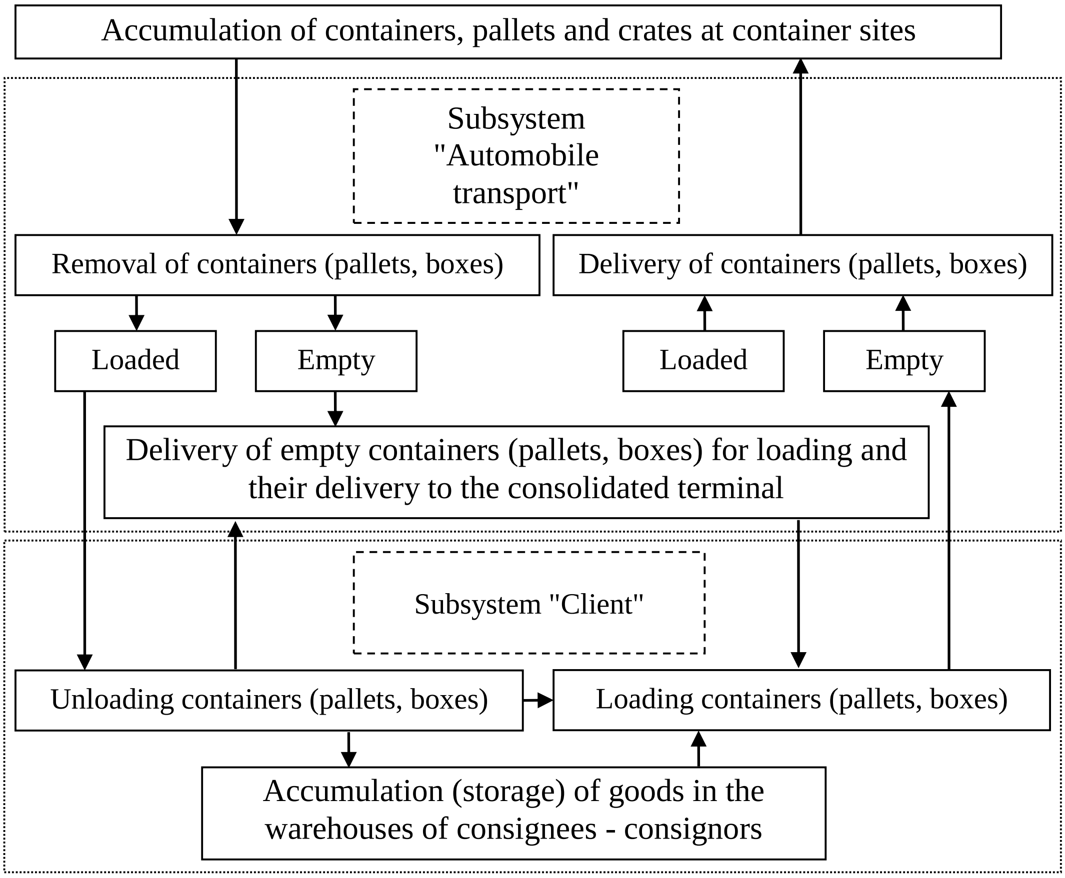

Figure 1. The flow chart of the transportation of containers (pallets, boxes) in mixed traffic

The state of the technological process for the import and departure of containers with agricultural products is determined by the state of the following vector (3):

$$S_x = \{s_{x_1};\ s_{x_2}; \dots ; s_{x_5}\} \tag{3}$$

where s_{x_i} is the number of containers in the xi state.

The state of the technological process upon arrival and removal of containers is determined by the state of the vector

$$S_y = \{s_{y_1};\ s_{y_2}; \dots ; s_{y_5}\} \tag{4}$$

where s_{y_i} is the number of containers in the yi state.

In total, on the territory of the consolidated terminal, we have four possible ways of moving containers (Table 1).

We determine the time and cost required to overcome each of the possible paths.

To each arc u_{ij} of the graph we associate a positive number $t(u_{ij})$, which is a long passage of a given arc. If the arc u_{ij} is the sum of technological operations, then the duration of the passage of this arc is determined by the formula:

$$t(u_{ij}) = \sum_1^k tk \tag{5}$$

where t_k is the duration of the kth operation.

Let $\mu = \{u_{1i_1}; u_{i_1 i_2}; \dots ; u_{i_n n}\}'$ be the path from the vertex x_1 to the vertex x_n. Then the duration of this path is equal to

$$t[\mu] = \sum_{u\in\mu} t(u) \tag{6}$$

Table 1

Possible ways to move containers (pallets, boxes) (3)

No.	The name of the method	Arc Duration
1	Direct option "wagon semi-trailer"	$\mu_1=\{u_{14};\ u_{45}\}$
2	Via point of semi-trailers	$\mu_2=\{u_{13};\ u_{34};\ u_{45}\}$
3	With transshipment to a consolidated terminal	$\mu_{3i}=\{u_{12};\ u_{22};\ u_{24};\ u_{45}\}$
4	Mixed option	$\mu_{4i}=\{u_{13};\ u_{32};\ u_{22};\ u_{24};\ u_{45}\}$

Thus, it is possible to determine the path between the initial and final states of the containers, the duration of which will be minimal.

It is very important to minimize the duration of each path. For the criterion of operation of the consolidated terminal of agricultural goods, you can take the duration

$$R_t = \min t[\mu_i] \quad (7)$$

We will show the procedure for calculating the duration of the arc passage using the example of arc u_{12}, which is the process of moving containers from the terminal gate to the container platform:

$$t(u_{12}) = t_{\text{del.}} + t_{\text{pap.}w.} + t_{\text{wait.}} + t_{\text{unload.}} \quad (8)$$

where $t_{\text{del.}}$ is the time from the arrival of the vehicles at the container terminal to the delivery to the site for unloading;

$t_{\text{pap.}w.}$ - time for paperwork;

$t_{\text{wait.}}$ - waiting time for unloading;

$t_{\text{unload.}}$ - time of unloading containers to the site.

To determine each of the possible ways of moving containers requires certain costs. And it is not at all necessary that the shortest path will be more economical at the same time. It is important to know the unit cost of overcoming each path. Since each of the paths consists of the sum of arcs, which are the essence of technological operations, the costs are defined as the sum of the costs of individual technological operations. Denote the unit costs by C. Then

$$C[\mu_i] = \sum_{u\in\mu} C(U_{ij}) \quad (9)$$

where $C[\mu_i]$ is the specific cost of overcoming the μ_i-th path.

$C(U_{ij})$ - unit costs associated with moving the container from the x_i-th state to x_j-th.

The objective function will look like this:

$$F = R_C = \min C[\mu_i] \quad (10)$$

For the criterion of optimal operation of the terminal, we can take the criterion

$$R_{tc} = t[\mu]C[\mu] \quad (11)$$

And the method of processing containers for which the product $R_{tc} = t[\mu]C[\mu]$ is currently minimal is optimal for this situation, i.e.

$$R_{opt.} = \min R_{tc} = \min(t[\mu]C[\mu]) \quad (12)$$

A similar analysis of the operation of road transport serving the container terminal (taking into account both the import and export of containers) made it possible to identify all possible ways of organizing the operation of cars to service the terminal. In total, 9 possible ways of organizing the operation of vehicles that were formed as a result of various combinations of possible ways of moving containers were revealed at the terminal. Table 2 summarizes these methods with an indication of the length of time spent in the terminal territory equal to the sum of the corresponding arcs of the combined column for importing and exporting containers from the terminal.

However, not only cars with containers arrive at the terminal, but also cars with semi-trailers without a container or no semi-trailer at all. When it comes to such cars, then, as you know, the delivery of containers is not carried out. Therefore, despite the fact that such cars will move along the same routes, the time to overcome them will be different. In this case, it is fair to single these out into autonomous vehicle operation options.

Table 2 shows all 15 options with the total time spent on vehicles in the terminal (excluding the queue), as well as the duration of their service at the terminal, excluding travel time between the individual elements of the terminal. The calculation results show that all options, depending on their duration, can be divided into eight digits, as shown in table 2.

In conclusion, we determine what options can be used depending on the condition of the cars at the time of arrival at the terminal:

1) cars arriving at the terminal without semitrailers can operate according to 6. 10, 12th options;

2) cars arriving at the terminal with semitrailers without a container can operate according to the 2nd, 9th and 15th options;

3) cars arriving at the terminal with a container (either loaded or empty) can be used for all other options. There are only 9 of them, and in this case they cope with the nine methods of organizing the operation of cars when servicing the container terminal, which formed the basis for the development of all options for organizing the operation of cars. We list these options: 1, 3, 4, 5, 6, 8, 11, 13, and the 14th.

Table 2

Possible options for the operation of vehicles for servicing a container terminal[1]

Shipping method number	Option number	Name of option	Option duration	Time spent in the terminal, min		Discharge number
				total	service	
1	1	Import and export through DO (direct option)	$U_{14}+V_{45}$	42	31	7
	2	Arrival without container, export by DO	$U'_{15}+U_{34}+V_{45}$	32	22	4
2	3	Delivery according to the DO, export from PST (point of semi-trailers)	$U_{14}+V_{43}+V_{35}$	40	29	6
3	4	Delivery according to the DO, export from CS (container site)	$U_{14}+V_{42}+V_{25}$	42	31	7
4	5	Delivery on PST, export by DO	$U_{13}+U_{34}+V_{45}$	43	32	8
	6	Arrival without semitrailers, export by DO	$U'_{13}+U_{34}+V_{45}$	36	26	5
5	7	Delivery on CS, export by DO	$U_{12}+U_{24}+V_{45}$	42	31	7
6	8	Import and export from PST	$U_{13}+V_{35}$	28	22	3
	9	Arrival without container, export from PST	$U'_{13}+V_{35}$	25	19	2
	10	Arrival without semi-trailers, export from PST	$U'_{13}+V_{35}$	20	14	1
7	11	Delivery on PST, export from CS	$U_{13}+U_{32}+V_{25}$	43	32	8
	12	Arrival without semi-trailers, export from CS	$U'_{13}+U_{32}+V_{25}$	36	25	5
8	13	Delivery on CS, export from PST	$U_{12}+V_{23}+V_{35}$	40	29	6
9	14	Delivery and arrival with CS	$U_{12}+V_{25}$	42	31	7
	15	Arrival without container, export from CS	$U'_{13}+U_{32}+V_{25}$	32	27	4

There will be different options for using cars working with uncoupling of semi-trailers and without uncoupling. So, options 1, 2, 4, 7, 14, 15 can be used when operating cars without uncoupling semitrailers, while with uncoupling reverse semitrailers, depending on the transport situation, you can use all possible (15) options for organizing the operation of cars according to container terminal service.

In order to implement the above objectives, a generalized block diagram of the operation of the terminal system has been developed (Fig. 2).

[1] Compiled by the author according to the methodology presented in the literature (3)

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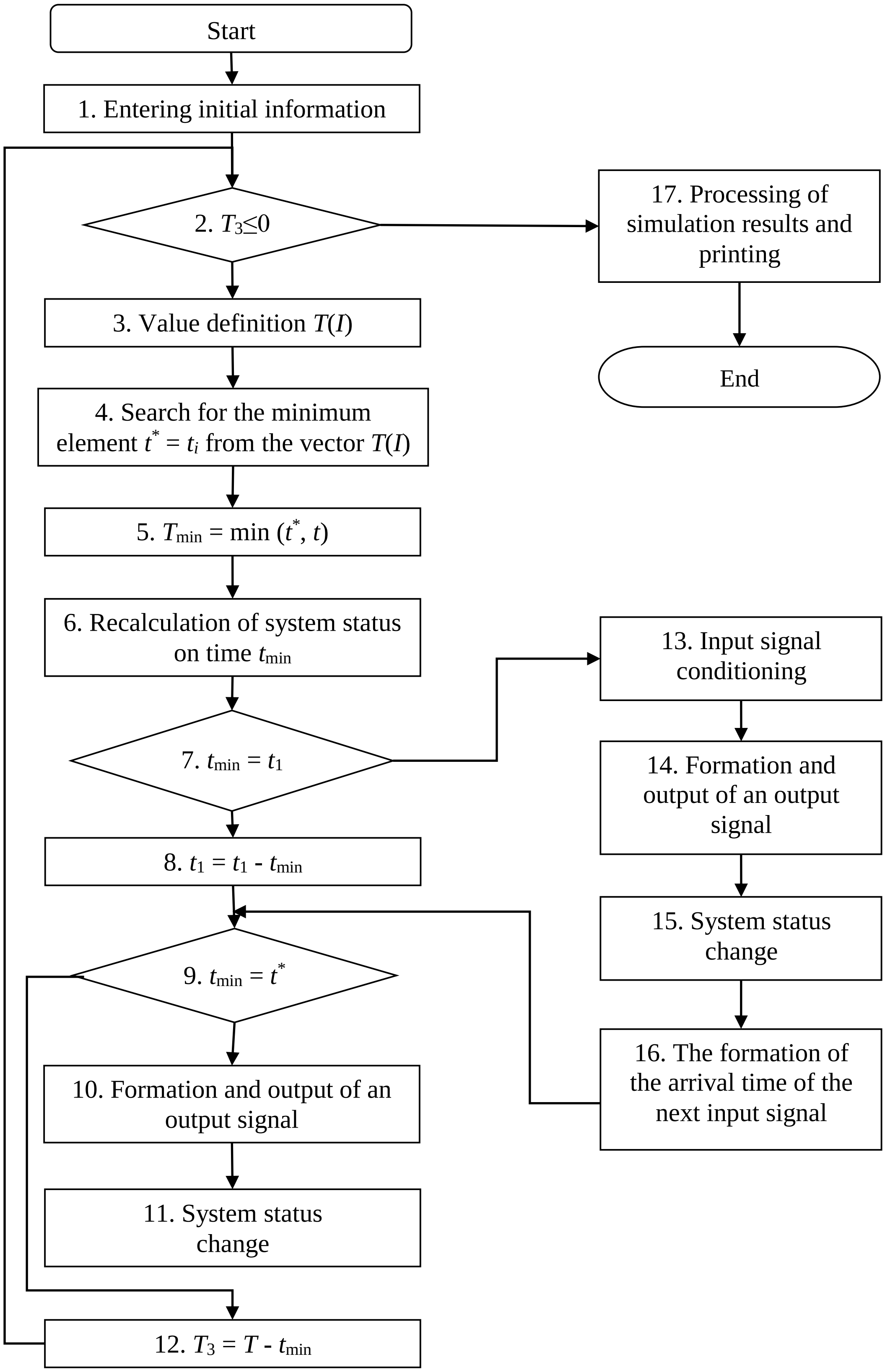

Figure 2. Generalized block diagram of the container terminal

Block 1. The initial state of the system and the simulation time T_3; a set of service elements that determine the type and type of the investigated terminal; distribution of service time for cars by these elements in the form of tables; time t_1 of arrival of the first input signal about the car arriving at the terminal; the intensity and composition of the arriving stream of cars. Block 3. For each of the vehicles located at the terminal, the time of the onset of the nodal moment (the moment the state of this vehicle changes) is calculated. This value is entered in the vector *T(I)*, where *I* is the number of cars located on the terminal. Block 4. A search is made for the minimum positive element $t^* = t_i$ from the vector *T(I)*; *i* is the number of the corresponding vehicle. Block 6. The system state is changed over a period of time $t_{\min}$ according to the law:

$$Z_1^i(t^*) = Z_1^i(t) - t_{\min} \quad ; Z_2^i(t^*) = Z_2^i(t) - t_{\min} \tag{13}$$

$i = 1, 2, \ldots, I$ (it is assumed that $\phi + \alpha = \phi$ for all α).

Block 13. An input signal is generated about the type of vehicle arriving at the terminal in accordance with a given stream composition .Blocks 10, 14. The appearance and content of the output signal is formed in accordance with the purpose of the simulation experiment. Block 15. In accordance with the content of the input signal, a certain change in the state of the system occurs. Block 16. In accordance with the specified intensity of the incoming flow of cars, the value of the time interval is formed, after which (starting from this moment) the next car will arrive at the terminal. Block 11. An abrupt change in the state vector of the *i*-th container is made, *i = 1, 2, ..., N*, *N* is the number of containers available on the terminal. In this case, in block 6, an additional operation is performed:

$$TK(i) = TK(i) + t_{\min} \quad ; \quad i = 1,2, \ldots N \tag{14}$$

If the car picks up the *i*-th container, then it is accordingly eliminated from consideration, and the value *TK(i)* is additionally printed. In block 1, you must also set the initial values of idle times for the containers available on the terminal, i.e. set the value of the array *TK(N)*.

4. CONCLUSION:

Thus, in the conditions of modernization of the economy of Uzbekistan, one of the effective means to comprehensively mechanize loading and unloading operations, to reduce downtime of automobile rolling stock under loading and unloading, to ensure maximum safety of goods during transportation, are container and package transportation. Evaluation of the economic efficiency of container services for logistics work in the agro-industrial complex should be based on a comparison of the costs of delivering products prior to the implementation of the container system and the results obtained by the serviced system after the introduction of the container system. In accordance with the above aggregated results of the implementation of the container system are the reduction of material and labor costs for the delivery of fruits, as well as the reduction of material and labor losses of the agro-industrial complex, provided by improving the quality and shortening the execution time of the process of moving fruits.

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