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Searching of the ways of definition of the rational configuration of divisions of the car-repair facilities on the basis of the flexible stream on the design stage

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S u m m a r y. The technique, allowing to carry out rational configuration of various divisions of the car-repair enterprise at a stage of its design is presented. The grafo-matrix principle considering interdependence between divisions is put in a basis of a technique. The authors chose the volumes of cargoes moved between divisions as the main criterion defining the value of communication level. On the basis of this technique it's offered the configuration mode of units of the main production builging for the car-repair enterprise for gondola cars repairing on the basis of a flexible stream.
K e y w o r d s . repair of cars, flexible stream, design of the car-repair enterprises, configuration of

INTRODUCTION

At a design stage of the modern car-repair enterprises applying a flexible stream for cars repairing there is a need of using the original layout decisions which could allow to realise all advantages of this repairing method. Considering the fact that repairing of cars involve a number of various specialised technological sites and units with continuous movement of labour objects, in the form of cars, their separate parties, various details and materials, there is a need for rational coordination of these units among themselves for minimising the ways of the internal goods turnover. Reduction of ways of cargoes moving promotes decreasing the intra production losses that affect a production cost. Therefore, rational configuration of production divisions is one of the important conditions of increasing the efficiency of car-repair production. The general questions of car-repairing facilities design of are considered in works [20, 22, 23, 25, 29]. As a rule, the existing car-repair enterprises using a stationary car repairing method or a traditional "rigid" stream, represent a rectangular building of a car building site with two or three cross-cutting tracks. The workshops are attached to both sides these tracks on all length [1, 2, 3, 4, 28]. And though the traditional car-repair enterprises have rather simple and convenient configuration of production rooms, there is absolutely other problem – the "rigid" structure of the most car assembly sites does not correspond to the requirements of the probabilistic nature of car-repair production and needs more difficult structure ensuring the flexibility. Thus, the flexible car-repair streams have more difficult configuration and, in this regard, the general configuration of production sites for them demands a special approach.

Purpose of this article consists of the development of the methods allowing to carry out rational configuration of divisions of the perspective car-repair enterprises using flexible car repairing streams. It's made an attempt to develop the concrete effective mechanisms for practical tasks.

MAIN MATERIAL

On a production stage various divisions of the car-repair enterprise co-operate among themselves. There are different types of interrelations between separate divisions of the enterprise: administrative, technological, supplying, informational. In the point of view of operational expenses these communications have various specific weight. There are communications expenses that don't depend of the range of divisions arrangement, and there the ones that depend. The most powerful are the material interrelations concerning movings of various cargoes. But also there are different interrelations. There are the cases associated with moving of the big weighed objects between units, and there is another situation when it's necessary to move, for example, the electric motor and to deliver it to the workshop, and after repair - to return the motor back. The most powerful are those connections that provide perfoming of technological process: continuous moving of cars, bogies, wheel pairs, and also other units, details and materials. Therefore, during arranging the rooms it's necessary ensuring the smallest value of the goods turnover between them (measured in tonne-kilometres). Considering the fact that we can't influence to the weight of moved products, there is only one variant – to reduce whenever it is possible the distances between adjacent technological divisions. In other words, rooms with biggest freight traffics, need to be located as closely as possible to each other in order to reduce the operational moving process expenses.

The works [9, 12, 13, 15, 17] describe theoretical development of flexible streams for cars repairing. The works [10, 11, 16, 19] discuss the modeling modeling methods and calculations of the main indicators of flexible car-repair streams. The articles [8, 14, 18, 24] presents the various configurations of car-repair sites and possible configurations of other production divisions. All divisions, in one way or another, participate in technological process of cars repairing. There is a constant process of moving various units, details, materials or even cars between them by means of floor transport or cargo transporters. As it's known any intershop moving demands certain operational expenses. The longer the distance of cargo moving is, the greater the expenses are. In order to minimize the transportation costs the divisions should be placed in the optimum manner. In this case it is more important to us to place the technologically related divisions more closely to each other as possible as we can, it allows to reduce the distances of intershop cargoes movings. It is naturally that the area of separate divisions depends of the enterprise capacity as well as the total area of all enterprise. This can affect the layout of the rooms in the particular enterprise.

Let's try to develop a rational configuration of enterprise divisions enterprise on a basis of example of depot for repairing gondola cars. For this purpose we'd better to use the theory of graphs [21, 30]. The graph is the abstract mathematical tool for solving many practical problems [6, 7]. Visually the graph represents the geometrical figure consisting of points (tops), connected among themselves with lines (edges) in a certain order. Therefore, the graph can be defined by a set of tops $v_1, v_2, ..., v_n$, denoted like V, and set of edges $r_1, r_2, ..., r_m$, connecting among themselves the tops denoted like R. In the analytical form the graph can be written down as follows: $G = (V, R)$, where V – set of tops, $v \in V$, R – set of edges, $r \in R$. Each edge is a combination two tops. If v_i and v_j are the end tops of an edge $r_к$, the tops v_i and v_j are incidental to an edge $r_к$ (or edge $r_к$ is incidental to the tops v_i and v_j).

There is also another approach. If two sets V_1 and V_2 are known, it's possible to form a set of all pairs (v_1, v_2), $v_1 \in V_1$, $v_2 \in V_2$. Each edge of the graph G represents a separate element in multiplication of sets $V \times V$. It's very convenient to present results of this multiplication in a form of cages of a square matrix M with quantity of elements of a set V as co-ordinates on both axes. The matrix of interactions or contiguity belongs to the most useful designing tools created as a results of searching the optimum design method [5]. The matrix of interactions between car-repair divisions of the enterprise is presented in tab. 1. In this table a "top" can be interpreted as technological division, and the "edge" – as process of moving of cargoes from one technological division to another.

In a section with coordinates (v_i , v_j) we will write down the figures from 2 to 0 depending of value of interaction between these tops. It means that existence of interrelations was estimated on a three-point scale: 2-interrelation considerable, 1-interrelation insignificant, 0-interrelation insignificant or there is no interrelation. In order to avoide the overloading of a matrix, let's fill only those sections of the table that are to the right of a diagonal. The assignment of some interrelations between divisions is conditional and depends of the subjective qualities of the specific designer. Hence, it's desirable to involve more accurate specialists ensuring the best accuracy of work. The more divisions are, the more difficult is to estimate interaction level between them. The value of cargoes moved between divisions can be very important, as we've already noted.

It is necessary to draw the preliminary graph on the following stage after drawing up of a matrix of elements interactions. As we already noted, it represents a configuration consisting of tops, connected among themselves with links (edges). Tops of graph we represent as circles, and edges – as lines. The form and lenght of lines isn't important. The fact of connecting two tops is an only important fact. The circle form for graph is the most convenient one, i.e. tops of graph can be arranged on perimetre of an imagined circle. The considerables interrelations (2) between tops can be represented as fat lines, and insignificant interrelations (1) – thin lines. The figures in circles correspond to numbers of the divisions presented in Tab. 1. The general view of the preliminary graph is shown on Fig. 1.

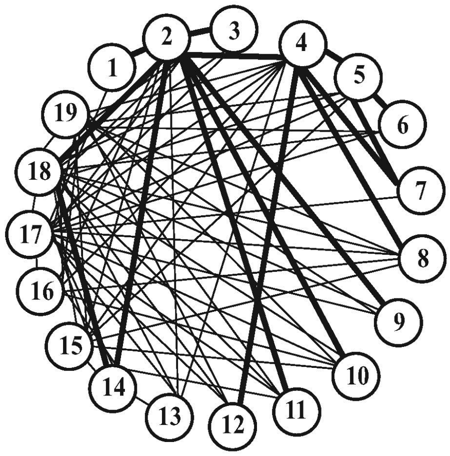

Fig. 1. A general view of the preliminary graph constructed on the basis of a interactions matrix

Tab. 2 presents the calculations of mass value of separate units of the gondola cars moved between divisions, and also the norms of material expenses for repairing purposes per one car. Expenses of materials on depot cars repairing can be found in [27].

As a matter of fact the graph shown on fig. 1, contains the same information as in an interaction matrix, but this information has a more acceptable for further actions form. Nevertheless, this graph represents still quite difficult interlacing of edges and doesn't allow accurately present a configuration of premises of the designed enterprise. Therefore, the following stage includes transformation of this graph to the more convinient one. For this purpose it is necessary to develop a topological structure of a network and to arrange the graph tops so that to avoid crossings of the most significant edges, or, at least, to minimise them. This procedure isn't absolutely simple also can take certain time. First of all it's necessary to construct the base structure of the graph consisting of tops with considerable interrelations. On tab. 1, and on fig. 1 it is visible that the main car-repaire site (2) has all considerable interrelations.

Table 1. The matrix of divisions interactions of the car-repair enterprise among themselves

№	Division name	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Site of preparation of cars to repairing		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
2	Main car-repair site	-		2	2	0	0	0	0	2	2	2	0	1	2	0	1	1	2	1
3	Painting site	-	-		0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
4	Bogies site	-	-	-		2	0	2	2	0	0	0	2	1	0	1	1	1	1	1
5	Wheel site	-	-	-	-		2	2	0	0	0	0	0	0	0	1	0	1	1	1
6	Department of roller bearings repairing	-	-	-	-	-		0	0	0	0	0	0	0	0	0	0	1	1	1
7	Yard of bogies and wheel pairs	-	-	-	-	-	-		0	0	0	0	0	0	0	0	0	1	0	0
8	Site of triangely repairing	-	-	-	-	-	-	-		0	0	0	0	0	0	1	1	1	1	1
9	Site of the brake equipment repairing	-	-	-	-	-	-	-	-		0	0	0	0	0	0	0	1	1	1
10	Site of the autochain equipment	-	-	-	-	-	-	-	-	-		0	0	0	0	1	1	1	1	1
11	Site of the hatches and doors covers repairing	-	-	-	-	-	-	-	-	-	-		0	0	1	0	0	1	1	1
12	Yard of the springs repairing	-	-	-	-	-	-	-	-	-	-	-		0	0	0	0	1	1	1
13	Forge yard	-	-	-	-	-	-	-	-	-	-	-	-		1	0	0	1	1	0
14	Metal store yard	-	-	-	-	-	-	-	-	-	-	-	-	-		1	1	0	2	0
15	Electro-gas welding office	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0	1	1	1
16	Mechanical yard	-	-	-	-	-	-	-	-	-	-	-	-	-	-			1	1	1
17	Yard of the depot equipment repairing	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1	1
18	Material warehouse	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		1
19	Tool and distributing storeroom	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

Table 2. The value of mass of separate units of the gondola cars moved between divisions, and norm of the material expenses per one car repairing

№	Cargo name	Mass of unit, kg	Quantity per car	Total, kg	Share in car weight, %
1	Gondola car (assembled)	24 000	1	24000	100,00
2	Bogie 18-100 (assembled)	4745	2	9490	39,542
3	Wheel pair RU1Sh-950-A (with axle-boxes)	1390	4	5560	23,167
4	Axle box case	45	8	360	1,500
5	Axle box bearing	17,5	16	280	1,167
6	Triangel	76	4	304	1,267
7	External spring	15	28	420	2,567
8	Internal spring	7	28	196	
9	Hatch cover	186	14	2604	10,850
10	Doors	515	2	1030	4,292
11	Automatic coupling (assembled)	206	2	412	1,717
12	Absorbing device Sh-2B-90	132,6	2	265,2	1,105
13	Brake equipment (set), including: Air distributor 483 Brake cylinder Reserve tank Automatic regulator Automode Main part Draughts Sleeve brake End crane	288 84 110 26 30 19 6 3 3,5	1 1 1 1 1 1 1 2 2	288 84 110 26 30 19 6 6 7	1,200
14	Metall rolling			696,0	2,900
15	Electrodes			20,0	0,083
16	Wire welding			22,9	0,095
17	Flux welding			20,0	0,083
18	Paint materials			10,21	0,043
19	Lubricants			20,0	0,083
20	Advis			17,0	0,071
21	Pipes and fitting			1,5	0,006

Bogie site (4) follows after the main car-repaire site. Therefore, on the transformed graph the corresponding tops should be in the centre of the graph, the other tops should be around them. Besides, it is desirable at this stage to form the graph as a future building of depot. During realisation of this stage it is desirable firstly to develop some alternative variants of the base graph structure, and then to choose the most preferable one among them. One of the possible variant of such transformed graph is shown on Fig. 2.

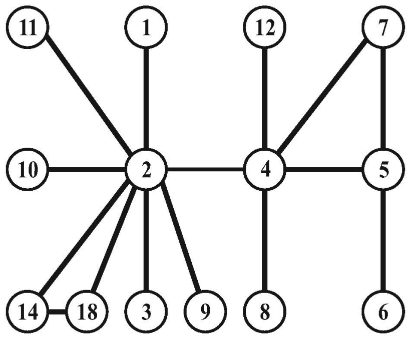

Fig. 2. The variant of base structure of the transformed graph

On the basis of the transformed graph structure presented on Fig. 2, let's make the updated graph. For this purpose we add the tops having insignificant interrelations. Let's try to arrange them so that they were closer to adjacent tops as possible as we can and to shape a configuration of future building. The updated variant of the graph is presented on Fig. 3.

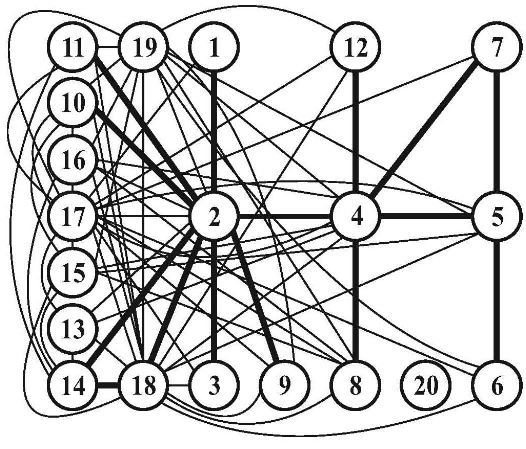

Fig. 3. The updated variant of the graph

On the basis of the graph presented on Fig. 3, we can to develop a configuration of divisions of the car-repair enterprise. Sometimes it's very difficult to consider the areas of separate rooms and a configuration of all building with correct form. In this article we aren't going to consider in detail a configuration of each separate division. Usually the rooms have a rectangular shape, and their area corresponds to technological design norms [26].

The final variant of divisions configuration of the car-repair enterprise is shown on Fig. 4.

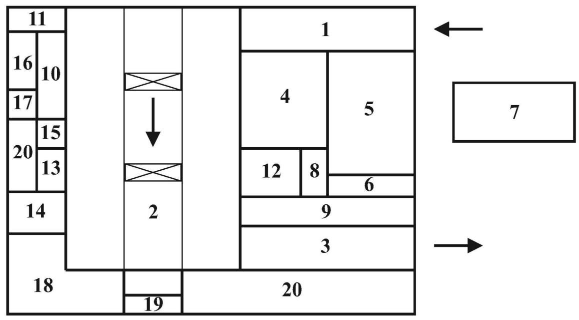

Fig. 4. The variant of divisions configuration of the car-repair enterprise (the arrows shows the direction of the general car-repair stream)

The top of the graph with number 20 represents the auxiliary rooms which directly aren't involved to the technological process, but accompany it and occupy a certain areas which should be considered in configuration of the main production building (knots of input-output of communications, ventilating chambers, transformer substations, lavatories, etc.).

It should be noted that it isn't possible to completely consider the all requirements. But it is possible to neglect the insignificant interrelations.

CONCLUSIONS

1. Reduction of operational expenses is an important indicator of the increase of production efficiency. The considerable part of these expenses is directly connected to the

continuous movings of various cargoes between technological divisions of the enterprise.

2. These expenses can be reduced at a design stage by means of rational configuration of the enterprise divisions.

3. This article discusses an example of the tools allowing at a design stage to arrange the perspective car-repair enterprises, using a flexible car-repair stream, to develop a rational configuration of divisions of the enterprise, to reduce the excess movements of inter-depot cargoes.

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ПОИСК ПУТЕЙ ОПРЕДЕЛЕНИЯ РАЦИОНАЛЬНОЙ КОМПОНОВКИ ПОДРАЗДЕЛЕНИЙ ВАГОНОРЕМОНТНОГО ПРЕДПРИЯТИЯ, ИСПОЛЬЗУЮЩЕГО ГИБКИЙ ПОТОК, НА СТАДИИ ЕГО ПРОЕКТИРОВАНИЯ

Владислав Мямлин

Аннотация. Представлена методика, позволяющая осуществлять рациональную компоновку различных подразделений вагоноремонтного предприятия на стадии его проектирования. В основу методики положен графо-матричный принцип, учитывающий взаимозависимости между подразделениями. В качестве главного критерия, определяющего величину уровня связи между подразделениями, выбраны объёмы, перемещаемых между ними грузов. На базе этой методики предложен вариант компоновки подразделений главного производственного корпуса вагоноремонтного предприятия для ремонта полувагонов, использующего гибкий поток.
Ключевые слова: ремонт вагонов, гибкий поток, проектирование вагоноремонтных предприятий, компоновка помещений