Formation of the through technological chains within the forest industry cluster

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Abstract. The article is devoted to the problem of formation of technological chains in timber industry clusters. Special attention is paid to the movement of material flows and the method of forming technological chains. As a result, a model of the movement of material flows of wood resources within the timber cluster has been developed.

1. Introduction

The production process of any industrial enterprise is a difficult economic category. Building optimal relationships between the individual elements of a working system is a long-term, continuous process. Moreover, the larger the enterprise, the greater the difficulties in organizing effective activities are. However, the effectiveness of large companies is a sequence higher than the one of small and medium-sized enterprises.

A more difficult task is the organization a sequence higher of relationships between business associations. In this case, in addition to building internal processes, there should be a functioning system of interaction between independent elements that differ significantly from each other in a set of parameters. They can operate according to various standards, in various fields and areas of the economy and production, focus on achieving different results, operate using different levels of automation, etc. Of course, the more participants in such an association, the more difficult their interaction and coordination is in achieving a shared (strategic) goal. The task of forming such the through technological chains is one of the most important within the framework of the activity of clusters, including forest industry ones [1]. Clusters act as a form of association of enterprises within one or several related fields in order to increase efficiency of activity and optimize processes in the conditions of developed infrastructure concentrated in a certain territory. The main goal of the study is to identify the foundations of the formation of the through technological chains within the forest industry cluster.
2. Methods and Materials
Technological chains for the processing of wood resources at forest enterprises were the objects of study. The study was built on the basis of theoretical and practical developments by the team of authors regarding the creation of forest industry clusters and the organization of production processes at the enterprises of the forest industry. Analysis, statistical and mathematical planning, modeling, forecasting, etc. were the main used methods.

3. Results and Discussion

3.1. Results
The feature of the forest industry and, in particular, forest industry clusters is the use of unique raw materials of vegetable origin – the wood. Its feature lies in the possibility of almost full use for obtaining a variety of products. At the same time, the waste received in the production process can be used for release of other goods [2]. The use of recycled wood resources is fully reflected in this industry. The term “waste” is incorrect and applied only to inefficient enterprises and (possibly) regional complexes. It should be noted that products obtained from recoverable wood resources, in some cases (according to the Russian Federal State Statistics Service) can be even more expensive compared to the main product obtained (table 1).

Table 1. The average price for certain types of FIC products in 2018, rubles [3].

| Name of goods                                                                 | Cost, rub. |
|------------------------------------------------------------------------------|------------|
| Coniferous timber, density m³                                                | 2232       |
| Round coniferous timber for sawing and planning, density m³                   | 2458       |
| Round hardwood for sawing and planning, density m³                           | 2169       |
| Round hardwood for production of wood pulp (pulpwood), density m³            | 1122       |
| Wood fuel, density m³                                                        | 725        |
| Softwood lumber, m³                                                         | 6616       |
| Hardwood, m³                                                                 | 6692       |
| Chippings, density m³                                                        | 1345       |
| Plywood, m³                                                                  | 26580      |
| Chipboards and similar boards made of wood or other lignified materials, m³   | 11286      |
| Fuel granules (pellets) from wood processing waste, t m³                     | 4695       |
| Woodpulp and pulp from other fibrous materials, t                            | 41552      |
| Newsprint, rolled and sheets, t                                              | 27945      |
| Offset paper, t                                                              | 49036      |
| Rosin and rosin acids and derivatives, t                                     | 72432      |
| Charcoal, t                                                                  | 18530      |

The range of products of the forest industry and the specifics of the activities of its enterprises are extremely wide [4]. A wide assortment is used in various industries - from construction and decoration to chemical and medical industries. The general (principal) structure of the industry is shown in figure 1.
Figure 1. Structure of the forest industry complex (FIC) [5].

Obviously, the forest industry complex includes a wide list of enterprises, where the production of various products was organized. However, any production operates according to a clearly defined algorithm, where the satisfaction of the buyer’s needs for a particular product is the key element. The conditions that are given by buyers to the products for sale determine the volume of its production, quality, production technology, etc. The theory of logistics indicates the organization of material flow management in industrial enterprises according to the principles of pulling and pushing systems. In the first case, the crucial role in the functioning of the entire production process was given to the market. The second case is typical, for example, for large businesses that requires continuous production and optimization of the involved production equipment. However, with a sharp change in market demands for products, the transformation of production for new requirements in a short time is practically impossible [6].

The uniqueness of forest industry clusters is including, but not limited to the availability in the organizational association of participants that perform various roles - both large-scale production and small business that can quickly respond to market fluctuations. It is possible to distribute responsibility and resources for the simultaneous operation of two material management systems with the functioning of the Cluster as a single economic system. At the same time, as already noted, the most important resource is recoverable wood raw materials that circulate throughout the cluster formation and serves as its strategic advantage and a connecting element of its participants. The principal diagram of the movement of material flows within the forest industry cluster is shown in figure 2.

In this case, the management system is the coordination body of the Cluster and / or the management (managers) of its individual enterprises. The level of management is determined by the scale and features of product orders by the market. Highlighted key blocks - woodworking, wood processing and deep processing - are the successive stages of involvement of wood raw materials in the production process. If some of the processing stages are not required, the proposed model shall be simplified by eliminating unused production processes.

A separate position in the system of material flows is occupied by logging enterprises and sites. Currently, there is a situation, where the market has an indirect effect on their activities. Almost all regions of the country have a steady demand for logging products (round timber). For this reason and
in conditions of the need to develop allotted forest areas, their main task is to minimize the cost of logging and transport operations, sell products at the highest possible price. If the logging is carried out by a division of a large enterprise for its own needs, then in reality all the logged wood used in production is used. Low market dependence is largely due to the production and economic specifics of the forest industry. The period for the return of funds invested in logging can reach one and a half years, provided that the company uses it to produce expensive products.

![Diagram](image)

**Figure 2.** Model of the movement of material flows of wood resources within the forest industry cluster.

It should also be clarified that recoverable wood resources, like any other material (wood) resources that are transported (used) in various processes inside the Cluster can act as a semi-finished product and as a final product. For example, coniferous flour, sawdust, woodchips, lignin, etc. are sold at the market. The market for these products is significantly limited, but exists. At the same time, in practice, in some cases, domestic enterprises not only do not involve them in the production process for profit, but dispose of them, incurring financial losses, or distribute them to the local population (entrepreneurs, state bodies, etc.) for free. In the latter case, obviously, there is a shortfall in revenue.

Analyzing the activities of enterprises within the framework of forest industry clusters, we can distinguish the following key features associated with the formation of technological chains [7]:

- a variety of types of wood resources, differing in quality characteristics, species, cost, directions of use, etc.;
- a wide range of options for using wood resources to produce a variety of products and, as a consequence, the use of a variety of equipment and technologies;
- limited resources, including wood ones;
- disunity and fragmentation of production capacities of enterprises;
- narrow focus of many technologies for processing of wood raw materials;
- remoteness from large sales markets, etc.

The main emphasis in the formation of technological chains should be given to the optimal use of wood resources in order to increase the efficiency of the Cluster. The extent of using of the main resource – (wood) and the extent of effectiveness of the technology determine the success of the functioning of the entire organization in many respects. Obviously, the task of forming of the technological chains should be set at the stage of creating the Cluster, and the process itself is to be strictly regulated. The study proposed a scheme for the formation of the through technological chain of the use of wood resources in the framework of the forest industry cluster (figure 3).

![Methodology for the formation of the through technological chain of the use of wood resources within the framework of the forest industry cluster.](image)

According to this technique, an important aspect is the determination of the optimal technological chain based on a number of factors:

1. Market demand, including forecasted one. It determines, ultimately, the volume of products for sale, its quality characteristics, assortment, price and a number of other parameters. The technological chains should be formed considering forecasts of changes in demand. Otherwise, there is a possibility of a lack of sales for the manufactured assortment of goods and a set of related problems. According to the research [Review of the FIC of Russia], the following FIC products are the most promising in terms of demand growth:
   - lumber;
   - cellulose;
   - plywood;
   - packaging materials;
   - wood pellets;
   - OSB;
2. The effectiveness of the enterprises of the Cluster. It is important to note that the selection of the optimal technological chain is influenced not only by the effectiveness of technological solutions, but also by the complex of organizational and economic impacts. Situations with an increase in productivity with competent management of enterprises, or losses even of the most technologically competently built industries are possible. Management is the most important component in the work of the Cluster, the functioning of individual technological chains and the activities of individual enterprises [8].

3. Compliance with the principles of sustainable development. Another key component in the functioning of technological chains in the forest industry cluster is the focus on compliance with environmental norms, rules and requirements. The principles of sustainable development should be adopted and put into practice in the Cluster. This provision is necessary both for the sale of products on the world market and for solving a range of issues in activities on the territory of Russia: relations with the local population, state bodies, creating a favorable image, reducing fines for environmental impact, etc.

Based on the results of the work, a model of the through technological chain of the use of wood resources in the framework of the forest industry cluster was formed. It provides the through movement of wood resources on the way from logging to deep processing (figure 4).

![Figure 4](image-url)

**Figure 4.** Model of the through technological chain of the use of wood resources in the framework of the forest industry cluster.

Four blocks are provided in this model: the field of use of wood, the type of enterprises, manufactured products and the alternative to using raw materials. The movement of wood resources begins with the stage of logging and goes through the process of conversion into final products up to
goods for deep processing. However, it is obvious that not all raw materials are converted to expensive products. Individual Cluster enterprises may specialize in the production and sale of, for example, lumber. Recoverable wood resources - croaker, wood chips, sawdust etc. are to be transferred at domestic prices to other enterprises of the Cluster. However, in some cases, they can be implemented outside. The given alternative options for the use of raw materials - burning, composting, leaving at the cutting area - may also take place in the Cluster technological chain. Their use in some cases is technologically and economically feasible. However, these areas have low economic efficiency and should be avoided.

3.2. Discussion
The following areas can be identified as promising areas of study by the authors:
- economic and mathematical modeling of processes of technological chains of the use of wood resources within the framework of the forest industry cluster;
- the formation of an algorithm for determining the optimal portfolio of products;
- the formation of models for the development of production and economic indicators of enterprises of the forest industry cluster;
- development of a methodology for assessing the effectiveness of technological chains of the use of wood resources in the framework of the forest industry cluster;
- development of methods, algorithms and software for the selection of optimal technological chains of the use of wood resources in the framework of the forest industry cluster;
- development of models for the development of production chains and interconnections of enterprises of the forest industry cluster, taking into account the factors of micro- and macroenvironment;
- development of a methodology for analyzing the impact of the state of infrastructure on the technological chains of the forest industry cluster, etc.

4. Conclusion
As a result of the study, the foundations of the formation of the through technological chains within the forest industry cluster were determined. The model of the movement of material flows of wood resources within the forest industry cluster was developed. Its main difference is the simultaneous use of pulling and pushing principles. This is one of the distinguishing features of clusters. The identified key factors affecting the determination of the optimal technological chain shall also be considered as priorities in the development of individual enterprises and organizations of the forest industry. The development of the Russian forest industry, according to the author, is to be based on the principles of clustering and increasing the efficiency and depth of processing of wood resources. The most important production and economic factors of the development are the applied through technological chains of the use of wood resources.

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