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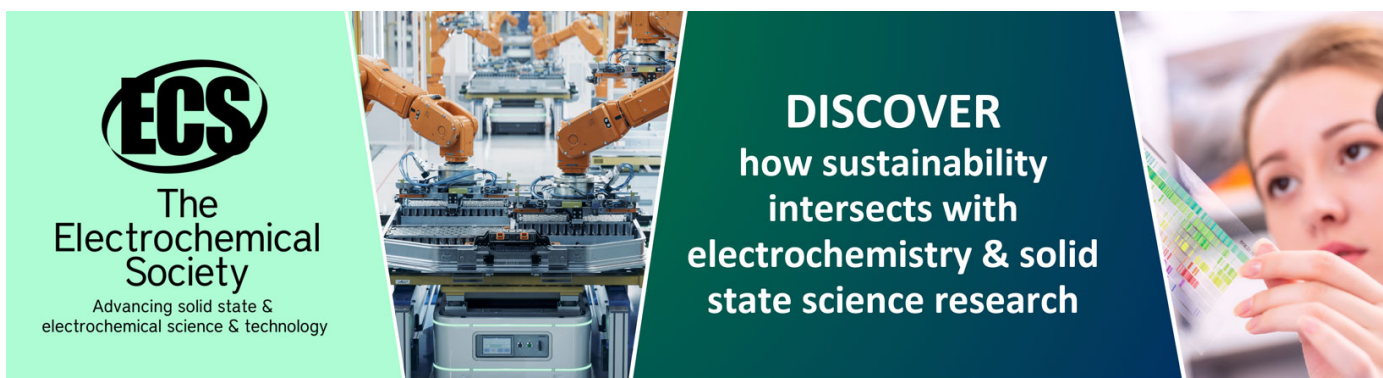
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Finding an effective technological chain of the logging process in the natural and production conditions of the Krasnoyarsk region

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Abstract. In the logging process, it is possible to build a technological chain in different ways. When transporting wood from the cutting area, water or land transport can be used. Using of lumberyards and processing of wood on them also increase the multivariance of the technological process. Execution of operations in various natural and industrial conditions differs in productivity and material costs. The efficiency of production depends on the choice of logging technology in dynamic natural production conditions. The authors presented a graphic-analytical model for solving the given task in the publication. The article is devoted to the graphic-analytical model for solving the task. A numerical example is solved for this purpose. The numerical example showed the efficiency of the method of finding a rational technological chain of logging operations in dynamic natural and production conditions.

1. Introduction

In recent years the removal of wood from the cutting area to the consumer is characterized by a multivariate technological process with the use of forest warehouses. Most of them are used for wood storage between transport seasons [1]. Finding the optimal variant of the technological chain is an actual task.

Logging operations require adequate and careful planning in order to rationally select the technological chain and effectively solve the problems of forest management. In addition, logging operations must be coordinated with the transportation of harvested wood to the consumer, since transport costs account for the majority of the total logging costs [2]. Also, when choosing technological chains, there is a question of the wood processing degree, the type of commodity products obtained from it. After all, this affects the consumer ability of the product and its price. Therefore, searching for optimal solutions that take into account both transport and procurement costs, as well as the cost of products sold is important for building reliable wood supply chains and maintaining the profitability of the enterprise.

Planning the movement of marketable products to the consumer in a dynamic environment is probably the most important decision at the operational level and is critical to maintaining the wood supply chain. These operations should be carried out ideally with minimal costs, while meeting the requirements of the consumer to the product. Besides, logging and transport operations account for the bulk of the costs, and disruption of wood supplies can lead to high costs in processing industries.



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To solve such problems graphic-analytical models may be successfully used, envisaging a construction of links between operations, allowing to perceive the technological chain for certain types of work in a logical sequence, eliminating the duplication of certain technological elements, giving the opportunity to evaluate different systems of machines and the structure of production flows in a variety of industrial processes of forest works [3].

Methods of substantiation of finding the shortest paths between the vertices of the graph are described in Moore's [4], Floyd's [5], Dijkstra's [6], Bellman's researches [7], etc.

They allow to carry out the analysis of static elements of the enterprises' work and serve as a basis for realization of stationary-dynamic tasks of stream programming at rationalization of flows in transport systems. [8-10].

The simplex method of linear programming can be used to solve such problems [11].

The above methods and algorithms can be used in the process of considering the operations of the logging technological process in dynamics when presenting them in the form of time-stretched graphs. These studies demonstrate in detail the basic scheme and analysis capabilities of the operating network. However, they characterize the possibility of passing through the arcs of each time interval only one flow option and do not take into account the specifics of the logging industry, envisaging the need for a comprehensive solution to the problems of developing several cutting areas within one time range when justifying the schedule of the logging technological process. In view of this, they cannot always be used in solving the issues of substantiating the technological chain of work at timber enterprises.

In the conditions of the need to implement such a comprehensive analysis, it becomes obvious that the use of machines and mechanisms involved in the performance of work on one of the analyzed areas of the logging enterprise reduces the resources of their possible application in the course of performing the same operations on the territory of another site in the time interval adopted for the analysis. The mentioned researches, stipulating theoretical possibility of passing several flows on the eponymous operations of technological process of each analyzed period provide the researcher with the possibility of the analysis only the graphs with independent from each other carrying capacities of separate parallel arcs of analyzed time intervals.

In the paper [12] the authors propose detailed graphical models of wood transportation from the cutting area to the consumer, loading, unloading and processing operations taking place at the intermediate and lower lumber yard. The research [13] suggests a methodology for solving this problem. The proposed mathematical dependences allow to carry out search of the maximum flow of the minimum cost in dynamic structure of technological process of works performance at the enterprise. In addition to the dynamic component, the methodology differs by taking into account the income of the enterprise from the sale of marketable products. The purpose of this study is to use this technique to improve the technological chain of transport, loading, unloading and processing operations of the logging process in dynamic natural-production conditions using the developed graphic-analytical model.

The initial data for the implementation of the numerical example were formed from the real data of logging enterprises of the Krasnoyarsk territory of the Russian Federation.

It is advisable to divide the natural and climatic conditions of the logging area into 5 periods: winter (124 days), winter-spring (31 days), spring (72 days), summer (62 days), autumn (71 days). In each period, the performance of machines on operations is different. Logging is carried out on two sites, from which it is possible to transport wood directly to the consumer or through the lower coastal warehouse (figure 1). The roads are partly temporary logging roads or year-round roads. The schematic diagram of the logging site is shown in figure 1. On two sites timber can be harvested in the form of whips or assortments of up to 20 thousand m^3 in the first area and up to 50 thousand m^3 in the second area. It is possible to transport the wood by rafting along the river from the lower coastal warehouse, rafts can be formed for this purpose. Timber storage between periods is carried out in stacks in the lower warehouse, for this purpose a land area is rented and personnel are hired for security. The consumer is ready to accept wood in any period in the amount of 70 thousand m^3 . To

solve the problem, the cost of performing technological operations C , the productivity of II machines and equipment for their implementation, as well as labor costs f for performing operations are determined.

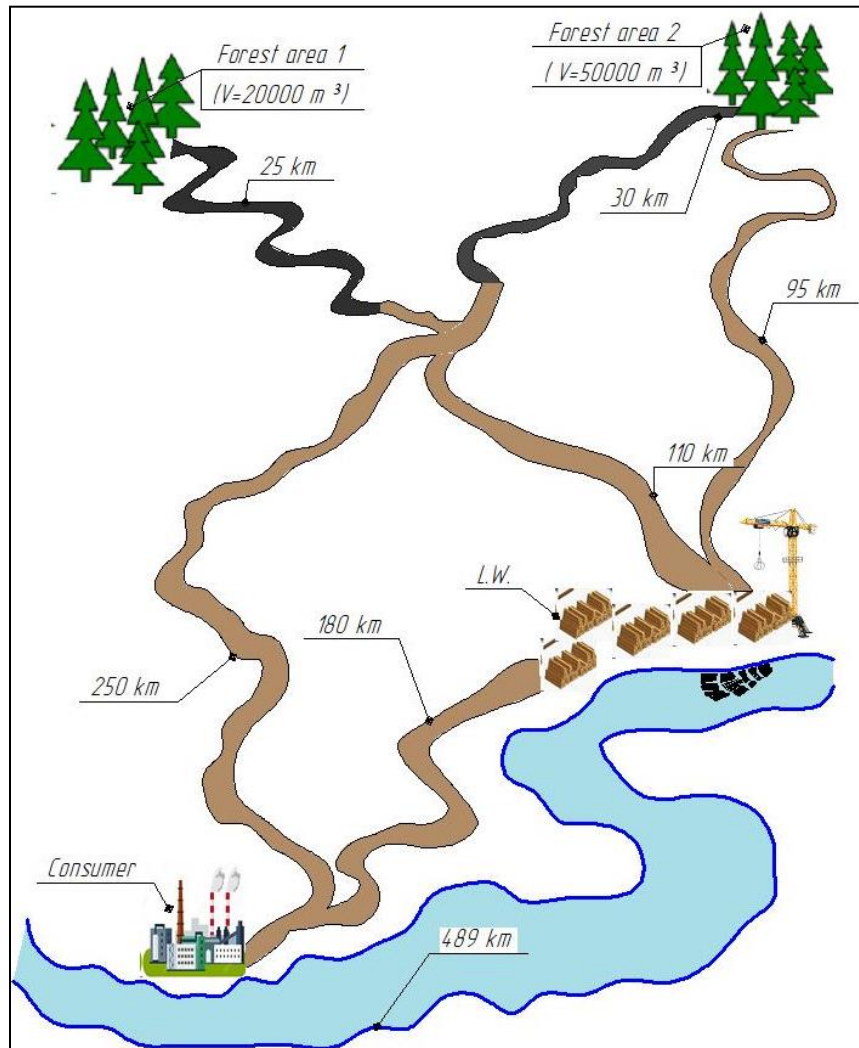


Figure 1. Schematic diagram of the logging site.

It is required to determine the technological chain of operations for primary processing and transportation of harvested wood from two forest areas to the consumer, characterized by a minimum cost and providing maximum integrated production when performing of all types of work, taking into account the initial data.

2. Results and Discussion

Analyzing the initial data, it can be assumed that the most effective periods of transportation are winter (I) and summer (IV). To simplify the solution of the numerical example, according to the method [13], make a graph for these periods, taking into account only the time parameters of the remaining periods (figure 2).

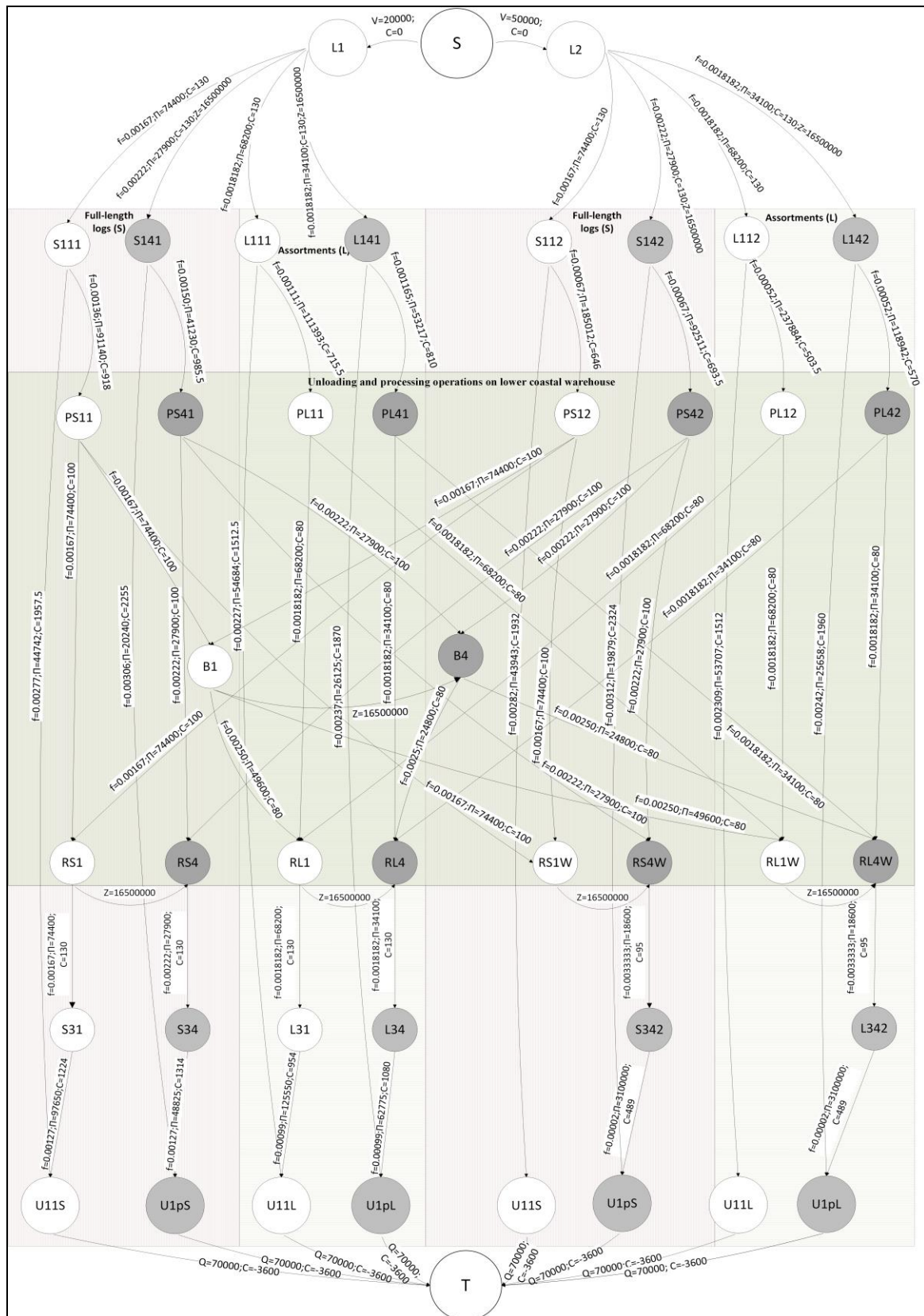


Figure 2. Initial graph for solving the problem.

This graphical model represents the "stretched in time" dynamic graph and allows to carry out graphic-analytical approach to the substantiation of logging process' technological chain of forest warehouses, raids of loading and unloading operations, processing operations, modes of transport (water, land), the choice of the consumer and type of final commodity products in dynamic natural production environmental conditions.

The vertex S (figure 2) represents a fictitious source, the vertex T is a fictitious final point. From the fictitious source, the arcs enter the vertices L , denoting forest areas. These arcs are characterized by capacity, which is determined by the volume of wood removal from the corresponding forest area V . Arcs are also characterized by the costs C with which the wood resource is included in the technological chain. This may be the costs of acquiring wood, performing technological operations preceding the considered technological chain. The entire technological chain is represented on the graph by intermediate vertices located between the vertices denoting the forest areas L and consumers U . From vertices L arcs are coming in vertices $Mh\theta N$ (M - name of the object of labor during the operation (whips - S , sortiments - L); h - stage of transportation; θ - period number; N - forest area number). At the stage, after the lower warehouse, the designation W can appear in the characteristic of the vertices, which symbolizes transportation by water. Arcs entering the vertex determine the loading operation, leaving the vertex - the transportation of wood. Arcs are characterized by capacity, limited by performance II . Also, arcs are characterized by labor costs f , variable C and fixed Z costs. Fixed costs are taken into account when storing wood between periods. In the arcs outgoing the fictitious vertex S to the arcs characterizing the cutting areas, the characteristic $V_{M\theta N}$ indicates the volume of the analyzed object of labor in a certain period θ , moved from the cutting area N . In the arcs incoming in the fictitious vertex T from the vertices of consumers, there is a characteristic Q_{AM} , symbolizing the maximum volume of production M , possible for the acquisition of consumer A . Also, this arc is characterized by the cost of products sold C .

The solution to this problem is based on the Basaker-Gowen's algorithm for determining the minimum cost flow in the transport network. It is modified taking into account the fact that when the flow passes through any of the arcs, the capacity of arcs reflecting similar operations in the same period decreases [14]. Thus, the decrease in productivity of machines and equipment involved in different technological areas is considering. The given minimum cost flow found in this way is optimal if there are no negative cycles in the network with modified arc values.

This graphical model allows to carry out the analytical approach to the substantiation of logging process' technological chain of forest warehouses, raids of loading and unloading operations, processing operations, modes of transport (water, land), the choice of the consumer and type of final commodity products in dynamic natural production environmental conditions.

Four iterations were required for a complete solution of the problem. The calculation result is shown in the graph of figure 3. Double line indicate the flowpath.

Thus, the timber harvested in the first forest area in the volume of 20000 m³ will be exported to the consumer by road in first period. From the second forest area, the volume of harvested wood equal to 33770 m³ will be exported to the consumer by road in the 1st period, the remaining volume of 16230 m³ will be transported by road to the lower warehouse and then by water in the 4th period.

The costs of the proposed technological chain, taking into account the sale of wood will be - 125061940 rub.

Characteristics of the technological chain of the entire route of wood delivery from the forest areas to the consumer are summarized in table 1.

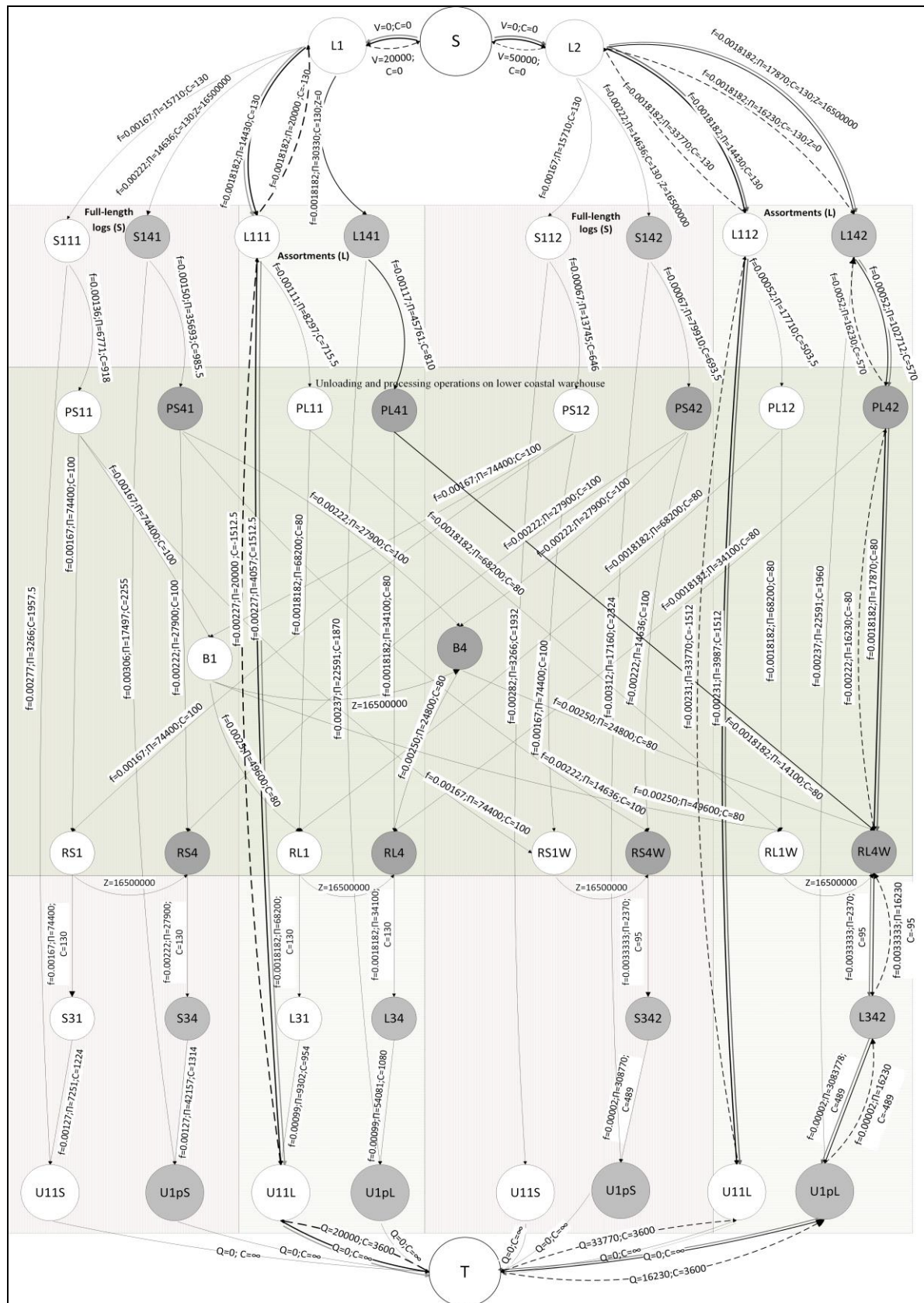


Figure 3. The result of solving the problem.

Table 1. Characteristic of the technological chain of the entire route of wood delivery from the forest areas to the consumer.

Characteristic	Route		
	S, L1, L111, U11L, T	S, L2, L112, U11L, T	S, L2, L142, PL42, RL4W, L342, U11L, T
Technological chain	L, T	L, T	L, T, U, R, WT
Type of products sold	sortiments	sortiments	sortiments
Forest area number	first	second	second
Transportation (implementation) period	first	first	forth
Transportation volume, m ³	20000	33770	16230
Distance of wood transportation by cars, km	275	280	95
Distance of wood transportation by rafting, km	-	-	589
Variable costs, rub	32 850 000	55 450 340	22 137 720
Fixed costs, rub	-	-	16 500 000
Sales income, rub	72 000 000	121 572 000	58 428 000
Profit, rub	39 150 000	66 121 660	19 790 280

where, L - loading, T - transportation by road, U - unloading, R - raft, WT - water transport.

3. Conclusion

The proposed graphical model allows to carry out an analytical approach to justifying the sequence of transporting timber from different forest areas, the use of lumber yards in the logging process, the raids of application loading and unloading works, processing operations, modes of transport (water, land), the choice of the consumer and type of final commodity products in a dynamic natural production environmental conditions.

A numerical example of the problem solution showed the efficiency of the methodology of finding a rational technological chain of logging operations in dynamic natural production conditions.

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