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INCREASING THE PROFITABILITY OF THE AGRICULTURAL MARKET BY OPTIMIZING GRAIN TRANSPORTATION

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Introduction. As for the profitability of agricultural enterprises, it provides food security for the state and the population, thus the study of the effectiveness of the functioning of agricultural enterprises is important and a priority for any state. Freight railway transportation is one of the main types of activity of JSC "Ukrzaliznytsia", they largely meet the transportation needs of the national economy.

Specialized wagons, intended for the transportation of one or more goods similar in their properties, have a special body shape, equipment and devices. Hopper wagons designed for transporting grain with a special body shape are equipped with special equipment for loading and unloading wheat, barley, oats, corn and other grains. 175 varieties of soft winter wheat, including about 80% of domestic varieties, are included in the state register of varieties that are suitable for cultivation in Ukraine and are in demand in foreign markets [4]. Winter wheat is one of the few highly profitable crops that can withstand competition with foreign varieties. Gross harvest of grain in our country is much higher compared to domestic consumption, and therefore there is an opportunity to increase its supplies to the world market. Domestic grain, provided that the relevant logistical aspects of its transportation are solved, can create a competitive advantage in the global agricultural market.

Volumes of grain freight transportation, including by rail, continue to grow. Ukrzaliznytsia is faced with the problem of a shortage of freight cars, especially hopper dispensers for grain and grain crops, as a result of which it cannot always fulfill requests received from customers. In the conditions of the entry of domestic grain traders to the world market, additional funds are planned to be directed to the purchase of new rolling stock for freight transportation of grain. An important aspect of design unification is the optimization of the nomenclature of modern hopper dispensers for grain and grain crops that have the same or similar operational purpose. The assortment policy regarding modern hopper wagons of a special body shape for the transportation of grain crops should determine a rational ratio according to the stages of the life cycle of products that are simultaneously offered by the manufacturer on the market of vehicles for grain transportation.

Analysis of recent research and publications. A product range is a group of products closely related to each other by similar principles of operation, sales to the same groups of buyers, a marketing method of promotion to the market, or belonging to the same price range [10, p. 654]. The strategy of a large manufacturer of vehicles in Ukraine includes the formation of a product range of freight cars. The management of

the wagon-building plant strives to expand the assortment, including in the market of hopper wagons for the transportation of grain crops, with the aim of both increasing its share in the market and ensuring the growth of the market itself in the conditions of an increase in the gross harvest of wheat and corn in the country. Merchandise assortment managers seek to expand the depth (line) of the product range of hopper wagons for the transportation of grain crops over time in order to use excess production capacities while simultaneously more fully satisfying the requests of grain traders.

Preparation for the creation and development of new products is mutually determined by taking into account the function of distribution of productivity of freight cars. The distribution function is obtained by statistical processing of design, technological, and production documentation related to ensuring the economic efficiency of the wagon. In the process of conducting marketing research, the issue of creating one type of modern hopper-dispenser for grain and grain crops, which can provide high productivity for any conditions of its operation, needs to be resolved. The company's design departments have the opportunity to offer several modifications of improved hopper dispensers for grain and grain crops with different productivity. Modification of a new hopper-dispenser with lower productivity is, as a rule, simpler and cheaper both in production and in operation [6; 8]. With a greater number of modifications, a reduction in transportation costs is achieved, since the appropriate type of wagon is selected depending on the required performance. At the same time, the costs of development, testing and delivery of the flow of modifications of the new hopper dispenser for grain and grain crops are increasing. Taking into account the above arguments, there is an optimal number of modifications of hopper dispensers for grain and grain crops for the rational productivity of each model series, which minimizes the total costs [8]. It is expedient for developers to determine the optimal number of modifications of hopper dispensers, for example, intended for the transportation of grain and grain crops from each model series, for which the total costs are minimized. A large number of foreign scientists, such as Antonyuk L., Poruchnyk A., Savchuk V. [1], Bezchasnyi L. [2], Galchynskyi A., Geets V., Kinakh A., Seminozhenko V. [5], and others. The analysis of scientists' works shows that the problem of increasing competitiveness with the optimal number of modifications of new products is very acute for Ukrainian enterprises.

Objectives of the article. The main goal is to find the possibility of optimizing each model series of hopper-dosers, intended for the profitable transportation of grain and grain crops, in the conditions of globalization of the agricultural market and intensifying competition in the railway rolling stock market.

The main material of the study. The private joint-stock company "Kryukovsky Carriage Building Plant" (PJSC "KVBZ") is a high-tech, multidisciplinary enterprise producing a wide range of mainline freight and passenger cars, high-speed interregional electric trains, subway cars and escalators. The plant offers consumers about 45 models of modern trunk freight and specialized wagons of various types and designs, including half wagons, bunker wagons, specialized bunker wagons, platform wagons, covered wagons, and tank wagons. The production and technological base of the enterprise allows to produce up to 12,000 freight cars per year, to quickly adjust production flows for the production of various models and modifications of cars, to build five different types of freight cars at the same time. The entire nomenclature of freight cars, as well as their components and spare parts, have appropriate quality certificates and licenses for their use within the railways of the CIS and Baltic countries, and, if necessary, also in far abroad. The company's quality system is certified according to ISO 9001-2008 and AAR [6; 7].

The plant staff is constantly improving the design of hopper cars intended for the transportation of grain crops and other loose cargoes that need protection from atmospheric precipitation on all railways of Ukraine, the CIS countries and the Baltic States, with loading through the upper hatches and gravity unloading through the lower hatches into the inter-rail space on special loading and unloading devices. Table 1 shows the technical characteristics of model 19-7016 and 19-7017 hopper cars with a traditional body shape, which have been produced for many years and are in high demand, with a design speed of 120 km/h. and service terms of 30 years.

Wagons with a traditional body shape are manufactured with different types of unloading devices: sliding or lever. Brakes – automatic, pneumatic with separate trolley braking, manual parking brake. The undercarriage is two two-axle carts of the corresponding model. Self-clutch CA-3 and absorbing apparatus of increased energy capacity not lower than T1. The plant has also mastered the production of hopper wagons model 19-765E for the bulk transportation of grain with a carrying capacity of 67 tons with a body volume of 80 m3 and a wagon base of 9000 mm. For the traditional number of four loading hatches of a hopper car, the number of unloading hatches has been increased in the range from three to four to six. The design speed of a loaded hopper car for

Table 1

Technical characteristics of hopper wagons models 19-7016 and 19-7017

The name of the characteristic	Model			
	19-7016-01	19-7017-03	19-7017-04	19-7017-06
Carrying capacity, i.e	70,2	71	71	71
Body volume, m^3	108	91	87	96
Mass of the wagon, i.e	23,5	22,5	22,5	22,5
The calculated load from the wheel pair on the rail, i.e	23,5	23,5	23,5	23,5
Wagon base, mm	10500	9500	9500	9500
The length of the car along the axles of the auto-coupling, mm	14720	13720	13720	13720
Number of hatches: – loading; – unloading.	 4/5 3	 4 3	 4 4	 4 4

grain transportation is 100 km/h, and an empty one is 120 km/h. The authors, together with the employees of the wagon-building plant, worked out in detail the approaches to optimizing the model range of hopper dispensers with a traditional body shape, intended for the transportation of grain and grain crops [8].

In order to increase profits, more fully satisfy the needs of grain traders, use excess production capacity, become a leading domestic enterprise in the field of freight car construction with an exhaustive assortment, the top management of "KVBZ" is constantly working to eliminate gaps both in the assortment and in depth, for example, lines product nomenclature of hopper wagons with an improved body shape for the transportation of grain crops. In accordance with the subject form of the organization of shops and departments adopted at the plant, the production of welded metal structures is concentrated in the car assembly block of shops. In the conditions of large-scale production of semi-wagons, grain trucks, and cement trucks, subject-specialized lines with rigid and flexible connections, which are equipped with vehicles, equipment, technological and organizational equipment, have been created. As a result, it contributed to increased productivity, improved quality, and freed assembly workers and welders from heavy and monotonous work. The technological process of manufacturing welded structures of hopper cars provides for both differentiation and concentration of the operations performed, taking into account the rhythm and cycle of the entire production process. Of the assembly and welding lines implemented at the plant, the lines for the production of transverse frame beams, assembly and welding of the body of a modern design deserve special attention. Thus, the manufacture of transverse beams is carried out on semi-automatic single-object direct-flow lines with flexible connection to several workplaces, which are connected by a general transport system in the form of driven or non-driven roller conveyors. The current line for the production of pivot beams includes equipment: a supplier with a roller conveyor, a mechanized assembly stand, an intermediate roller conveyor, accumulators, a stand for automatic welding, a stand for welding, monorails – longitudinal and transverse.

Marketers, together with the employees of the design department of the enterprise, in the process of working out a decision to increase trade volumes, including by increasing export deliveries, proposed to expand the existing assortment group of hopper wagons for the transportation of grain crops with an improved body shape of model 19-7053 with further deepening of the product line nomenclature of options for their production. The method of solving a one-dimensional problem of choosing one variable N, which minimizes total costs, has an analytical expression, and is most suitable for use at enterprises that create and develop modern products. In practice, the cost of production of a new product (C_o) is proportional to the argument (x):

$$C_o = a \cdot x \quad (1)$$

The function of the cost of development, testing and production of the new model 19-7053 hopper dispenser for grain and grain crops is formulated $C_p(x)$, the cost of production of one modification from this argument $C_в(x)$ and the cost of operation per unit of time $C_в(x)$.

Such dependencies are often encountered in practice,

$$F(x) = 0 \text{ at } x \le x_o. \quad (2)$$

The differential function $b(x - x_o)$ of the demand in the argument is constant in a certain range of the argument and, as is known from the special literature [10], is equal to zero beyond its limits:

$$C_p(x) = c \cdot x, \quad (3)$$

that is, the cost of development (C_p) is proportional to the value of the argument [8; 10].

The solution to the problem is as follows: we specify the number of modifications, choose the optimal argument values for this case using the usual methods and calculate the costs. The procedure is repeated for a different number of modifications of the 19-7053 model. At the final stage, the optimal number of modifications of the corresponding model range is substantiated.

For a specific type of new model 19-7053, the value of the argument should be x_N. The total costs (S) in this case are calculated according to the formula known from the special literature [9].

$$S = b \cdot (x_N - x_o) \cdot a \cdot x_N + c \cdot x_N. \quad (4)$$

In the future $\tilde{\tilde{x}}_o$, we will denote the value x_o.

If there are two modifications, then the argument of the hopper car of the first modification is determined under the conditions of minimizing total costs. For the second modification of a specific type of new hopper car, it is equal to $\tilde{\tilde{x}}_N$. In this case, the total costs:

$$S = x_1 \cdot (x_1 - x_o) + (1 - x_1) + kx_1 + k. \quad (5)$$

In formula (5), the ratio of these values to x_N is denoted by x_o and x_1. We equate the first derivative of S to zero. After solving the obtained equation, we determine that:

$$x_1 = \frac{1 + x_o - k}{2}. \quad (6)$$

Expenses for this case are calculated according to the well-known formula:

$$\tilde{\tilde{S}}_o = \frac{3k + kx_o - k^2}{2} + \frac{3 - 2x_o - x_o^2 + k}{4}. \quad (7)$$

The first term of equation (7) shows the costs of development, testing and delivery of production (S_p), and the second – production costs ($\tilde{\tilde{S}}_b$).

In the same way, the problem is solved in cases where the number of modifications is three or more. By their nature, the problems of choosing the optimal series are related to well-known distribution solutions [10], but they differ from them in the presence of unfixed values of the argument. Reasoned arguments of N types $x_1, x_2, \ldots x_N$ are used in the range from x_{k-1} to x_k in the k-th modification of the new hopper dispenser. The values of the arguments in the development of the methodology are assigned to x_N. It is appropriate to trace how the relative costs of modification production change in the simplest case, that is, when $x_o = 0$; $k = 0$.

In Figure 1 shows the trend of changes in development costs and production costs depending on the number of modifications of the hopper dispenser model 19-7053 with an improved body shape. Costs attributed to production decrease with an increase in the number of modifications according to the corresponding dependence shown in Figure 1. The relative costs of development and installation for production S_p / k at x_o=0 and small k grow linearly with increasing N. It should be noted that at significant values of k this dependence may differ significantly from the linear one.

In recent years, the plant team has developed and produces a modern hopper-doser with an improved body shape for transporting grain and grain crops, model 19-7053, tests and puts its modifications into production. The team of the company faces the task of providing high efficiency, the best operational characteristics, in combination with the reliability of the design and the quality of production, to ideally contribute to solving the problems of optimizing the number of modifications in order to minimize costs when carrying out grain transportation using hopper dispensers. To meet the growing needs of consumers, manufacturers offer a line of modifications of hopper dispensers for grain and grain crops. During the reorganization of the production process, the plant's employees paid attention not only to improving its technical equipment, but at the same time solved the problems of improving the quality of hopper dispensers. The most important indicator of the quality of hopper dispensers for grain and grain crops is reliability, which combines durability and maintainability. Metal structures of wagons are calculated for a service life of 30-35 years under the conditions of influence on them of significant sign-changing loads, taking into account their use for the transportation of goods in different climatic zones. This purpose of hopper wagons requires special attention from designers and technologists when solving issues related to increasing the reliability and operational durability of products.

Processing of statistical data showed that the specific capacity of hopper dispensers for grain and grain crops is evenly distributed from 0.650 to 0.820 t/m3. It is necessary to choose the optimal capacity range of hopper dispensers for grain and grain crops for the conditions of the company's work, if their total quantity before release is planned to be 1,000 pieces. The cost of production of the hopper dispenser for grain and grain crops model 19-7053 is C_0 = 7950 thousand UAH. For other modifications of the new machine (product), the cost is proportional to the capacity of the hopper dispenser for grain and grain crops.

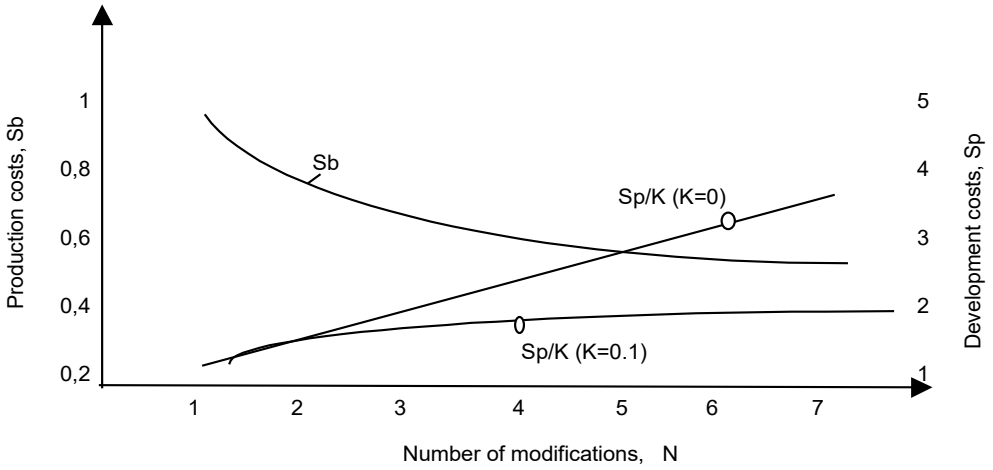

Figure 1. The trend of cost dynamics when the number of modifications of the new model 19-7053 hopper dispenser changes

Hopper wagons of the 19-7053 model for the transportation of grain crops and other loose cargo are equipped with two two-axle carts manufactured under the license of "Amsted Rail". In the table 2 shows the technical characteristics of model 19-7053 hopper cars, with a design speed of 120 km/h. and service terms of 30 years.

Table 2

Technical characteristics of model 19-7053 hopper wagons

The name of the characteristic	Model			
	19-7053	19-7053-01	19-7053-02	19-7053-03
Carrying capacity, i.e	75,4	70,5	70,5	70,5
Body volume, m^3	116	116	116	116
Mass of the wagon, i.e	24,5	23,5	23,5	23,5
The calculated load from the wheel pair on the rail, i.e	25,0	23,5	23,5	23,5
Wagon base, mm	10500	10500	10500	10500
The length of the car along the axles of the auto-coupling, mm	14720	14720	14720	14720
Number of hatches: – loading; – unloading.	 5 3	 5 3	 5 3	 5 4

Hopper wagons of different degrees of novelty offered by the plant for the transportation of grain crops guarantee the manufacturer stable conditions for ensuring sales volume at acceptable profitability. Model 19-7053-05 is not present on the market of vehicles for transporting grain, but is being developed, so it should also be taken into account in the assortment policy of the plant.

Hopper wagons of models 19-7053-01 and 19-7053-02 for the transportation of grain crops are at the stage of maturity, are successfully sold on the market and bring significant profits to the plant. The production of hopper cars of the mentioned models is carried out with small investments, production and sales costs are minimal, and therefore the proceeds from the sale of this group of vehicles are used to finance models 19-7053-03 and 19-7053-04, which are at the stage of entering the market.

From Figure 1, it can be seen that a series of five hopper dispensers for grain and grain crops is optimal. At the same time, the total relative development costs and production costs of a family of hopper dispensers for grain and grain crops are $S = S_p + S_b = 0{,}2409$, which are the minimum values for the given number N.

Note that, in accordance with the extremum, a number of four or five modifications of model 19-7053 hopper dispensers for grain and grain crops with a specific capacity of 0.670, 0.730, 0.795 and 0.850 t/m^3 can be adopted without large losses. In the conditions of intensifying competition in the market of hopper dispensers for grain and grain crops, additional considerations may appear regarding the expansion of the number of types of new machines by the leading manufacturer of rolling stock in Ukraine. Thus, choosing the optimal range can reduce costs by 10-15% for the working conditions of PJSC "KVBZ".

With our participation, the methodology was refined in terms of taking into account the potential costs of operating modifications of modern hopper dispensers of models 19-7053 for consumers. The cost of operating hopper dispensers for grain and grain crops per unit of time was determined by taking into account the costs of current and capital repairs, and the provision of service personnel. We calculated the ratio of operating costs ($B_{екс}$) for a year to the cost of a hopper dispenser for grain and grain crops (B_o) of models 19-7053 (with a body volume of 116 m3):

$$K_{екс} = \frac{B_{екс}}{B_o} = \frac{B_{рем} \cdot K_{рем} \cdot \phi(t) + B_{пр} \cdot k_{пр}}{B_o}, \tag{8}$$

de $B_{рем}$, $B_{пр}$ – the cost of repairs and the average salary of service personnel; $k_{рем}$, $k_{пр}$ – quantitative indicators of needs, including repairs and service personnel; $\varphi\ (t)$ is a function showing the increase in operating costs as the hopper dispensers for grain and grain crops wear out.

The processing of actual data on operating costs of model 19-7053 hopper dispensers for grain and grain crops on the railways of Ukraine showed that the function is well approximated by an exponential dependence:

$$\varphi\ (t) = exp(\mu \cdot t) - 1, \tag{9}$$

where μ is the value of the calculated coefficient.

The problem of choosing the optimal series in the well-known mathematical formulation [10] is reduced to the one solved for the specific operating conditions of the plant, but instead of k, one should substitute k', which is determined by the formula substantiated by specialists [9], taking into account the time (T) of operation:

$$k' = \frac{C}{b(a + K_{екс} \cdot T)X_N}. \tag{10}$$

The method of solving the problem in a complicated setting has no fundamental difference when the optimal series of modifications of the hopper-dosers of the model 19-7053 for grain and grain crops are determined. In the course of processing the operating data, equations were drawn up for costs from x_0 to $x\phi_1$; from $x\phi_1$ to $x\phi_2$, etc., where $x\phi_1$, $x\phi_2$,.. are fixed values of the arguments. We calculated the optimal values of the intermediate values of the arguments at 1,2 and the like for the rational operation time of the hopper dispenser for grain and grain crops.

So, with $N = 1$, we got:

$$S_N = abx_N^3 + q_1, \tag{11}$$

where $q_1 = C_p(x)$.

With $N = 2$, we got:

$$S_N = ab[3x_N x_1^2 - x_1^3 + x_N^3 - 2x_N^2 x_1] + 2q_1. \tag{12}$$

In this way, N was fixed according to the known method [6; 10], the optimal series of the 19-7053 model was calculated at a fixed N, and S_{NO} was determined. N was successively increased and its value was found at which S_{NO} has a minimum value. The creation of an optimal range of specific capacity from 0.670 to 0.850 t/m^3 of modern designs of hopper dispensers model 19-7053 for grain and grain crops, which must have high technical and economic characteristics, is a complex complex task that is successfully solved.

Model 19-7053 hopper wagons are designed for the transportation of 1520 mm gauge grain crops and other loose cargoes that require protection from atmospheric precipitation throughout the railway network of Ukraine, the CIS countries, and the Baltic States, with loading through the upper hatches and gravity unloading through the lower hatches into the interrail space on special unloading devices. Wagons are built with different types of unloading devices (sliding and lever). Brakes – automatic pneumatic with separate trolley braking, manual parking brake. The design of the hopper-dispenser model 19-7053 for grain and grain crops can be

considered technological, the development and production of which in the specified production volumes will be carried out with minimal production costs and with a short production cycle. The production manufacturability of constructions of the optimal series is characterized by indicators of material intensity, labor intensity, cost and production cycle. Manufacturability indicators have a decisive influence on the creation of an optimal range of modifications of hopper dispensers for grain and grain crops.

Conclusions. After a detailed study of scientific sources [11–15], and based on our own research, we can come to the conclusion that increasing the profitability of agricultural enterprises is an integral part of the information system for effective management of the activities of these enterprises. The forecast of transportation needs indicates an increase in demand for certain types of freight cars: grain trucks, pellet trucks, tanks, which have a competitive design. The hopper-doser for grain and grain crops is a unique, carefully thought-out product, and taking into account the competition with transportation from other types of transport, the company's team must constantly continue work on improving the designs of wagons in the directions of increasing the speed of movement and increasing efficiency. In the conditions of increased competition on the domestic market, the plant received permission to manufacture new versions of the wagon for transporting grain – model 19-7053-03 with a carrying capacity of 71 tons and an axle load of 23.5 tons per axle and model 19-7053-04 with a carrying capacity of 76.5 tons and with an axial load of 25 tons. Such a verdict was issued by the interdepartmental commission that worked at the enterprise. In the family of hopper wagons, 11 models were previously presented. The plant expanded it with two more new representatives of the model range. The new models are designed for the transportation of grain and other bulk products that require protection from atmospheric precipitation. One of the means on the basis of which an automated procedure for making an optimally coordinated decision regarding the release of modifications of new hopper dispensers for grain and grain crops can be implemented is the inclusion of computers in communicative relations within the team of designers in the decision-making process.

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Liudmyla Khomenko, Ph.D. in Economics, Associate Professor of the Department of Accounting and Finance, Kremenchuk Mykhailo Ostrohradskyi National University. **Svitlana Tkachenko,** Doctor of Economics, Associate Professor of the Department of Global Economy, State Biotechnology University. **Oleksandra Vodolazska,** Earner of the Second (Master's) Level, Kremenchuk Mykhailo Ostrohradskyi National University. **Increasing the profitability of the agricultural market by optimizing grain transportation.**

Goal. Finding opportunities to optimize each model series of hopper dispensers, intended for profitable transportation of grain and grain crops, in the conditions of globalization of the agricultural market and intensifying competition in the railway rolling stock market. Methodology. The sequence of solving the one-dimensional problem of substantiating the optimal model series and approaches to clarifying the results in complicated conditions related to the unification of products for the specialization of each division of the appropriate level in the performance of a narrow range of functions regarding the organization of production for the introduction of innovations regarding the special shape of the body of hopper cars for transportation of grain and grain crops. The results. The components of the calculation of costs for development, testing and production and the cost of production of new products are considered, as well as the value of the optimal range of modifications of hopper-dispensers for grain and grain crops. The sequence of creation of flexible production systems as an innovative leap in the development of hopper wagons for grain transportation for the introduction of innovations while increasing production volumes is presented. Novelty. The scientific approaches to determining the essence of the product range are generalized by means of a critical understanding of the process of expanding the range of products with the aim of using excess production capacities while satisfying the needs of consumers more fully at the same time. Practical significance. To meet the growing needs of consumers, a justified line of modifications of hopper dispensers for grain and grain crops with a special body shape. Work was carried out to eliminate gaps both in the assortment and in the depth of the product range of hopper wagons. In the conditions of large-scale production, subject-specialized lines with rigid and flexible connections have been created. The technological process of manufacturing welded structures of hopper cars provides for both differentiation and concentration of the operations performed, taking into account the rhythm and cycle of the entire production process. The production of transverse beams is carried out on semi-automatic one-piece direct-flow lines with flexible connection to several workstations.

Key words: profitability, model, row, optimization, hopper-dispenser, grain, grain crops.

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Мета. Винайдення можливостей оптимізації кожного модельного ряду хопер-дозаторів, призначених для прибуткового транспортування зерна і зернових культур, в умовах глобалізації аграрного ринку та загострення конкуренції на ринку залізничного рухомого складу. Методологія. Викладена послідовність вирішення одномірної задачі обґрунтування оптимального модельного ряду і підходи до уточнення результатів в ускладнених умовах, що пов'язані з уніфікацією виробів за спеціалізації кожного підрозділу відповідного рівня при виконанні вузького кола функцій щодо організації виробництва за впровадження нововведень стосовно особливої форми кузова вагонів-хоперів для транспортування зерна і зернових культур. Результати. Розглянуто складові з розрахунку витрат на розробку, випробування і постановку в серію та собівартість виробництва нової продукції, а також значення оптимального ряду модифікацій хоперів-дозаторів для зерна і зернових культур. Наведено послідовність створення гнучких виробничих систем як інноваційного стрибку в розвитку вагонів-хоперів для транспортування зерна за впровадження нововведень при нарощувані обсягів виробництва. Новизна. Узагальнено наукові підходи до визначення сутності товарного асортименту шляхом критичного осмислення процесу розширення лінійки номенклатури з метою використання надлишкових виробничих потужностей за одночасного більш повного задоволення запитів споживачів. Практична значимість. Для задоволення зростаючих потреб споживачів обґрунтована лінійка модифікацій хопер-дозаторів для зерна і зернових культур за особливої форми кузова. Проведена робота з ліквідації пропусків як в асортименті, так і в глибині лінійки товарної номенклатури вагонів-хоперів. В умовах крупносерійного виробництва створені предметно-спеціалізовані лінії з жорсткими та гнучкими зв'язками. Технологічним процесом виготовлення зварних конструкцій вагонів-хоперів передбачена як диференціація, так і концентрація операцій, що виконуються, з урахуванням ритму і циклу всього виробничого процесу. Виготовлення поперечних балок здійснюється на напівавтоматичних одно предметних прямоточних лініях з гнучким зв'язком в декілька робочих місць.

Ключові слова: рентабельність, модель, ряд, оптимізація, бункер-дозатор, зерно, зернові культури.