INFORMATION AND MATERIAL FLOW MODELING IN SYSTEM OF PARTS REGENERATION IN MULTI-LEVEL SUPPLY SYSTEM

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With the efficient influence on making an adequate and prompt managing decision it is possible to improve operation of any system. This study presents one of the possible ways of exerting influence on the information and material flow so that the management could make optimal decisions in the system of parts regeneration which exists in a multilevel system of supplying the spare parts. The optimization process consists of generating functional variants in the system of supply with regenerated parts, then determining the values of characteristics of these variants and forming the model of multi-criteria decision making. Flow variants were determined by using modelling and simulation and the method of multiple attribute decision (Analytic Hierarchy Processes-AHP in this case). Variants were analyzed and after that, some conclusions were adopted. This is an example of how it is possible to make right decisions with the purpose of getting the user's satisfaction and on the other hand also reducing the costs within the system, direct or indirect ones.

Keywords: AHP method, model and simulation, multi-level supply system, parts regeneration

Modeliranje tokova informacija i materijala u sustavu regeneracije dijelova u višerazinskom sustavu snabdijevanja

Izvorni znanstveni članak

Efikasnim utjecajem na donošenje odgovarajućih i blagovremenih upravljačkih odluka moguće je unaprijediti funkcioniranje bilo kojeg sustava. Ovaj rad predstavlja jedan od mogućih načina utjecaja na tokove informacija i materijala kako bi uprava mogla donijeti optimalne odluke u sustavu regeneracije dijelova koji postoji u višerazinskom sustavu snabdijevanja rezervnim dijelovima. U postupku optimizacije navednih tokova utvrđuju se moguće varijante funkcioniranja sistema snabdijevanja regeneriranim dijelovima, zatim se određuju vrijednosti karakteristika funkcioniranja tih varijanti i formira se model višekriterijskog odlučivanja. Varijante tokova u sustavu određene su primjenom modeliranja i simulacije, a odabranom metodom operacijskih istraživanja analizirane su, u ovom slučaju metodom višeatributnog odlučivanja (AHP metoda), nakon čega su usvojeni zaključci. Na ovaj način mogu se donositi prave odluke u cilju zadovoljenja korisnika, a na drugoj strani također i smanjenje troškova u sustavu, bilo direktnih ili indirektnih.

Ključne riječi: AHP metoda, model i simulacija, regeneracija dijelova, višerazinski sustav snabdijevanja

1 Introduction

The system of spare parts supply includes regeneration of faulty parts (parts regeneration) as a separate system as well as one of the material sources of supply system. However, production and domestic and foreign market, as material sources, are also important [1]. Each one of the mentioned sources is obliged to replenish and/or to keep stocks of the spare parts at a certain level in order to ensure quite enough prompt reaction when the need arises for the spare part.

Just the parts regeneration, as a technological process, represents a series of the technological programs and maintenance procedures in which, with the precisely fixed technological procedures and activities, the worn or damaged (faulty but repairable) part can get the characteristics and quality of the new one [1, 2].

Parts regeneration, as a system, is also dynamic, interactive and in continual communication with other systems. So, it is in close connection with maintenance system because it is in the service of meeting the needs of maintenance. On the other hand faulty parts are brought back again into the supply system just with the procedures of maintenance [1, 2].

Stocks, as an economic category, mean the cost for the system. When the stocks are not used in a regular way then the costs become enormously high. The main problem is deficiency of the spare parts at a certain level of maintenance, at the moment when the need for the parts is permanently present and, on the other side, there is unnecessary stockpiling which appears as the problem in an inventory procedure [3].

Information system in all life segments and also, in the system of parts regeneration is an imperative of modern epoch and technical-technological development. It must provide managing and control of the system, evaluation of the validity of the system as well as enable prompt influence when it is necessary and in an extent which is necessary. With the procedure of monitoring the status of the system through the information system, prompt reaction to any breakdown is ensured which influences the efficiency and/or economy of the system.

Parts regeneration is interesting because of many reasons and, first of all, because the regeneration costs are as a rule lower than those of the new-purchased part (up to 70 %). Then, the procedure of filling the stocks with regenerated parts is simplified, in a great extent, in regard to the law regulation. Finally, if the production stops regeneration becomes the only possible way to replenish the stocks.

Complexity of decision-making in coordinated management has been persistently increasing. This paper describes an example of making-decision support tool for management. The process of forming management decisions is based on application of modelling and simulation and selection of operational research methods, multi-criteria decision analysis, in this case AHP. Few functional variants were generated, then the values of characteristics of these variants were determined and finally multi-criteria decision-making model was formed.

Several works concerning application of multi-attribute decision-making techniques for the spares classification can be also considered connected with complex supply chain structure in the area of inventory control decision support system.

The article by Braglia at al. [4] presents an example of functional model for inventory management. Spare parts classification is defined with respect to multiple attributes (inventory constraints, costs of lost production, safety and environmental objectives, strategies of maintenance adopted). The decision diagram is integrated with a set of analytic hierarchy process models used to solve the various multi-attribute decision sub-problems.

Pantelić in his PhD thesis [5] defined new derived models of managing the stocks in the spare parts hierarchical supply system. He gave a vision for generating new decision-making of inventory management in the army.

In paper Kalchschmidt at al. [6] present consistency between managerial solutions and multi-echelon spare parts supply chain structure which enables to enhance operative performances. The work describes an integrated system for managing inventories in a multi-level spare parts organization, in which customers of different size lay at the same level of the supply chain.

By Bronja [7], the main idea of supply chain management is applying an approach of a complete system to manage the material flow, backflow of information and services, starting from the raw material suppliers, through retailers and warehouses to the final customer. In the paper, he observes material flow and backflow of information by using multi-criteria mathematical model for ranking suppliers in the supply chains concept. A similar research is presented by Fazlollahtabar at al. [8] with integrated AHP, TOPSIS[1] and multi-objective nonlinear programming and Ng. The authors dealt with the proposed five key factors for selection of suppliers: supply variety, quality, distance, delivery and price [9].

The study given by Milićević [10] examined the supply system spare parts with material flow and flow of information and their correlations and significance. He described item manifestations in the system too.

Bošnjaković in his research paper [11] proposes a methodology for spare parts inventory control applying multi-criteria inventory model. It is based on ranking and classifying the spare parts in groups according to similar attributes. He joins the appropriate inventory policy model and forecasting demand model to each group of spares, depending on attributes of the spares that belong to it.

2 Description of the existing parts regeneration system and problems which appear in the same

Parts regeneration is present in various social spheres and, in the same, it has got a significant influence as for example: in military service, in maintenance of complex systems, in the mines and at the open pit mines, in the energetic systems, in maintenance of hydroelectric and thermo power stations, then in maintenance of the building machinery, railways, shipbuilding industry, industrial systems.

The system, the subject of this study is a three-level system of supplying the spare parts and it is in direct function of the multilevel system of maintenance (in this

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[1] Technique for Order Preference by Similarity to an Ideal Solution

case, three and four level system depending on the kind of the means which are maintained). The first supply level is directly at the user (with the basic assets) and it is in the function of direct support of the first maintenance level (user level). The second supply level are the users' warehouses of the spare parts located close to the workshops and depots (overhauls) in the function of supporting the second, third and possible fourth maintenance level. The third supply level is central level; more exactly, it is about the stocks for replenishing the all supply levels. This system of supply operates in practice and it appeared as the result of necessity to apply organizational changes in the army, in the last few years.

The most important characteristic of the system is that the users' warehouses are filled from the central storehouse as well as that the users' warehouses are not interconnected and cannot be filled from among them.

Immediately upon the occurrence of need, the users' warehouse issues spare parts to the workshop, requiring the faulty parts to be turned back (exchange the correct for faulty part). In the same way, the users' warehouse issues spare part directly to the user with the purpose of carrying out maintenance activity at its user's level, also, with the obligation to turn back the faulty part. In that way, faulty parts are systematically collected for regeneration. Faulty parts, whose regeneration is not justified from the economic point of view, are worn out.

Central storehouse does the analysis of the needs for regeneration in respect to the available assets at the stocks, per assortment and quantity and after the data are processed, collects the parts and sends the same to be regenerated. Parts as regenerated (regenerate parts) are ready for a system of the spare parts supply (Fig. 1).
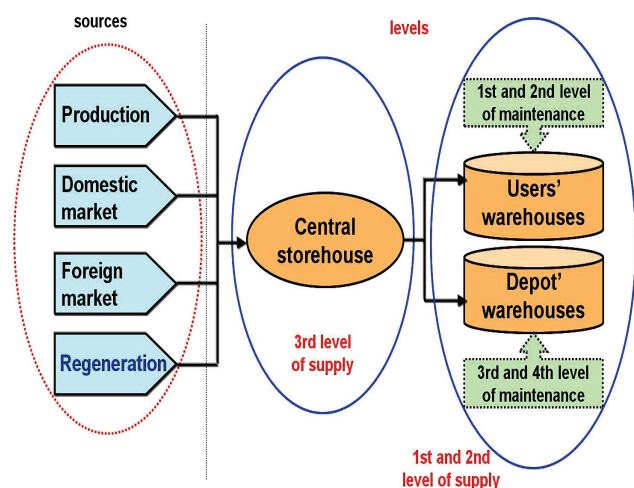

Figure 1 Parts regeneration within the system of supply of spare parts

Parts regeneration, as the planned activity, is carried out systematically, at the precisely defined deadlines, four times during one calendar year.

In the observed system of regeneration there are some problems of which the biggest are:
- Large number of nodes-funnels (choking) which cause slow reaction of the system when the need arises for a part;
- High inertness of the system which is reflected in a slow sending of the adequate part in the necessary quantity, in a situation of continual need for the part;

- Poor and slow information flow, from the highest to the lowest level and vice versa, what is directly reflected in the time of reaction to the arisen need for the part, more exactly, regeneration;
- Incompatibility of the information system with the system of material monitoring the stocks of the parts (material accounting) as well as incoherence of the material accounting systems at the users' level;
- Lack of the interlinks between the warehouses at the users' level when the parts come only from the central warehouse and not between the warehouses, without manifestation of the special influence;
- Ignorance and inexperience of the procedures by the participants especially at the lower supply levels (it is not the subject of this study and can be solved by continual education of the participants who realize the procedures of regeneration).

In order to overcome the arisen problem, just a few years ago the project of the information systems development was initiated, first of all in order to make possible intercommunication between two systems, the information one and the system of material accounting and to establish the links between the warehouses at the users' level. Also, creation of the new organizational structure of the spare parts supply system was initiated. At the moment, the project is in a phase which does not enable a prompt solution for this problem.

In such situation it is imagined to eliminate the problems operationally or, at least, to reduce the effects of the existing problems. The questions were asked to which it was necessary to reply efficiently, in a short period of time, without special investment in the system or in the creation of its new organization: which is the right part, which are the right quantities, the right conditions, which is the right delivery destination and delivery time and which is the right price. With a view of realizing the project in Logistics of The Serbian Armed Forces [12] in order to improve the system of supplying the spare parts, the need for improving the system of parts regeneration was considered as a special segment.

Analysis indicates that in practice only one flow variant of sending parts exists - all parts are sent back to the central storehouse.

Starting from the above mentioned and considering the problems in structure, it is concluded that the optimization is possible only in the information and material flow of the system without any investment. Research in organisation and structure with modelling and simulation can help the management on all levels in making adequate decisions.

3 Description of the models and simulation of their functioning

One of the ways for finding out a solution for the observed problem is construction of the model. The model has been created similar to the real system but simplified. Simulation is presented with the computer software. For simulation language and for the purpose of quick and easy making computer software, licensed, object-oriented language of simulation MODSIM III (The Modular Simulation Language, today SIMSCRIPT) was

chosen while visual presentation of the simulation flow was enabled by SIMGRAPHICS II, as an integral part of the language [13, 14, 15].

Constructed model consists of the central storehouse and, in this case, of four users' (regional) warehouses of the spare parts which satisfy the needs of the maintenance system. The above mentioned means that those users' warehouses have got certain assortment and quantities of the spare parts, required for providing maintenance in a given period of time. On the basis of the arisen need, the users' warehouses have got the task to respond to the demand and to give the parts, providing the parts are on the stock. In reality, the parts are given with obligatory reception of the faulty part for further regeneration (so called, exchange of the correct spare part for the faulty one). In that way, collection of the parts for further regeneration is performed and it is described with probability distribution. Time for sending the faulty part for further regeneration is also a changeable category described with probability distribution.

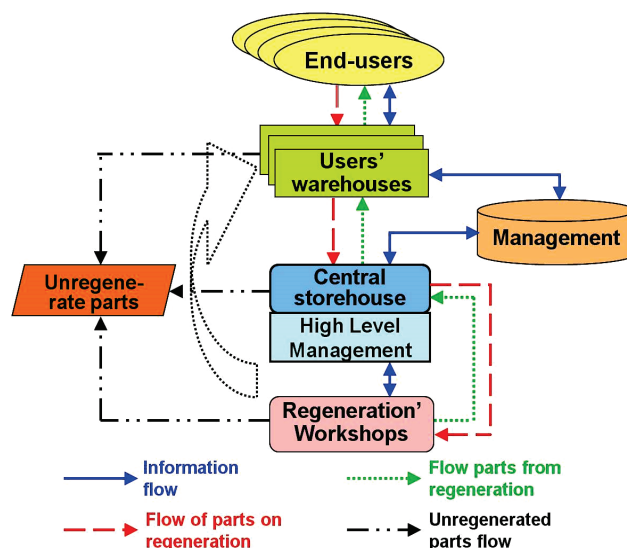The elements which participate in the process of regeneration and their inter-links are presented in Fig. 2.

Figure 2 Organizational chart and flows in a system of regeneration

Information flows are marked with the blue colour while the material flows are marked with the red and green colour (the faulty parts flow is marked with red colour and the flow of turning back regenerate parts in the supply system is marked with green colour). Flow of the parts impossible to be repaired and sent to be worn out is marked with a black colour (unregenerate parts). Users' warehouses replenish the first and the second maintenance level with the spare parts. The depot's warehouses fill the third and fourth maintenance level and they are also considered as the users' warehouses of the spare parts. In that sense, the elements which carry out maintenance procedures at any level are presented as the users.

Users' warehouses, as in reality, are not interconnected and they are replenished from the central storehouse. In a situation when the part is not on stock, the users' warehouse issues a demand for replenishment of the stock at the central storehouse. This condition is called unsatisfied demand of the customer and the waiting

line (queue) is formed. According to the issued demand, central storehouse replenishes the users' warehouses with the required assortment and quantity of the spare parts. No matter which form of the partial replenish is applied (assortment or quantity), condition of unsatisfied demand of the users' warehouse is recorded and then a waiting line is made.

Replenishing of the users' warehouses is described by (s, Q) model of inventory management[2], as in reality [1, 5]. The time for sending the demand for replenishing is random value described with probability distribution while the demand for the spare part is described with Poisson probability distribution. The waiting line empties according to the principle "First In-First Out" (FIFO) as in reality, more exactly, the stocks are consumed following the order in which they were provided. Firstly provided parts are issued as the first ones and, therefore, the remaining items at the end of a certain period are those ones the last provided.

Central storehouse is completely replenished from the inexhaustible supply source, and it is described with (S, S) model of inventory management[3] [1, 5]. Replenishing time is accidental value and it is described with probability distribution. After the need arises, the acceptance of the inexhaustible source is done and the waiting line is emptied, completely or partially.

Central storehouse, based on the demands, delivers the parts to the users' warehouses and there is a possibility for partial delivery. In that case, unsatisfied demand is put in the waiting line. Also in this case, the waiting line is emptied as per principle FIFO. Time of sending the parts to the users' warehouses is accidentally variable described with probability distribution.

Central storehouse can also receive regenerated parts and the procedure is the same as when the parts are received from other sources[4]. Also in that case, waiting line is emptied completely or partially.

Regeneration' workshops with certain probability[5] do regeneration of the faulty parts (repair). Time for regeneration is a random variable described with probability distribution.

Model was created in the way that parts from regeneration can be turned back only to the central storehouse or only to the users' warehouses or part of them to the central storehouse and part to the warehouses, depending on the defined variant. Time of sending back parts to the system is accidentally variable described with probability distribution. According to the above reported, flows of the parts from regeneration were defined: all

regenerated parts are sent back to the users' warehouses from where they were taken (variant V_1) or all regenerated parts are sent back to the central storehouse (variant V_2). The third variant V_3 means that one part of regenerated parts should be sent back to the central storehouse and a part of them to the users' warehouses.

Regardless of the chosen variant, it was necessary to define characteristics which, taking into consideration significance, are crucial for the elements - decision makers within the system. The above mentioned meant to get the value of the variables which, in fact, were outputs or solutions of the software:
- Coefficient of filling in the user's warehouses (K_p) is the ratio between the number of the demands that are satisfied without waiting and the total number of the demands in the user's warehouse. It is, in fact, the probability of satisfying the demands without waiting.
- Average time waiting in line (W) is the ratio between total waiting time and number of the demands in the waiting line.
- Total costs in the system (Lg) are the sum of the procurement costs of spare parts from the inexhaustible source, the regeneration costs and the transport and storage costs. Simplified, the costs will be at the annual level although they can be calculated per structure and for each element of the system what, in this case and in this moment, is not important.

Simulation was carried out in the following way. Parameters of the model with numerous relevant values were defined. They were the following:
- Values of the stock levels at the central storehouse which indicated low, medium or high stock level. Defined values: 7, 14 and 21;
- Values of the stock levels in the users' warehouses which were low, medium or high stock levels. Defined values: 4, 8 and 12;
- Values of the intensity of the demand for the parts in the users' warehouses with the small, medium and high intensity.

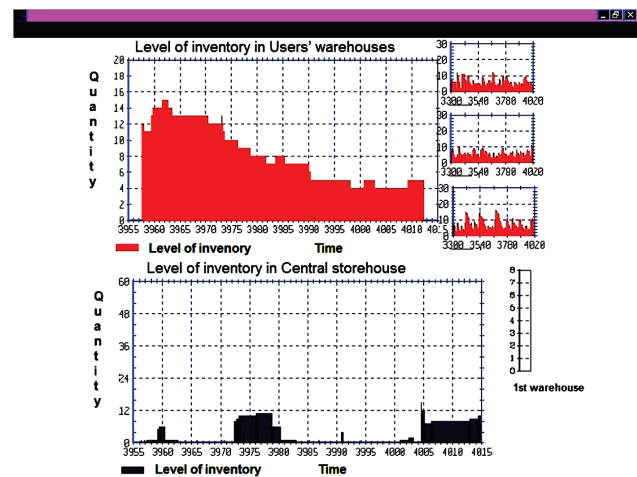Defined values: $\lambda=0,08$ to $\lambda=0,5$ (day^{-1}) with the rate 0,105.

Figure 3 Visual survey of the simulation flow

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[2] Model (s, Q) is model with ongoing order decisions. A control of stock level is not written in advance and is performed after each issuing from the warehouse. If the stock level is lower than the ordering at the time of control, there will be always the same order of supply. Otherwise, there is not ordering.

[3] Model (S, S) is model with periodic order decisions. The control of stock level is periodical and ordering is at each time when is the control of the level of inventory.

[4] Fill the central warehouse is made from the production, procurement from the domestic market and the purchase of imports. To simplify, all sources of replenishment can be observed in bulk and can be treated as a single source without restriction.

[5] It was not less than 0,7 (It is data from annual analysis of the parts regeneration in the last 12 years in The Serbian Armed Forces).

Then, the choice of one variant of the parts flow was made. Simulation was allowed to run 11 years with defined values of the chosen parameters whereby the first year was cancelled (because of the "start to work smoothly system "). After the simulation was finished, the output data were read off. In the following step, change of the value of only one of the mentioned parameters was done while the values of the other parameters remained unchanged. When all the possibilities to change parameters in one variant were depleted, the variant of the regenerated parts flow was changed and the simulation was repeated again with the change of parameters value. Simulation was repeated while all the combinations of the parameters value and all the flow variants were depleted. In Fig. 3 visual survey of the simulation flow is shown.

The obtained results of the simulation were classified according to defined characteristics. They were grouped on the basis of intensity of demand to levels of inventory in users' warehouses and central storehouse for all combinations of the stocks levels and all variants of parts flows.

4 Analysis of the obtained results of the simulation and presentation of the same

With the software application, three types of variables values were obtained. One of these values ware the values of the replenishment levels, in the central storehouse and also in the users' warehouses. The second were the values of intensity of demand expressed by the time waiting in line, and the third were the values of costs within system. The aim was to create the decision table as well as the decision making tool on the variant the flow of materials and information can be influenced by.

With the analysis of the obtained values of the variables for all levels of the stocks at the central storehouse and users' warehouses and also for the defined variants of the regenerated parts flows, the following was observed:

- Coefficient of filling in User's warehouses declined at all the variants of the regenerated parts flow with increase of the demand intensity, what was expected. At the medium stock level in users' warehouses, Coefficient of filling was the biggest for the first flow variant V_1 (turning back to the users' warehouses) regardless of the value of the stock levels at the central storehouse and intensity of the demand (Tab. 1).
  At the same conditions, Coefficient of filling in User's warehouses was the least for the second flow variant V_2 (turning back to the central storehouse). At the other combination of the stock values at the central storehouse and users' warehouses and value of the demand intensity, it was not possible to recognize the rules in movement of the Coefficient of filling.
- Average time waiting in line was the lowest and slightly increased with the increase of the demand intensity, at low level of inventories in users' đwarehouses and at all levels in the central storehouse for the second flow variant V_2 (turning back to the central storehouse). Also, progress of the waiting time in a line suddenly happened with increasing intensity of the demand. The aforementioned was

especially evident for the situation of the low stock level at the central storehouse and at the users' warehouses. At the high stock level at the users' warehouses, change of the average time waiting in line showed the biggest vacillations what is especially evident for the situation of the low stock level at the central storehouse (Tab. 2).

Table 1 Obtained values of the Coefficient of filling in Users' warehouses

Coefficient of filling in User's warehouses $K_p \cdot 10^{-3}$					
Level of inventory in Users' warehouses S_1	Level of Inventory in Central storehouse S_2	The intensity of demand $\lambda \cdot 10^{-3}$	Back to the Users' warehouses V_1	Back to the Central storehouse V_2	One part in Central storehouse, another part in Users' warehouses V_3
Medium level 8	Low level 7	80	993,2	986,3	982,9
		185	967,1	955,2	967,1
		290	942,8	918,0	927,5
		395	910,7	842,3	881,4
		500	872,9	811,5	865,2
	Medium level 14	80	993,2	982,9	989,8
		185	983,5	970,1	973,1
		290	968,5	924,7	950,4
		395	946,9	887,0	912,1
		500	875,6	844,4	880,0
	High level 21	80	993,2	986,3	993,2
		185	979,1	968,6	974,6
		290	970,4	932,3	960,9
		395	960,2	897,4	918,3
		500	922,7	859,2	910,1

Table 2 Obtained values of the average time waiting in line waiting

Average time waiting in line W / day					
Level of inventory in Users' warehouses S_1	Level of Inventory in Central storehouse S_2	The intensity of demand $\lambda \cdot 10^{-3}$	Back to the Users' warehouses V_1	Back to the Central storehouse V_2	One part in Central storehouse, another part in Users' warehouses V_3
Medium level 8	Low level 7	80	1,652	1,625	2,020
		185	3,774	2,903	2,154
		290	3,168	3,358	3,498
		395	3,961	5,354	4,040
		500	4,040	55,778	4,300
	Medium level 14	80	1,800	1,838	2,471
		185	2,981	3,794	3,957
		290	3,423	3,156	4,365
		395	2,603	3,872	4,568
		500	3,541	4,044	3,632
	High level 21	80	1,720	3,400	5,196
		185	5,183	2,657	2,379
		290	2,151	3,536	4,092
		395	2,728	4,120	2,806
		500	3,268	3,963	3,318

- Values of the Total costs were very similar for all of these three variants of the regenerated parts flows at all combinations of the stock levels, so the graphical representation was unclear. But, it can be clearly seen that the total costs were linearly increased following the increase of the demand intensity at all variants of the regenerated parts flows and stock levels combination. Percentage differences of the costs per variants were small except in the case of low stock

level in the central storehouse, high stock level in the users' warehouses and low intensity of demand. Then, there was a more significant difference in the costs between the first and third variant in favour of the first flow variant (turning back to the users' warehouses), more exactly, between second and third in favour of the second flow variant V_2, in other words, turning back to the central storehouse (Tab. 3).

Table 3 Obtained values of the total costs in the system

Total costs in the system L_g / currency					
Level of Inventory in Central storehouse S_2	Level of inventory in Users' warehouses S_1	The intensity of demand $\lambda \cdot 10^{-3}$	Back to the Users' warehouses V_1	Back to the Central storehouse V_2	One part in Central storehouse, another part in Users' warehouses V_3
Low Level 7	Low level 4	80	1 012 340	1 014 354	1 008 680
		185	2 339 741	2 336 773	2 344 877
		290	3 592 441	3 634 709	3 631 626
		395	4 896 051	4 995 194	4 961 818
		500	6 239 240	6 353 890	6 284 129
	Medium level 8	80	978 637	986 399	1 001 838
		185	2 266 170	2 299 102	2 300 176
		290	3 481 654	3 585 308	3 545 894
		395	4 779 940	4 907 845	4 851 945
		500	6 110 649	6 234 820	6 229 297
	High level 12	80	969 434	982 542	1 223 299
		185	2 247 312	2 264 042	2 288 762
		290	3 500 420	3 510 739	3 546 474
		395	4 775 879	4 868 037	4 804 674
		500	6 097 458	6 241 455	6 090 802

Table 4 Making decision table for the variants of sending regenerate parts

Level of inventory in Central storehouse S_2	Level of inventory in Users' warehouses S_1	The intensity of demand λ		
		Low	Medium	High
Low level	Low level	V_2	V_2	V_1
	Medium level	V_1	V_1	V_1
	High level	V_3	V_1	V_1
Medium level	Low level	V_2	V_3	V_1
	Medium level	V_1	V_1	V_1
	High level	V_3	V_3	V_1
High level	Low level	V_3	V_3	V_1
	Medium level	V_1	V_1	V_1
	High level	V_3	V_1	V_3

In order to be able to use the obtained results in a valid way, they were observed as hierarchically structured criteria, more exactly criteria according to the significance levels. The most important criterion was attributed to the Coefficient of filling in User's warehouses, then to the Average time waiting in line and finally, to the Total costs in the system. The reason why the costs at the scale of significance were just at the third position was relatively small differences between the costs per flow variants. In

such situation, it was difficult to use costs as the more significant criteria for creating decision making table.

The next step was the choice of flow variant of sending parts which, for the given functional conditions, the system gives the best values of the system's functional characteristics. For the choice of the best variant defined characteristics will be used also in the future.

Obtained results of simulation were the base for creating decision making table. Creating decision making table was done in the following way: The values of the Coefficient of filling for the defined variants, under conditions of certain stock level of spare parts in the central storehouse and users' warehouses and values of the demand intensity, were observed. In the case that one variant was much more significant than the others, it got priority. In a situation of the identical results (so called uncertainty) the next characteristic per significance was introduced - average time waiting in line. If we had identical results again, other characteristic could be introduced - total costs.

Based on analysis of the decision making table it can be concluded that in addition to the three above mentioned variants, a new variant was derived (variant V_4). Decisions for sending regenerated parts are made on the basis of the rules from the decision making table.

In order to define the variant for sending regenerated parts which, for the given conditions of the system functioning, gives the best values of the system's function characteristics, the model of multiple attribute decision making was used.

Four new simulations were performed for finding the criteria values. Criteria for evaluation and comparison of the variants remained the same, software also remained the same but new constraints were introduced. The change appears at the characteristics of the demands for parts. User's demands for the parts have not been the simple Poisson's process any more, but stream of the demands has got season changes. During the year, in the same time intervals, alternately rotate low, medium and high intensity of the demands for parts. Each of the mentioned demand intensity value was described by the Normal (Gaussian) distribution.

Using the existing model, two new process models were built. The first one was for determination of criterion values of the first three variants and the second, for determination of criterion values of the fourth variant. The main differences were, in fact, changes in the input flow of the demands, more exactly, for introducing the rules for sending the parts from the decision making table. Decision for sending the parts was made on the basis of the instantaneous value of the stock levels of the spare parts at the users' warehouse and central storehouse and prognostic value of the demand intensity.

Simulation for determination of the criterion values of the first three flow variants was derived in a way that the system's parameters were set. The variants were determined, and values of sending probabilities were fixed as well as defined values of reparation probability. Simulation was allowed to run 31 years with a remark that the first year was not taken into consideration when the output values were calculated. Simulation was carried out in two passes. The first was when all the users' warehouses started with the same level of demand and the

second, when the users' warehouses started with mutually different levels of the demand intensity.

Simulation for determination criterion values of the fourth flow variant was performed in a way that previously listed parameters of the system were set while the variant of sending repairable parts was determined during simulation, on the basis of the rules from the decision making table.

In addition to the already known characteristics, the new ones were obtained, monitored and analysed: average stock level in the central storehouse (Y_c) and average stock level in the entire system (Y_s). The reason to make the analysis of the new introduced parameters was the evaluation of the model's functional stability. Obtained values in the first pass were compared with the results in the second pass.

The analysis has shown the least deviations of the values, except for average time waiting in line, at the fourth variant of sending regenerated parts. And it could be assumed that the fourth variant is the most efficient, more exactly, it has got the highest level of stability at the exchange of the conditions of functioning. That variant suffered continual influence of the change conditions of the function. Testing of the system's stability was the main reason to repeat simulation with changeable initial conditions.

For further research the results of simulation obtained in the first pass were used. According to the obtained results it was concluded as follows:

- For the variant of sending regenerated parts to the central storehouse (variant V_2), average stock level in the central storehouse and average stock level in the system were the least, while the costs were the highest at the same time. Low average stock level in the system resulted from the low average stock levels at the users' warehouses what was an expected result taking into consideration that the regenerated parts were sent to the central storehouse. Very important characteristic was that the Coefficient of filling in User's warehouses was the lowest for this variant.

- The highest values of Coefficient of filling in Users' warehouses and minimal values of the Average time waiting in line were for variant V_4, when the regenerated parts were sent following the rules from the decision making table. Then were also relatively low total annual costs in a system. Average stock level at the central storehouse was the biggest in comparison with the other variants and therefore, average stock level in the system was also high. Analysing values of the average stock levels at the central storehouse and users' warehouses of the spare parts as well as in the entire system, it was concluded that the obtained values were close to the given, initial values.

The last step of research was to define the order of the defined variants of sending regenerated parts as well as the choice of the best variant. In order to achieve this, it was necessary to set the values of the by weight factors of criteria, more exactly, importance of the criteria, one with respect to the other [16, 17, 18]. Starting matrix of the multiple attributive decision making model is given in Tab. 5.

Table 5 Starting matrix of the multiple attributive decision making model

Starting Matrix		Criterions		
		Coefficient of filling in User's warehouses K_p	Average time waiting in line W	Total costs L_g
V a r i a n t s	V_1	0,9658	2,654	3 783 727
	V_2	0,8899	2,895	3 889 245
	V_3	0,9262	3,464	3 834 639
	V_4	0,9664	1,840	3 804 817
Weight factor W_j		3	1,5	2
max / min		max	min	min

Today, there are several methods for solving the problem of the multi-attributive decision making, as follows: AHP, PROMETHEE[6], ELECTRE[7], VIKOR[8], etc. Each method has got its own specificities and certain demands in regard with defining parameters of the model.

In this study, for the purpose of defining the order of the variants in the defined model of multiple attribute decision making, the AHP method was used. The speciality of AHP is its flexibility to be integrated with different techniques like Linear Programming, Quality Function Deployment, Fuzzy Logic, etc.
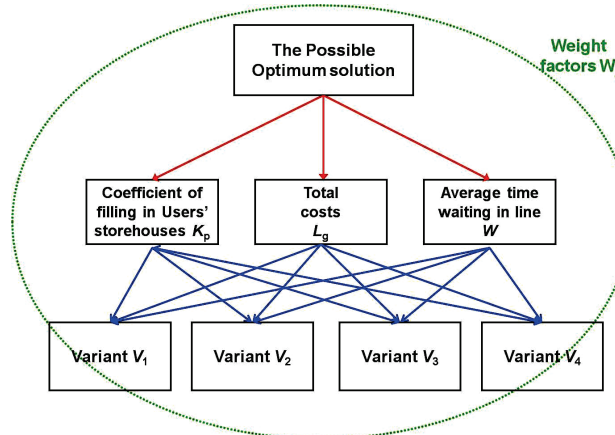

Figure 4 Criteria and alternatives by AHP

Using the AHP method and software Expert Choice the final order of the variants of sending repaired parts was obtained. Variant V_4 took the first rank; the second rank was taken by variant V_1 and then, variants V_2 and V_3.

Further, there was a question whether this order of the variants is valid only for defined values of the weight factors or the change of the value of the weight factors causes the change in the variants' order.

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[6] Preference Ranking Organization METHod for Enrichment of Evaluations
[7] ELimination Et Choix Traduisant la REalité or ELimination and Choice Expressing the REality (in English)
[8] VIšeKriterijumska Optimizacija i kompromisno Rešenje or Multicriteria Optimization and Compromise Solution (in English)
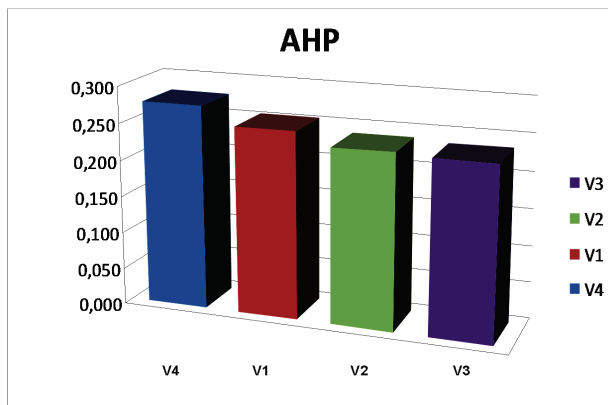
Figure 5 The rank of variants by AHP

After repeated comparison of the method AHP with the change of weight factors, it was concluded, as follows:
- In the case the weight factors had the same values, the order of the variants was unchanged;
- In the case when the weight factor value of the total costs was increased in regard to the other criteria, the order of the variants V_4 and V_1 remained unchanged but the change of the order of the variants V_2 and V_3 occurred;
- If the value of the weight factor of the medium waiting time in a line was increased in regard to the other criterions, the order of the variants remained unchanged.

The above mentioned conclusions show that the obtained solution was not sensitive to the change of the weight factor values and therefore, the obtained order of the variants was absolutely useful for further analysis.

Taking this into consideration, it is to be supposed that variant V_4 gives the best results because it currently reacts to the changes of the system functioning conditions. With the application of the variant V_4 the best Coefficient of filling in User's warehouses is obtained, users spend minimum time in a line, with relatively low costs.

5 Conclusion

This study analyses the function of one real system, in this case the system of the parts regeneration with its characteristics. Then, it describes real problems that appear in a system. The observed system is from the army, but the similar can be found in railway and energetic systems, in maintenance of complex systems, etc.

According to the analysis, problems in the system were noticed and determined, assumptions were then defined and the model conceived to overcome the problems that occurred in it.

The model was developed as a simplified system and the functioning of the system was simulated with computer software. First of all, three new variants of sending parts were generated. The first variant was that all regenerated parts were sent back to the users' warehouses (variant V_1); the second was that all regenerated parts were sent back to the central storehouse (variant V_2). This particular variant is in the real system today. The third

variant V_3 means that one part of regenerated parts should be sent back to the central storehouse and the other to the users' warehouses.

The noticed three flow variants of sending parts are generated very easily. Certain suppositions were previously given to the software and as the outputs of the simulation - the results were processed. Obtained results were properly described and processed.

On the other hand, the fourth generated variant V_4 requires the application of certain scientific methods and plenty of knowledge and time. Decisions for sending regenerated parts are made on the basis of the rules from the decision making table for this variant. The input data for the simulation were also processed. However, this way of decision making may result in significant costs, which is not considered in this paper. In this sense, the question is of justification of the procedure of generating decision rules for sending the parts from the matrix. Nevertheless, the fact is that variant V_4 gives the best results and supports the feasibility of this method. Considering the above, the complex analysis should be done in cases where it is a very expensive part or a large number of components or a very significant one built-in to some aggregate. In addition, such an analysis also needs to be done when it comes with uncertainty condition of filling the inventory.

This study also acknowledged the demands that were subject to seasonal changes and took into consideration several conditions and requests the researchers were faced with.

The presented method is one of possible ways for forming management decisions. The result of generalization is that this way of consideration could be applied to several real systems. But, with modelling and simulation and with processing the obtained results, it is possible to get only the prognosis of behaviour of supposed system of regenerated parts supply and, therefore, the obtained results should be understood in that sense.

As the final result, this example points out the possibility of scientific principles to reach conclusions, as it is necessary to influence the system - to optimize the same. In the study there are possibilities to choose the optimal variants from several options in conformity with the best results and, at the same time, it gives the frame in which it is possible to optimize the system in a short period of time, without special investments in the system.

Also, the study indicates possible directions of acting among which it is necessary to find the adequate one, without special experiments on real system which can often be long lasting, expensive and with uncertain results. It is a special value and benefit. The system is not exposed to the special costs and it has given the vision of the functioning of more efficient systems with the costs reduction, dependent or independent. The results become especially important for repairable assemblies/parts of the higher values. Introducing the classes of the parts and the other methods, for example ABC and Pareto analysis, RCM[9] maintenance conception and techniques of prognosis, the results can be even more significant.

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[9] Reliability Centred Maintenance

It is interesting that this study can be upgraded if the new requirements are set for the system. For example, finding a proper ratio on where and when the regenerated parts should be sent, either to the central storehouse or to the users' warehouses. Or, it is possible to consider the problem of the uncertainty of replenishment with the new parts (with other replenishment sources), what this study did not take into consideration.

And finally, taking into account obtained results, a new way of functioning of the system of parts regeneration is defined, with the new material and information flow with which it is possible to eliminate the problems or, at least, to reduce their influence and consequences within the system.

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