Problems of technological processes selection in logging

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Abstract. The article deals with current issues of the logging enterprises effective functioning with assortment technology for wood harvesting in the Leningrad region of the North-West Federal District of Russia. A survey of the production activity of a number of enterprises that use logging technology based on harvesters and forwarders was carried out. The results of technical and economic assessment of this technology usage are presented, the reasons of the decrease in the efficiency of the technological process of the logging are identified, the alternative assortment technologies are considered, and recommendations on selection of technological processes and systems of logging machines are made.

1. Introduction
The relevance of the study is that a number of works are devoted to the introduction of logging sorting technology based on multi-operation machines of foreign production without a solid justification of the effectiveness of their application, which often leads to erroneous technological decisions in choosing systems of logging machines [1, 2]. In this paper, an assessment of the effectiveness of the assortment technology of timber harvesting is considered and the problems of its implementation are identified by the example of logging in the Leningrad region in the near future.

The purpose of this study is to identify the reasons of the decrease in logging efficiency, both dependent and independent of the applicable technological process of logging, in particular assortment technology, as well as the development of recommendations for the selection of technological processes and systems of logging machines.

2. Methods and Materials
Research methods include simulation of the machine systems functioning, comparative analysis and modeling of logging efficiency indicators in assortment technology, a systematic approach, and abstract logical methods for substantiating recommendations on the choice of technological options.

3. Results and Discussion
The results of the research are to substantiate the reasons of the decrease in the efficiency of logging with the use of assortment technology for a five-year period (2014-2018). The calculation of performance indicators was carried out for logging production with a volume of 100 thousand m³ completed material, in forests, the species composition of which is as follows: 40 % - spruce, 30 % - pine, 20 % - birch, 10 % - aspen, an average volume of a whip of 0.36 m³, the average distance of wood removal 50 km, and 75 % of commercial wood. These forest growing conditions are the most typical for logging in the Leningrad region [3].

During comparative assessment of the technological processes of assorted wood logging, the following technological variant was adopted as the base one: for logging operations machine technology
based on John Deere 1270E harvesters and John Deere 1510 forwarders is used, for wood transportation and the lower warehouse the KAMAZ-timber truck 65111 with the Palfinger Velmash VM10L74 hydraulic manipulator and a three-axle trailer, the forklift truck LT-72B type are used. In the calculations it was assumed that only 85% of the total volume is logged by machine complexes according to the Harvester-forwarder system, and 15% of the volume (mainly large trees) is logged by fellers using chain saws with logging by tractors with sliding choker equipment such as TLT-100A and then bucking of whips to assortments at loading areas of the cutting area followed.

The comparative results of calculating the cost, profit and profitability of the production and sale of round timber (final products of forest harvesting) in rubles per 1 m³ for 2018 and 2014 [4], as well as the indices of changes in these indicators are given in table 1. The calculations were performed in accordance with industry recommendations [5].

Table 1. Cost price, profit and profitability of the production and sale of round timber.

| Cost item                                       | Expenses, (rub./m³) | Expenses, (rub./m³) | Indexes of change indicators (2018/2014) |
|------------------------------------------------|---------------------|---------------------|-------------------------------------------|
| 1. The rent for the wood                        | 115                 | 181.3               | 1.576                                     |
| 2. Forestry costs                               | 120                 | 132                 | 1.1                                       |
| 3. Remuneration of production workers           | 124.1               | 157.6               | 1.27                                      |
| 4. Contributions to social funds (30%)          | 37.2                | 47.2                | 1.27                                      |
| 5. Costs of preparation and development of production | 73.6                | 101.2               | 1.37                                      |
| 6. The cost of maintenance and operation of equipment | 210                 | 302.4               | 1.44                                      |
| 7. Logging transport services                   | 132.2               | 191.8               | 1.44                                      |
| 8. Maintenance costs of logging roads           | 73.8                | 101.1               | 1.37                                      |
| 9. Shop expenses                                | 50.9                | 64.6                | 1.27                                      |
| 10. General running costs                       | 64.3                | 81.7                | 1.27                                      |
| 11. Other operating expenses                    | 32.5                | 41.3                | 1.27                                      |
| 12. Production cost                             | 1033.6              | 1402.2              | 1.356                                     |
| 13. Loading assortments into Russian Railways wagons | 52.6                | 75.7                | 1.44                                      |
| 14. Advertising and other business expenses     | 88.8                | 112.8               | 1.27                                      |
| 16. Cost of commodity production, (full)        | 1175                | 1590.7              | 1.353                                     |
| 17. The average selling price of 1 m³           | 1403.5              | 1684.2              | 1.2                                       |
| 18. Profit from sales of products               | 228.5               | 93.5                | 0.41                                      |
| 19. Product profitability, %                   | 19.45               | 5.88                | 0.30                                      |
During the above-mentioned five-year period the cost of timber harvesting has increased in all cost items. Moreover, the largest increase in costs (57.6%) occurred under the item “Payment for standing timber”. The reason for such a significant increase of rent was the decision of the government of the Russian Federation on the approval of the raising factor to the minimum rates of rent [6], which is 2.17 in 2018, which is significantly higher than in previous years.

The second item, which significantly affected the cost of harvesting – "Forestry cost", it is generally not characteristic of logging production. According to the current Forest Code [7], the activities related to reforestation, forest management, removal of cutting areas, safety and protection of forests on forest areas leased are assigned to the tenant. Forestry costs are usually included in the cost of round timber and financed from the profits from the sale of timber.

The amount of costs for the above articles is practically independent of the type of used technology, but in general it leads to lower profits and a decrease in sources of investment in new equipment, the other cost items more or less depend on the adopted technology and the system of logging machines.

One of such cost items is "The costs of maintaining and operating logging equipment". So, using the harvester-forwarder system of assorted wood logging in the technological process, the cost of operating harvesters and forwarders per 1 m³ of harvested wood was 210 rubles in 2014, and it increased by 44% and became 302.4 rubles in 2018. Thus, the share of costs of this item in the cost of harvesting round timber using the technology "harvester + forwarder" is most significant and amounts to about 20%.

This is due to the fact that in the Russian forest market the harvesters and forwarders produced by John Deere, Ponsse and Komatsu manufacturers (so called “Big Three” forestry equipment manufacturers) are the most popular, which in addition to some differences in design and performance have a common negative side for Russian loggers: the high cost of equipment and services, which eventually leads to an increase depreciation charges and costs during operation process.

So the costs for the removal of wood from the upper warehouse to the lower ones are also significant, which in 2018 it was about 293 rubles per 1 m³ and increased over five years by 42%. At the same time the logging transport services for timber removal was 191.8 rubles per 1 m³ (transport component), the cost of maintaining forest roads was 101.1 rubles per 1 m³ (road component). The reason for such high costs is the lack of year-round roads, which is covered by the construction of winter roads at the expense of cost. The problem of construction of logging roads is very acute, it is comprehensively discussed, but solved too slowly, so we cannot expect a rapid reduction in costs.

As a result, the prime cost of round timber has grown by 35.3% over five years. The annual cost increase was about 7%, which exceeds the rate of inflation. As of 2014, the level of profitability of products amounted to 20.45% with the average current sales price of 1 m³ of harvested wood in 1403.5 rubles. The prices for selling round timber for 2018 have not yet been published in the open press, so the changes of the final result are possible: an annual increase of sale prices of timber products in accordance with the rate of inflation growth would lead to a reduction in profitability by 2018, up 6.8%, and the increase in the price level, the cost would maintain the profitability at the same level.

However, the forest market is developing according to its own laws, so if you do not consider investing in new foreign equipment, it is very risky to predict a sharp increase in prices for forest products and expect the payback of such equipment in the future. It turns out from the foregoing that the purchase of expensive imported equipment will be able to afford only large timber enterprises, medium and small businesses should focus on the use of domestic machinery and equipment.

As an alternative to the basic process described above using the “harvester + forwarder” machine systems (hereinafter - option 1), on the basis of a survey of the production conditions of some enterprises, it was selected several options for the most common technological processes of assortment harvesting and considered timber and given their comparative technological and economic assessment for the conditions of the Leningrad region.

A brief description of the variants of technological processes and machine systems is presented in table 2.
The calculation of technical and economic indicators for the options is done by modeling. In that case, if the designed machines and equipment are of foreign production, then all the technical and economic indicators of the operation of machines and equipment are taken according to actual data without the involvement of foreign data. The comparability of the indicators of the compared options is ensured by the volume of production, the analogy of the technological operations performed, the main operating conditions, methods for determining the cost and natural indicators, i.e. compared options are given to the same features.

Technical and economic indicators of the compared variants of technological processes are brought to the technological cost of logging operations without taking into account rent and costs of forestry works, the value of which practically does not depend on the technological process, and are summarized in table 3.

### Table 3. Variants of technological processes and machine systems.

| Type of main cutting operations, sequence of their execution (technological process) | 1 | 2 | 3 | 4 | 5 |
| --- | --- | --- | --- | --- | --- |
| Harvestera Forwarderb | CS®+Forwarderb | CS®+CS®+ChS®+CS®+HM® | FB®+DFGS®+CBBM®+HM® | FB®+DFGS®+CBBM®+HM® | FB®+DFGS®+CBBM®+HM® |
| Felling of trees, cutting branches, bucking whips on assortments at the cutting sites – John Deere 1270E; Husqvarna 372XP; – forwarderb John Deere 1510; Loading Deere 1510; with HM® | Felling of trees – Husqvarna 372XP, cutting branches – CS® | Roll felling trees – John Deere 853M; skidding of packs of trees – DFGS® John Deere 748L; | Trimming branches and bucking of slips for assortments – CBBM® John Deere 2154D with a Waratah harvester | Roll felling trees – FB®-LP-19 with a mill and a Quadco drive (Canada); skidding of packs of trees – DFGS® | Roll felling trees – FB®-LP-19 with a mill and a Quadco drive (Canada); skidding of packs of trees – DFGS® |

© Harvester – feller-deliming and slitting machine (Wheeled Harvester).

b Forwarder – tractor for skidding round timber (skidding of assortments).

c CS – gasoline powered Chain Saw.

d FB – tracked Feller Buncher.

e HM – hydraulic manipulator mounted on the chassis of a logging vehicle.

f CBBM – machine for cutting branches and bucking trees (tracked harvester-processor).

g DFGS – skidding tractor with pincer grip package of trees (Skidder with Dual-Function Grapple).

h ChS – skidding tractor with sliding cable equipment (Cable skidder).

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Technical and economic indicators of the compared variants of technological processes are brought to the technological cost of logging operations without taking into account rent and costs of forestry works, the value of which practically does not depend on the technological process, and are summarized in table 3.
The comparative analysis of various technological processes allowed to estimate efficiency of their application on logging works and to identify advantages and disadvantages of each of them.

In contrast to the basic 1st option, the technological process in the second option involves the use of Chain saws on felling trees, delimming and bucking whips. This technology takes place in medium-sized enterprises, as a result the labor intensity of cutting operations increases in more than 2 times and, accordingly, labor productivity decreases, which leads to an increase in wage intensity. So wages with contributions to social insurance funds increased here to 228.8 rubles per 1 m³ of harvested wood compared to the first option (113.5 rubles). At the same time, there is a decrease in the cost of maintenance and operation of equipment, which ultimately leads to a decrease in the technological cost of the workpiece by 55 rubles per 1 m³. The second option shows a significant advantage in the need for capital investments. So the capital intensity of the process is 403.8 rubles per 1 m³, which is 2.8 times lower compared to the first option.

The third variant of the technological process, organized with the use of mainly domestic equipment, is characterized by a significant labor intensity and labor intensity of the process. The values of these indicators are the highest and are respectively 0.701 man-hours and 273.4 rubles per 1 m³ of harvested wood. According to these indicators, this version of the technology loses to the first two. However, the advantage of this option is a significant reduction in the cost of maintenance and operation of equipment and, accordingly, the technological cost, which is 447 rubles per 1 m³, which is lower by 115.5 rubles. compared with the first option and 60.5 rubles – compared with the second. In addition, under this option, the need for capital investments is reduced by 5.4 times compared to the first option and by 2 times compared to the second. These indicators are economically very significant for small and medium-sized business.

The fourth and fifth options provide for the use of Feller bunchers in the assortment process. The difference between these options is that the fourth option involves the use of systems of machinery and equipment of foreign production, and the fifth involves the machinery of domestic production.

The pattern of change in performance indicators is the same here, they are slightly inferior to option 1 in terms of labor productivity and, accordingly, in labor input and salary intensity, however, the technological cost price for them is much lower in comparison with other options. In addition, these options require significantly less investment in equipment compared to the first option. So the fourth

| Name of indicator                                                                 | Options for technological processes and systems of logging machines (according to table 2) |
|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| 1. Leading machine (mechanism) in the system                                       | Harvester John Deere 1270E, Forwarder John Deere 1510, Cable skidder MSN-10, Feller Buncher John Deere 853M, Feller Buncher Deere LP-19 |
| 2. Labor intensity of cutting works, man-hours per 1 thousand m³ including the main works | 283.6, 177.5, 106.1, 3.53, 5.63, 113.5, 378.6, 562.5, 1124 |
| 3. Labor productivity, m³ per 1 person-hour including on the main works           | 589.5, 481.5, 108.0, 1.7, 2.08, 229.8, 277.6, 507.5, 403.8 |
| 4. Remuneration with deductions to the Social Insurance Fund, rub. on 1 m³         | 701.3, 565.9, 135.4, 1.43, 1.77, 273.4, 173.6, 447.0, 208.1 |
| 5. Equipment maintenance and operation costs, RUB per 1 m³                         | 307.3, 187.9, 119.4, 3.25, 5.32, 119.8, 270, 389.8, 520.8 |
| 6. Technological cost of cutting operations, rub per 1 m³                          | 351, 236.7, 114.3, 2.85, 4.22, 136.8, 265.3, 402.1, 283.6 |

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option is higher priority in comparison with the first and second at cost, it is lower by 172.7 rubles, respectively, and 117.4 rubles per 1 m³, and especially in terms of capital intensity, whose performance is 2.16 times lower compared to the first option. A comparison of two options with domestic equipment (the third and fifth) shows the advantage of the fifth in all performance indicators, except for capital intensity, which is slightly higher.

4. Conclusion
The choice of the technological option for logging operations should be made taking into account the capabilities of the forest user according to three criteria: the complexity of the work, the technological cost, and the capital intensity of the process.

Studies have shown that the use of machinery and equipment of foreign production in logging operations in the current state of the forest market is not effective for all conditions, and it is practically inaccessible for small and medium-sized businesses. Therefore, at present, the necessity of forestry engineering development in Russia is particular relevance, and first of all, it is very important to organize mass production of those types and items of domestic equipment that have proved their effectiveness in operation.

References
[1] Gigel T 2017 During the transition to market relations logging suffered the most Lesprominform [in Russian - Lesprominform] 7(129) pp 28-29
[2] Irtuganov T 2017 Measures for the development of the timber industry Lesprominform [in Russian - Lesprominform] 8(130) pp 20-23
[3] Gilts N R, Fedorov V V, Vasyukov V A and Demin K K 1986 Selective logging (Moscow: Forest industry) p 192
[4] Sheherbin A M, Chernobaeva E A and Smirnova A I 2015 Efficiency of technological processes in logging Proceedings of the faculty of Economics and management [in Russian – Sbornik Trudov Fakulteta Ekonomiki] (St Petersbrg: SPbFTU) pp 157-163
[5] Methodical recommendations (instruction) on planning, accounting and calculation of the cost of production of the timber industry complex 2006 (Moscow: Moscow state forest University) p 256
[6] Collection of legislation of the Russian Federation 2017 Decree of the Government of the Russian Federation of 11.11.2017 #1363 «About the coefficients of the rates of payment per unit volume of forest resources and the rates of payment per unit area of a forest plot owned by the federal» vol 47
[7] Forest Code of the Russian Federation: Federal Law of 04.12.2006 No. 200-FZ (ed. of 27.12.2018) available at: https://http://www.consultant.ru/document/cons_doc_LAW_64299/