Aspects of modeling the main production processes of wood enterprises

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Abstract. This article describes the main production processes at forest industry enterprises. The container has free space for the process of goods delivery, which enables customs inspection with partial unloading of goods. This enables to have enough time to inspect the container. It is believed that the costs associated with carriers are increasing. The ratio of free and occupied space when loading a container is not obvious. Two approaches to process modeling have been considered. The methods and algorithms for transport processes simulating have been presented. A solution to the problems of optimal container loading during customs control has been proposed. A simulation model of roundwood transportation across the borders has been implemented, which enables to determine the optimal loading volume of containers in order to minimize the time for customs clearance. The proposed option of partial loading reduces the time of customs inspection, which significantly reduces the costs associated with transportation of timber products, as well as the risk of customer refusal from the products delivered out of schedule.

1. Introduction

The forest resources are an important part of Russia's economic potential, and issues related to the use of forest resources and the development of the forest industry have always been the focus of state attention. The effective development of forest industries is directly related to the scale and level of use and reproduction of forest resources. However, “forest becomes a natural resource when forest utilization is possible to be organized, before that it is only a natural condition” [1]. Both resource support of the growth of individual sectors and the needs of population in a wide range of goods depend on the state of the timber industry enterprises. The forest industry occupies a special place in the system of inter-branch and foreign trade relations of the country's economy. Its development not only reflects the links between the involvement of primary resources in the economic turnover and final national economic demand, but also the system of world economic relations in Russia. The industrial complex of forestry was considered as the main form of territorial-sectoral association of industries related to the use and reproduction of forest resources. It is characterized by: the totality of productions, the presence of stable production relations, ensuring the process of integrated use of raw materials starting from its...
preparation up to the production of finished products. A distinctive feature of forestry complex is the unity of raw material base, means of production and labour resources. All this determines a large variety of production processes of enterprises. The enlarged diagram of the main production processes in forest enterprise is presented in figure 1. Any manufacturing enterprise strives to increase production and expand sales markets for manufactured products by improving technological processes, which will allow you to get additional profit [2-4].

**Figure 1.** Enlarged diagram of the main production processes of the forest industry enterprise.

The specificity of timber industry enterprises is as follows: firstly, commodity products are made of wood raw materials, which vary in processing depth; secondly, the main blocks of timber industry complex and forest resource base are located in the large areas, therefore, transport infrastructure is required.

Transportation of raw materials and finished products is one of the most important production processes of a wood industry enterprise, which links all the stages of production and sale of timber products (figure 2).

**Figure 2.** Scheme of traffic flows at wood enterprises.
The transportation process is accompanied by significant financial and time resources. Cargoes can be shipped both directly from the cutting area, and from the transit-transloading terminal or finished goods warehouse [5-6]. But all cargoes (for external customers) undergo a procedure of customs inspection at check-points. The loss of time during the passage of the border is considered to be an idle time and increases the costs associated with the international transportation of forest products. The customs operation is one of the factors that significantly slows down the process of transporting products, which can lead to disruption of product delivery times and, as a result, to the loss of profits [7-9]. As a rule, cargo inspection at customs points is carried out with complete unloading the contents of the container and then inspecting each individual unit of goods and checking the markings on timber with numbers listed in the Unified State Automated Information System (ESAIS). However, the time of inspection may be significantly reduced if there is free space in the containers, which enables customs inspection with partial unloading of goods. This technique can significantly reduce the inspection time. The ratio of free and occupied space when loading a container is not obvious. As a rule, cargo inspection at customs operation is one of the factors that significantly slows down the process of transporting goods. Let the transport system be such that, firstly, there is a prediction of the load percentage when crossing a border. Further, the algorithm issues a check or no check for the vehicle, which belongs to the sending company, which does not bear the costs of gasoline. We introduce the concept of cash expenses $C_i$ when transporting cargo on the $i$ highway

$$C_i = c*s_i$$

Where $c$ is gasoline costs per km, $s_i$ is delivery distance using the $i$ road. We define the following parameters as functions

$$p_{ij} = f(b)$$

$$p_{ij} = f(k)$$

$$U = g(k)$$

There is a calculation $p_{ij}$ when crossing a border. Further, the algorithm issues a check or no check of the cargo at the border. There are no gasoline expenses, except $T$ in case of checking it at the border. The transport passes on without losing time if there is no control at the border. If a consumer refuses to purchase goods during transportation, the transport is sent to a deliberately agreed warehouse and does not additionally cross any borders, but also carries all transportation costs $c$. Revenue is generated at the time of receipt of the goods by the buyer, after the transport stays at the same point and does not have incremental costs.

To solve the similar task, it is necessary to consider two approaches, on the basis of which the algorithms are built. The first is those approaches that use implementation of numerical types of calculation (analytical method). An example is “genetic algorithm”. At the first stage, a mathematical continuous or discrete model is constructed. At the second stage, “reproduction” and “mutation” of solutions take place. After analyzing the values of the objective function with such solution sets, the best
“individual” (the “selection” process) is determined and it is planned to “multiply” it further [13-15]. The second approach is a simulation solution to the optimization problem. It is possible to distinguish analogs of devices and elements of a real system and the conditions of their functioning in the program that implements the simulation model. The simulation program reproduces the composition of the system under study, the processes of the system’s operation over time, simulating the elementary phenomena that make up the process while preserving their logical structure and flow sequence over time [1, 16-18]. The main algorithms implementing these two approaches are presented in Table 1.

Table 1. Basic algorithms for solving the problem of optimal loading.

| Short description | Features |
|-------------------|----------|
| Linear stochastic programming [19-20] is an approach in mathematical programming that allows taking into account the uncertainty in optimization linear models. | While deterministic optimization problems are formulated using specified parameters, real application problems usually contain some unknown parameters. When parameters are known only within certain limits, the approach to solving such problems is called robust optimization. This approach is to find a solution that is valid and optimal for all such data. |
| The genetic algorithm [21-22] is a heuristic random search method based on the principle of simulating the evolution of a biological population. The population updating is performed for a certain (specified) number of times, and the result of the algorithm is the best of the found coverings. | In the general case, there is a sequential change of populations during the operation of the algorithm, each of which is a family of coverings, called individuals of the population. The coverings of the initial population are constructed at random. The stationary scheme of a genetic algorithm is the most common and best-proven one, in which another population differs from the previous one only in one or two new individuals. |
| The agent modeling [23-24] is the direction in simulation modeling that is used to study decentralized systems the operation dynamics of which are determined not by global rules and laws (as in other modeling paradigms), but, on the contrary, when these global rules and laws are the result of individual activity of group members. | The purpose of agent models is to get an idea of these global rules, the general behavior of the system, based on assumptions about individual, particular behavior of its individual active objects and interaction of these objects in the system. An agent is an entity that has activity, autonomous behaviour, can make decisions in accordance with a certain set of rules, interact with the environment, and also change itself. |

The simulation was chosen to solve the problem of container optimal loading, since it makes it possible to take time factor into account.

3. Results and discussion

Let manufacturers send trucks from their factories across the borders of the Russian Federation - Belarus (the Ukraine) – the European Union. Sigmoid is taken as the probability distribution function \( f(b), f(k) \), (formulas 4-5) (figure 3).

In case the goods are refused, the car with the cargo carries the goods to the agreed point (warehouse), which also means economic losses. The process was implemented by means of a high-level programming language JavaScript (JS).

In the first step, a map of Central and Eastern Europe was downloaded from the corresponding package of JS programming language application programs, including the lengths and capacities of the roads.
Figure 3. Sigmoid: $b(k)$ values are plotted on the horizontal axis, $f(b)$ or $f(k)$ – on the vertical axis.

Then the process of round timber transportation in containers with a length of up to 4 m and a diameter from 32 cm to 40 cm by one of the wood processing companies located in the territory of the Russian Federation (RF) was modeled. The number of vehicles is not limited, the cost of ordering vehicles is equal to 0, and it is believed that vehicles belong to the company, but if each additional unit of transport is used, the cost of gasoline will increase, so it is possible to consider the number of the used vehicles. Let’s note that gasoline $c$ is the upper limit, and the minimum load of transport ($k$) is the lower limit. The algorithm chooses the shortest path. The production locations are: the Moscow Region, the Pskov Region, Volgograd. The number of borders – 2: EU, Belarus (the Ukraine), the Russian Federation. The warehouse is located in Wroclaw. Consumers are located in the following cities: Gdansk, Berlin, Dresden, Prague, and Warsaw. The quantity of the transported goods is the same, but it is randomly generated. Orders can be fulfilled at one of two tariffs: $p=100$ standard conventional units for 1 unit of goods and $p=200$ standard conventional units for 1 unit of goods, at the same time the higher cost order will be primarily executed. The cost of gasoline for transportation per 1 km is $c=0.1$ standard conventional units.

This task of wood products transportation was launched 10 000 times in the simulation process, the average values of the most illustrative simulation results are presented in table 2. Column 2 presents the percentage of the total number of vehicles that did not violate the delivery time under the contract due to time losses when inspecting goods at customs check-points.

Analyzing Table 2, you can see that profit is positive in the interval of container load level [24%-86%]. The maximum conditional profit, obtained in the process of simulation modeling, corresponds to the container loading by 54%-56%. However, this will require a greater number of vehicles with half empty containers. We calculate the reduced profit. This is the average profit per one vehicle which reached the destination point with the minimum idle time at the customs check-point and passed the terms of the supply contract. It will be maximum one when container is loaded for 80%. It is not necessary to empty the container for inspection with such a load. It will significantly reduce the loss of time when crossing the border, figure 4 shows the visualization of “Present profit” parameter depending on the percentage of container load.
Table 2. Average values of simulation results.

| Container loading, % | Vehicles not violating the terms of delivery, % | Conditional profit, cu | Number of vehicles, pcs. | Average number of vehicles not violating the terms of delivery, pcs. | Average present profit, cu |
|----------------------|-----------------------------------------------|------------------------|---------------------------|-------------------------------------------------------------------|---------------------------|
| 1                    | 2                                             | 3                      | 4                         | 5                                                                  | 6                         |
| 10                   | 39                                            | -108.33                | 1251                      | 410                                                                | -0.26                     |
| 20                   | 38                                            | -16.58                 | 660                       | 216                                                                | -0.08                     |
| 30                   | 35                                            | 17.65                  | 510                       | 167                                                                | 0.11                      |
| 40                   | 33                                            | 23.85                  | 392                       | 128                                                                | 0.19                      |
| 54                   | 35                                            | 62.63                  | 266                       | 87                                                                  | 0.72                      |
| 56                   | 32                                            | 64.02                  | 260                       | 85                                                                  | 0.75                      |
| 60                   | 23                                            | 53.23                  | 234                       | 77                                                                  | 0.69                      |
| 62                   | 34                                            | 59.65                  | 229                       | 75                                                                  | 0.79                      |
| 64                   | 28                                            | 51.09                  | 225                       | 74                                                                  | 0.69                      |
| 66                   | 35                                            | 57.97                  | 220                       | 72                                                                  | 0.80                      |
| 70                   | 32                                            | 57.07                  | 210                       | 69                                                                  | 0.83                      |
| 74                   | 30                                            | 28.95                  | 201                       | 66                                                                  | 0.44                      |
| 78                   | 34                                            | 23.02                  | 190                       | 62                                                                  | 0.37                      |
| 80                   | 38                                            | 56.96                  | 188                       | 62                                                                  | 0.92                      |
| 82                   | 32                                            | 19.07                  | 178                       | 58                                                                  | 0.33                      |
| 84                   | 31                                            | 28.29                  | 170                       | 56                                                                  | 0.51                      |
| 90                   | 15                                            | -55.37                 | 161                       | 53                                                                  | -1.05                     |
| 92                   | 14                                            | -63.54                 | 160                       | 52                                                                  | -1.21                     |
| Average %            |                                                |                        |                           |                                                                    |                           |
| 33                   |                                                |                        |                           |                                                                    |                           |
| Maximum profit, cu   |                                                |                        |                           |                                                                    | 0.92                      |

Figure 4. Dependence of profit in terms of each vehicle that arrived with minimal downtime at the customs check-point (cu) on the loading level container (%).
The simulation results enable to conclude that loading containers, carrying timber products, for 100% leads to losses of time at border crossings and customs clearance.

4. Conclusion

The wood transportation and products are a demanded service, since wood and forest products of various depths of processing are used for the production of a wide range of products, as well as in construction. Despite the fact that all three elements of material production are involved in the transportation process: tools are vehicles, the object of work is carried goods, work is expediently directed activities, an additional quantity of a social product is not created in this process, but there are significant input requirements: material, labour, and time ones. All this increases the cost of the cargo. International transportation of timber and roundwood by road is a high-cost process, which is explained by transport, technological and organizational factors [25]. The proposed variant of partial container loading is intended for enterprises whose activities are related to the transportation of roundwood by road with crossing state borders. The partial loading enables to read the markings on the logs, without unload of the container for cargo inspection. All this reduces the time of customs inspection, which significantly reduces both the time costs associated with the transportation of timber products, and the risk of refusal (by customer) from the goods which are delivered in violation of delivery terms.

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