Determining the order volume of spare parts for a fleet of vehicles with a limited purchase cost

Abdunabi Tadjibaev a), Turgunbai Kadirshaev

*Tashkent State Transport University, Tashkent, Uzbekistan*

a)Corresponding author: [Abdunabi-t@mail.ru](mailto:Abdunabi-t@mail.ru)

**Abstract.** The article presents theoretical prerequisites for determining the volume of spare parts orders for a fleet of vehicles with limited (and unlimited) purchase costs. For a fleet of vehicles with limited purchase value, it is important to determine the order volume of spare parts, which helps to improve the performance and efficiency of the rolling stock by optimizing the purchase volume and the spare parts stored.

**INTRODUCTION**

In the context of market relations in road transport, reliability and various costs in the transport process are particularly important. These depend not only on the quality of the vehicles but also on the provision and management of their operational performance. During operation, the technical condition of the vehicle and its components changes, which can lead to partial or complete loss of performance [1-4,].

Therefore, improving the organization and functioning of the logistics system in road transport will contribute to increased vehicle performance and efficiency while minimizing costs [7-10, 13-17].

Spare parts inventories are not intermediate or final products intended for sale to the customer, and the management policy for spare parts differs from that for work-in-process and other inventories. The papers review the literature on management issues, age-based replacement, multi-level management problems, obsolescence issues, repairable spare parts, and special applications [11, 12].

A motor transport company must maintain a certain level of spare parts inventory to avoid downtime or interruptions in vehicle operation. Maintaining a high inventory level improves the reliability of the logistics system. On the other hand, creating inventory requires additional costs for storage, warehousing, transportation, insurance, and other expenses. Furthermore, excess inventory ties up working capital and hinders the profitable investment of capital.

By determining the volume of spare parts orders and managing their inventory at an optimal level, this solution allows for the systematization of inventory levels, minimizing the costs of creating and maintaining them at a given level, and ensuring the continuity of production processes.

METHODS

The annual spare parts inventory requirement is determined by various methods (based on actual consumption and parts resources, as well as a probabilistic approach) [5]. These methods are used to determine the required quantity of spare parts for a vehicle fleet over the operating period in question. This allows for the determination of the volume of spare parts for the period in question, based on both inventory and cost.

To determine the amount of stock and order time, various methods are used, from the simplest demand tables to complex economic and mathematical calculations using computer programs.

Economic and mathematical methods are based on determining the optimal sizes and frequency of orders at which the cost of obtaining and storing one part is minimal [5].

The annual costs (without limiting the purchase price) of inventory management are determined by the formula:

(1)

Here,

− annual demand for j-type of products, pcs;

− the sum of fixed transportation and procurement costs per one batch of deliveries of the j-type of products, USD;

− order quantity for product j - type;

− cost of j-the product;

− coefficient of costs from storage of products.

The main parameter of this system is the order size of the supply batch. It is strictly fixed and does not change under any circumstances. Therefore, sizing is the first task that is solved when working with this inventory management system.

The optimal size () of a supply order, which depends on the annual demand for parts of a given item and the costs of fixed transportation and procurement expenses per batch of deliveries and the ratio of storage costs for the received parts, is determined using the Wilson formula [5]:

(2)

In practice, most warehouses store a large number of different types of products. If all the necessary spare parts are ordered or obtained at the upper limit and maximum investment of their stocks, this leads to the expenditure of the invested capital of the enterprise and the accumulation of excess spare parts as dead capital.

In this regard, the volume of orders for a delivery batch must be determined taking into account the purchase price limit, i.e. a reduction in the order volume.

A motor transport company needs to order () types of spare parts.

In this case, all requirements for spare parts must be met from the stock available in the company’s warehouse. If we denote by () the size of the stock for the product of the ()th type, then, subject to the limitation of the purchase cost, the following inequality must be satisfied:

(3)

Here,

− capital investment in warehouse facilities, USD

If the capital investment in warehousing is less than the maximum permissible or more, then the volume of spare parts order is determined with the capital investment limitation () in stocks.

To determine the optimal values of , the Lagrange multiplier method is used [6]:

(4)

Here,

− is the Lagrange multiplier.

Expression (4) is an objective function, the minimum value of which corresponds to the optimal volume of the order batch with a limited purchase cost. To do this, we differentiate equation (4) with respect to and obtain:

(5)

After some rearrangements, we obtain a formula for determining the optimal volume of an order batch, taking into account the constraint:

(6)

The Lagrange multiplier is defined as follows:

(7)

i.e.

(8)

After the transformation we get:

(9)

Equation (9) is solved as follows:

(10)

(11)

Let us designate:

(12)

(13)

To determine the Lagrange multiplier (13), we square both parts of the equation, i.e.

(14)

Then the Lagrange multiplier is defined as:

(15)

Variants of using the Lagrange multiplier:

1. the volume of spare parts is determined without limitation, i.e. at the maximum permissible purchase price.

2. the volume of spare parts is determined with a limitation, i.e. less than the maximum permissible purchase price.

3. the volume of spare parts is determined with a limitation, i.e. more than the maximum permissible purchase price.

Under conditions 2 and 3, the volume of spare parts is determined with a limitation on the purchase price.

The minimum costs for equipment retooling and inventory storage for () types of products in the absence of a purchase price limit are determined by the formula:

(16)

The corresponding minimum cost in the presence of a purchase price limit is determined by the formula:

(17)

The developed methodology will facilitate the adoption of optimal order volumes when managing stocks and organizing digital warehouse management.

**Results.** The basic principles for determining the volume of spare parts orders for motor vehicles at different purchase prices are included in a computer program developed in Visual Basic and tested at enterprises in Tashkent.

**Example.** It is necessary to determine the optimal batch size of spare parts order with and without regard to the capital investment limitation. The necessary information is given in Table 1.

**Table 1.** Initial data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **№** | **Indicators** | **Name of products** | | | |
| **1** | **2** | **3** | **4** |
| 1 | Annual requirement, pcs. | 500 | 700 | 115 | 500 |
| 2 | Cost of the part, USD | 80 | 150 | 140 | 60 |
| 3 | Amount of fixed transportation and procurement costs, USD | 250 | 350 | 400 | 450 |
| 4 | Storage Cost Ratio | 0,18 | | | |

Optimal order sizes for each type of product, without limiting the purchase price, are given in Table 2.

**Table 2.** Optimal order volume without limiting the purchase price

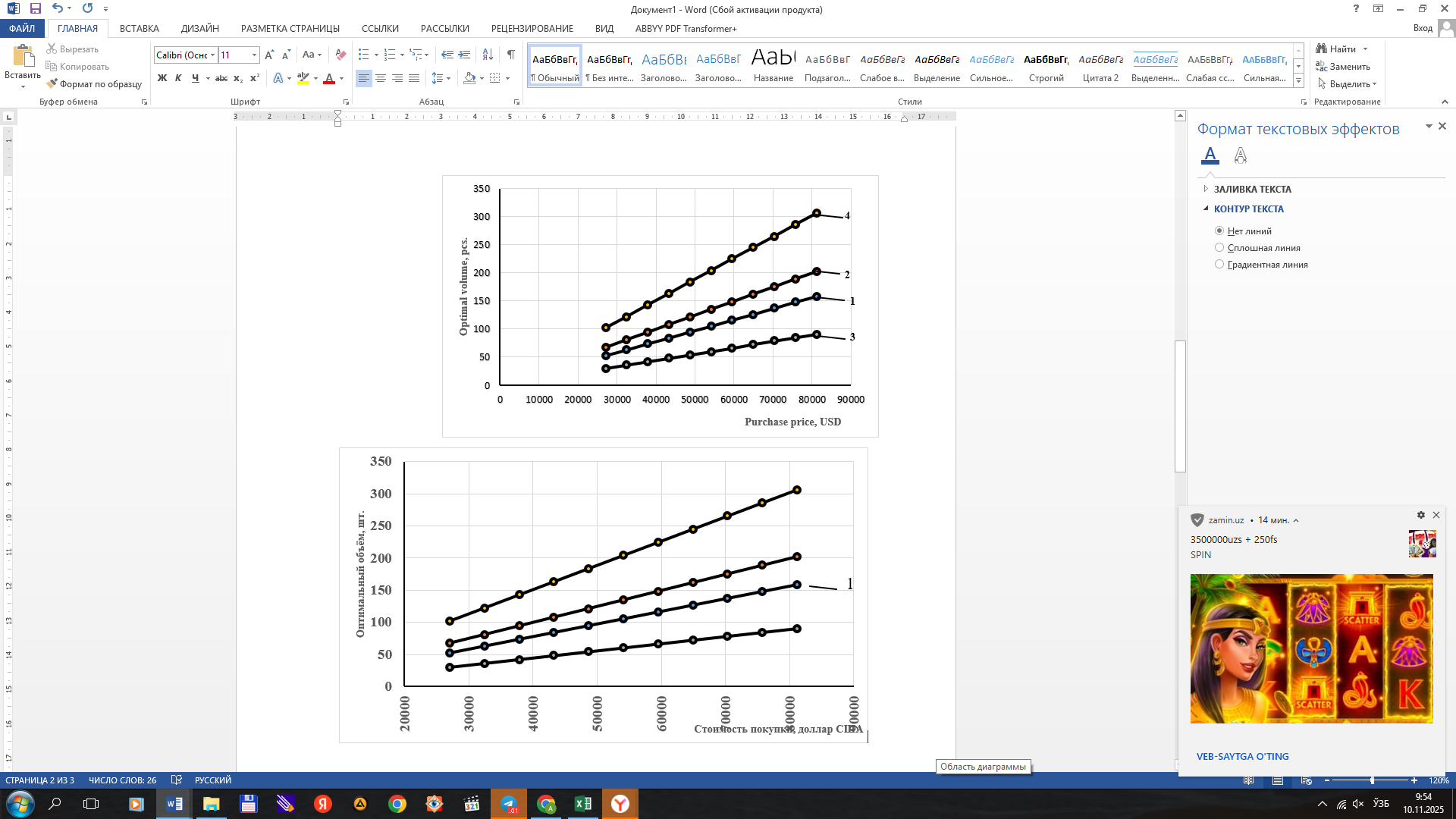
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **№** | **Indicators** | **Name of products** | | | |
| **1** | **2** | **3** | **4** |
| 1 | Optimal order volume without limitation, pcs. | 105 | 135 | 60 | 204 |
| 2 | Cost of purchasing -th product without restrictions, USD. | 13176 | 20207 | 8459 | 12247 |
| 3 | Purchase price for optimal order volume, all products (100%), USD. | 54090 | | | |
| 4 | Minimum purchase price for all products (50% of the cost without limitation), USD. | 27045 | | | |
| 5 | Maximum purchase price (150% of the price without limitation), USD. | 81135 | | | |

The calculation of the optimal order volume of spare parts and the Lagrange multiplier for different (less than and more than the maximum permissible) purchase prices for products are given in Table 3 and Figures 1 and 2.

**Table 3.** Optimal order quantity and Lagrange multiplier for different purchase prices

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Indicators** | **Purchase price intervals, USD** | | | | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| Purchase price at limit, USD | 27045 | 32454 | 37863 | 43272 | 48681 | 54090 | 59499 | 64908 | 70317 | 75726 | 81135 |
| Lagrange multiplier | 0,270 | 0,160 | 0,094 | 0,051 | 0,021 | 0,000 | -0,016 | -0,028 | -0,037 | -0,044 | -0,05 |
| Name of products | Optimal order volume | | | | | | | | | | |
| 1 | 53 | 63 | 74 | 84 | 95 | 105 | 116 | 126 | 137 | 148 | 158 |
| 2 | 67 | 81 | 94 | 108 | 121 | 135 | 148 | 162 | 175 | 189 | 202 |
| 3 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 73 | 79 | 85 | 91 |
| 4 | 102 | 122 | 143 | 163 | 184 | 204 | 225 | 245 | 265 | 286 | 306 |

**FIGURE 1.** Change in Lagrange multiplier depending on purchase price.

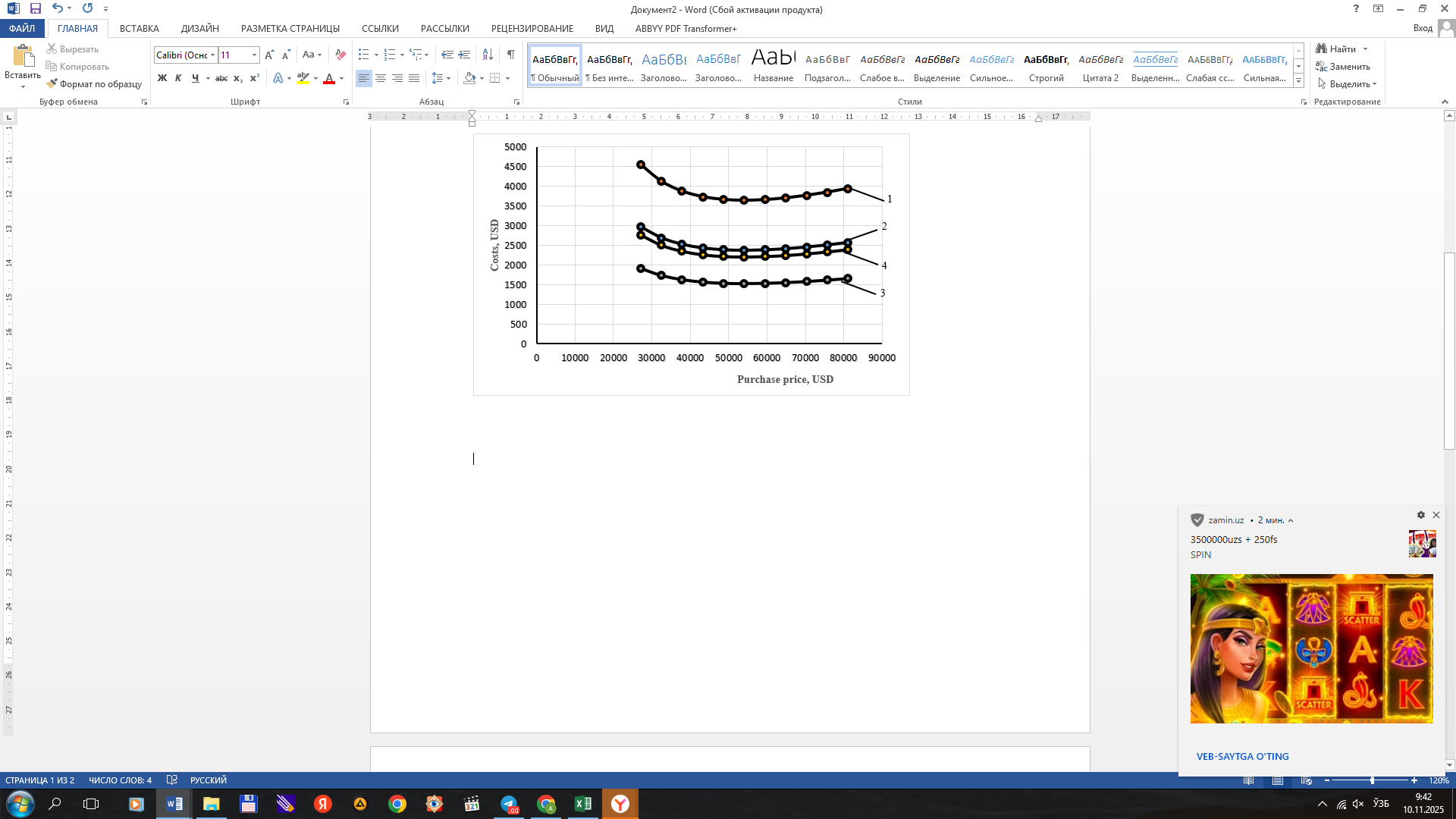


**FIGURE 2.** Change in the volume of spare parts order depending on the purchase price: 1-4 respectively the name of the products

From Table 3 and Figures 1 and 2 it is clear that the lower the purchase cost, the Lagrange multiplier (Figure 1) increases, and the volume of spare parts ordered (Figure 1) decreases. The change in minimum costs and annual losses for different purchase prices of spare parts are presented in Table 4 and Figures 3, 4 and 5.

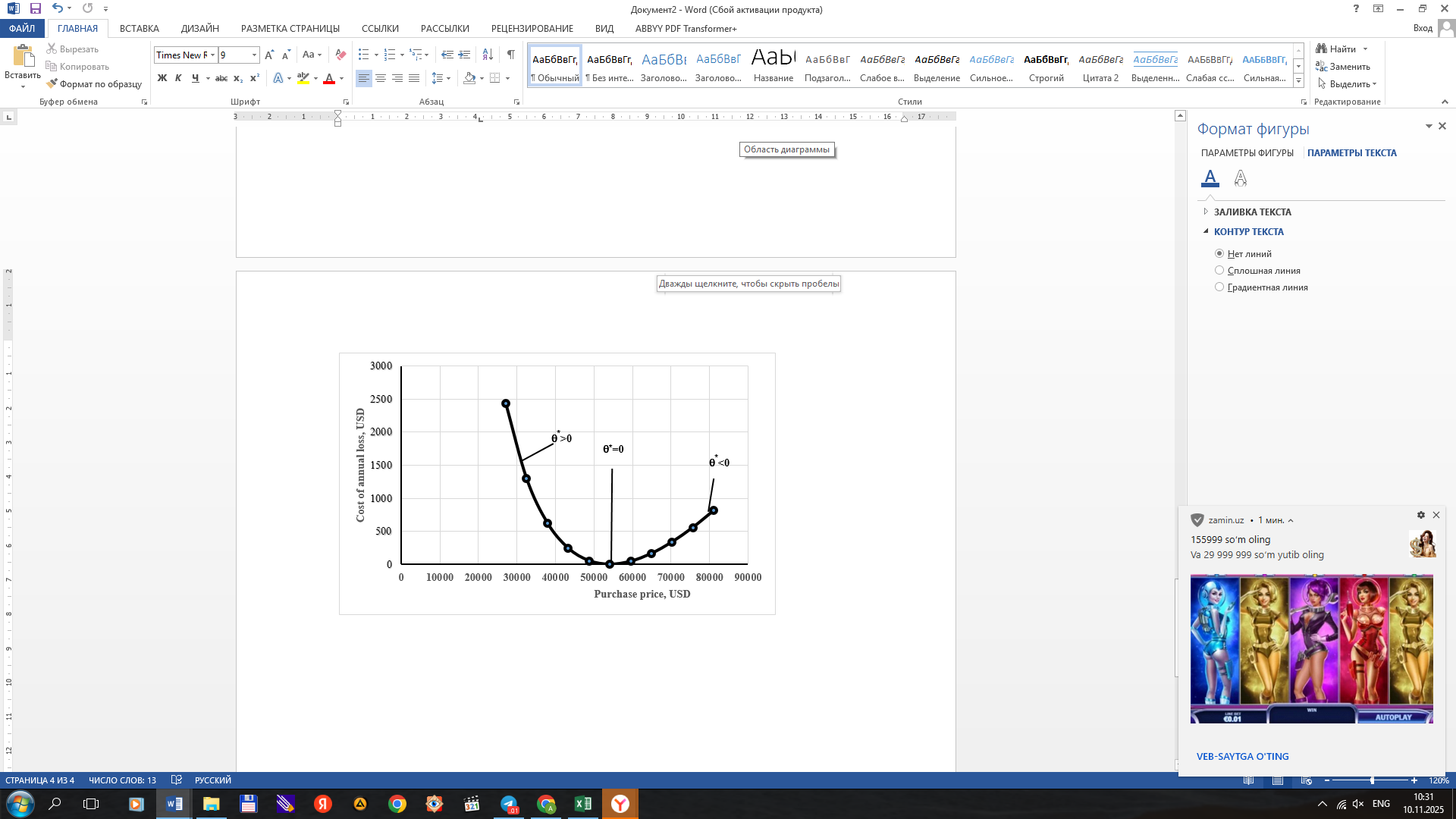
**Table 4.** Minimum costs for different purchase prices of spare parts

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Indicators** | **Spare parts purchase cost intervals, USD** | | | | | | | | | | |
| **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **Name of products** | 27045 | 32454 | 37863 | 43272 | 48681 | 54090 | 59499 | 64908 | 70317 | 75726 | 81135 |
|  | | | | |  |  | | | | |
| **1** | 2965 | 2688 | 2524 | 2431 | 2385 | 2372 | 2382 | 2411 | 2454 | 2507 | 2569 |
| **2** | 4547 | 4122 | 3871 | 3728 | 3658 | 3637 | 3654 | 3698 | 3763 | 3845 | 3940 |
| **3** | 1903 | 1726 | 1621 | 1561 | 1531 | 1523 | 1530 | 1548 | 1575 | 1610 | 1650 |
| **4** | 2756 | 2498 | 2346 | 2260 | 2217 | 2205 | 2215 | 2241 | 2281 | 2331 | 2388 |
| **Total costs, USD** | 12170 | 11034 | 10362 | 9980 | 9790 | 9736 | 9780 | 9898 | 10073 | 10293 | 10548 |
| **Cost of losses during the year, USD** | 2434 | 1298 | 626 | 244 | 54 | 0 | 44 | 162 | 337 | 557 | 812 |



**FIGURE 3.** Change of minimum costs at different cost of purchase of spare parts: 1-4 respectively name of products.

**FIGURE 4.** Change in total costs for different purchase prices of spare parts.



**FIGURE 5.** Change in annual cost of losses depending on different purchase prices of spare parts.

From Table 4 and Figures 3, 4 and 5 it is clear that under the condition with a decrease in the purchase price, the annual costs of spare parts (Fig. 3) and, accordingly, the total costs increase, the minimum costs under the condition , and under the condition , i.e. with an increase in the purchase price, the annual costs and the cost of losses increase (Fig. 3, 4, 5).

Based on the calculation results, if spare parts are purchased at the minimum cost, then the enterprise will lose USD during the year, and at the maximum cost USD. Based on this, one should always strive to purchase spare parts from the optimal volume without limitation.

**CONCLUSION**

The examples given convincingly show that by ordering spare parts at different purchase prices (minimum or maximum), the enterprise will lose a certain amount over the course of a year (Fig. 5). Therefore, it is recommended to determine the order volume for spare parts without purchase price restrictions, which allows to sharply reduce the number of illiquid and scarce parts, as well as annual cost losses.

**REFERENCES**

1. A. A. Tadjibaev, “Methodology for determining the need for spare parts for cars,” *TADI Bull.* 3–4, 81–85 (2017).
2. A. A. Tadjibaev, “Influence of the resources of replaceable parts on the reliability of cars during operation,” *TADI Bull.* 1, 3–9 (2020).
3. B. Ibragimov, A. Tajibaev, S. Narziev, and M. Alimov, “The economic aspect of the reliability of vehicles,” *AIP Conf. Proc.* (2023).
4. T. Kadirshaev, A. Tadjibaev, and K. Ibrahimov, “Improving the technological accounting of maintenance stations located in cities,” *AIP Conf. Proc.* 2789, 040091 (2023). <https://doi.org/10.1063/5.0145667>
5. A. A. Tadjibaev, *Logistics and Resource Conservation in Road Transport*, Vol. 2 (Ministry of Higher and Secondary Specialized Education of the Republic of Uzbekistan, Tashkent, 2020), 135 p.
6. Online Resource, “Wilson formula,” available at <https://blog.oy-li.ru/formula-uilsona> (accessed year not specified).
7. A. A. Tyukhtina, *Inventory Management Models: A Tutorial* (Nizhny Novgorod State University, Nizhny Novgorod, 2017), 84 p.
8. A. A. Tadjibaev, *Research on the Reliability of Vehicles During Operation* (Innovation-Ziyo, Tashkent, 2022), 150 p.
9. G. Ubaydullayev, D. Riskaliev, N. Ergashev, A. Rashidov, and S. Shadiev, “Determination of installation bases of parts during their mechanical processing,” *E3S Web Conf.* 264, 05046 (2021). <https://doi.org/10.1051/e3sconf/202126405046>
10. T. Kadirshaev and H. Ubaidullaev, “The reliability status of the automatic transmission of MAN buses operated in hot and sandy climates and its improvement,” in *Proc. Int. Sci. Conf. “Automobile Equipment and Equipment for Operation and Innovation”* (Chirchik, 2022), pp. 169–172.
11. W. J. Kennedy, J. W. Patterson, and L. D. Fredendall, “An overview of recent literature on spare parts inventories,” *Int. J. Prod. Econ.* 76(2), 201–215 (2002). <https://doi.org/10.1016/S0925-5273(01)00174-8>
12. B. O. Odedairo, “Managing spare parts inventory by incorporating holding costs and storage constraints,” unpublished manuscript, University of Ibadan, Ibadan, Nigeria.
13. T. Baxtiyor and N. Khalmurzaev, “Features of regeneration of air filters of Mercedes-Benz buses in the conditions of Tashkent,” *AIP Conf. Proc.* (2024). <https://doi.org/10.1063/5.0197845>
14. D. Ahmedov, Sh. Alimuhamedov, I. Tursunov, S. Narziev, and D. Risqaliyev, “Modeling the steering wheel influence by the driver on the vehicle's motion stability,” *E3S Web Conf.* (2021). <https://doi.org/10.1051/e3sconf/202126405015>
15. M. Rakhmatov, A. Riskulov, and K. Nurmetov, “Composite materials with enhanced abrasion resistance and certain functional characteristics based on thermoplastics,” *Mater. Mech. Eng. Technol.* (2025). <https://doi.org/10.52209/2706-977X-2025-2-86>
16. B. M. Nuritdinovich and O. M. Uktamjonovich, “AI-driven VIN verification and RFID integration for error-proofing in automotive manufacturing,” *Vibroengineering Procedia* (2025). <https://doi.org/10.21595/vp.2025.24957>
17. Sh. P. Magdiyev and M. I. Rakhmatov, “Standardization of the motor oil change frequency in automobiles in the mountainous conditions,” in *Proc. Int. Conf. Thermal Engineering: Theory and Applications (ICTEA 2024)* (2024)