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Automated Logistics Processes Improvement in Logistics Facilities

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Abstract:

Modern trends in the development of the economy lead to a significant increase in the needs of enterprises for warehouses, which provide temporary storage of stocks of material resources, work in progress and finished products. In this paper we analyzed main modern management methods in warehouses, their differences, and advantages. Authors propose their software development for automated system of logistics processes in warehouses. For operating with user requests a special server based on NodeJS was implemented.

Key words: Warehouse system, Robot, Logistics, Automated warehouse systems

Introduction

Automated warehouse systems not only eliminate manual labor, but also allow you to save warehouse space, speed up warehouse operations, and improve inventory control, since the computer monitors the location of each product in the warehouse. These systems are also called automated warehouses.

The object of the study is an automated system for searching for goods in warehouses.

The subject of research is the process of developing functional, mathematical and software automated systems for searching goods in warehouses.

The purpose of the work is to improve and optimize automated logistics processes in logistics facilities.

Tasks that need to be implemented: - analyze the existing logistics systems; – perform a description of the automated system and mathematical modeling of the process; – to develop algorithmic software of an automated system; - study the results of software development. The main results of the work are the development of a method of selecting cars in the warehouse using various software components and information systems.

New requirements are now being put forward for the management of warehouse complexes. This is related to global economic processes, the state of the market, and changes in consumer behavior. Every year, work in warehouses becomes more difficult, acquires new functions [1]-[5]. The Internet of Things, artificial intelligence, big data, blockchain, and other innovative technologies make it possible to effectively solve tasks that are constantly becoming more complicated. Not so long ago, robotic systems were mainly used to process large volumes of cargo. Robots were introduced where it was necessary to carry out repetitive actions with loads of the same size, located in the same place [6]-[10]. With the development of e-commerce, there was a need to automate various actions with heterogeneous goods and orders of small volumes. Warehouse workers are now used not only in receiving and transporting goods, but also in the assembly of orders, in sending goods to the consumer. Robotization of small and medium-sized warehouses was initially considered uneconomical. Now it is proving its effectiveness: in addition to large retailers, industrial giants, transport and logistics companies, more and more small businesses are using automated warehouse management systems.

Related works

Warehouse systems are an integral part of enterprises, especially those that produce a large number of goods.

Ronald Joshua Salvador and others in [11] note, that warehousing is the act of storing goods that will be sold or distributed later. Larger businesses typically own or rent space in a building that is specifically designed for storage.

Moreover, according to some experts, transportation activities spend 44% of the total cost. So, the process of sending and loading finished goods is very important [12]. Warehouse automation often has challenges in design and successful deployment. The effective management of the warehouse and inventory plays a pivotal role in the supply chain and production [13].

Authors [14] propose their own method to plan products allocation in a warehouse. Their model, as developed software, can support the decision and decrease the risk of the inappropriate choice of product location planning.

We must understand necessity of optimal warehouse organization.

Researchers in [15] develop their fulfillment system applicable to small and medium-sized companies performing frequent shipments characterized by low volumes, variable product mix, reduced overall dimensions for products and products. Their proposed solution consists of a series of smart drawers, controlled by a communication architecture designed in 4.0 Logic, equipped with hardware and software interfaces that can be easily integrated with any existing management or departmental system.

We also must remember other problem connected with warehousing. In [16] scientists write that the integration and application of a warehouse system and manufacturing system has become a manufacturing problem for enterprises. The main reason is that the information control system based on automation and stereo warehouse is inconsistent with the production and management information system of the enterprise in terms of business, data, functions, etc. [17]-[29].

And also we must pay special attention to software development for warehouse systems. And in this paper we propose our own software for our warehouse system.

Developed automated system main components

System construction is characterized by structures that describe stable connections between elements.

When describing an automated system, the following types of structures are used, which differ in the types of elements and connections between them:

- functional (elements – functions, tasks, procedures; connections – informational);
- technical (elements – devices, components and complexes; connections – communication lines and channels);
- organizational (elements – collectives of people and individual performers; connections – informational, subordination and interaction);
- documentary (elements – indivisible constituent parts and documents of the automated system; connections – interaction, input and subordination);
- algorithmic (elements – algorithms; connections – informational);
- software (elements – software modules and products; connections – control);

- informational (elements – forms of existence and presentation of information in the system; links – operations of information transformation in the system).

Taking into account the classic system of the automated system, a diagram of the automated system of warehouse logistics processes was drawn up, which will have the following form, shown in Figure 1. In it, precisely those complexes and structures are selected, which collectively realize the main task of the system.

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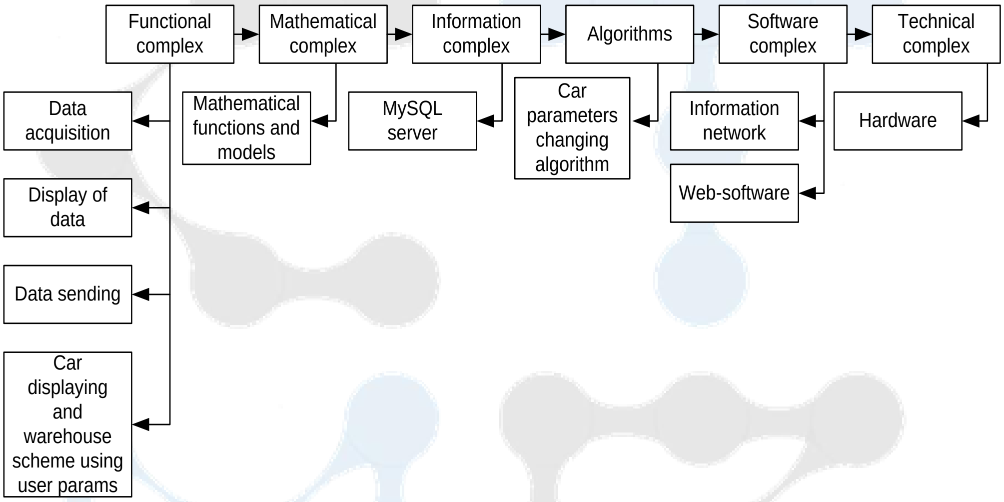

Figure 1: Automated system scheme.

The functional complex is responsible for the main tasks of the web application, namely: receiving, displaying, and sending data, cars, and warehouse schemes according to the relevant user parameters.

The information complex is a repository of data with which the system works. In our case, this is the MySQL server.

The algorithmic block is responsible for the functioning and coordinated operation of the program, the main function of which is to respond to changes in input parameters.

The main structure of the software complex is a developed web application and an information network.

The decision-making sequence is shown in Figure 2.

It is important to justify the problem correctly. For example, the idea of the Japanese professor Ishikawa. The Ishikawa diagram is a graphical method of research and determination of the most significant cause-and-effect relationships between factors (factors) and consequences in the situation or problem under study.

The Ishikawa diagram for the car selection process is shown in Figure 3.

Decision-making under conditions of multicriteria and under conditions of uncertainty according to the analytical hierarchy method (AHM).

The analytical hierarchy method is based on the principles of decomposition and synthesis, the implementation of which makes it possible to reduce the number of possible errors in the process of obtaining information from an expert. With the help of AHM, a structure in the

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VOLUME-3, ISSUE-3

form of a hierarchy is obtained, which allows you to avoid complex comparisons by replacing them with pairwise comparisons. This method makes it possible to check the consistency (consistency) of the expert's statements.

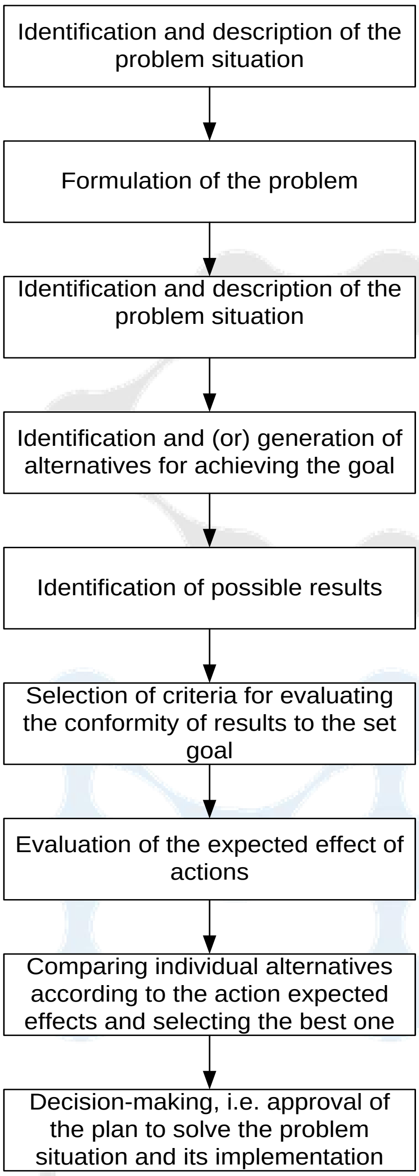

Figure 2: Diagram of decision-making sequence

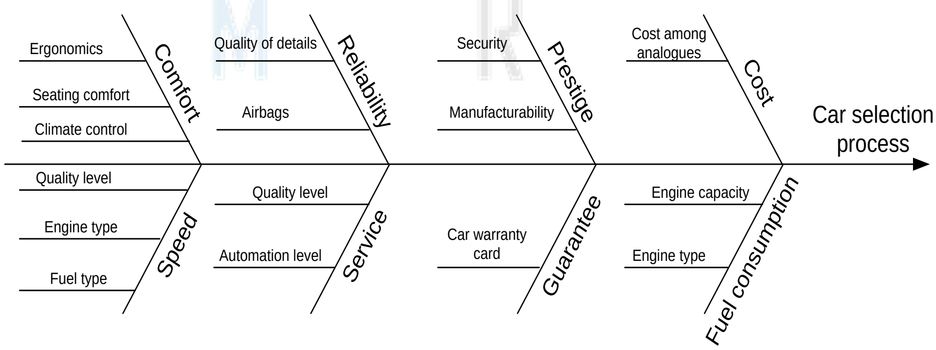

Figure 3: Ishikawa diagram

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889
ResearchBib Impact Factor: 8.848 / 2023
THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY
VOLUME-3, ISSUE-3

Analytical hierarchy method (AHM) is a systematic procedure based on a hierarchical representation of the elements that determine the essence of the problem. The problem is subjected to decomposition into simpler components with subsequent assessment by the decision-maker of the relative degree of interaction of the elements of the resulting hierarchical structure. The method is based on the principle of identity and decomposition, according to which the structuring of problems in the form of a hierarchy or network includes procedures for synthesizing multiple statements, evaluating the priority of criteria and finding alternative solutions.

Sequence of AHM stages:

– formulation of the problem to be solved;

– setting the problem in general – including it (if necessary) in a large system in which there are other interested actors (actors), consideration of their ideas and desired results;

– identification of criteria by which the quality of problem solving will be evaluated;

– building a hierarchy of common criteria, individual criteria, properties of alternatives and the alternatives themselves. In a multi-stakeholder problem, levels can refer to the environment of the actors, their goals, policies, and outcomes that will lead to a generalized outcome (the state of the sphere of action). To eliminate ambiguities, each element in the hierarchy should be carefully defined;

– prioritization of primary criteria (forces) regarding their impact on the general goal;

– clear question formulation for pairwise comparisons in each matrix. Pay attention to the orientation of each issue (for example, the cost should decrease and the efficiency should increase);

– setting priorities of partial criteria in relation to general ones. Collection of results of pairwise comparisons;

– processing of collected data according to the AHM algorithm to calculate global priorities and global consistency of results;

– in the case of a choice among alternatives – the choice of the one with the greatest value of global priority. In case of allocation of resources, evaluation of the cost of alternatives, calculation of the efficiency-to-cost ratio and appropriate allocation of resources: fully or proportionally. If it is necessary to determine the priorities of the cost – allocate resources in proportion to the priorities.

In AHM, pairs of problem elements are compared in pairs about their influence (action, weight, intensity) on their common characteristic.

The matrix has the form:

$$A = \begin{pmatrix} 1 & a_{12} & a_{1n} \\ \frac{1}{a_{12}} & 1 & a_{2n} \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & 1 \end{pmatrix},$$

After obtaining quantitative statements about (B_i,B_j) in numerical form is required for

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ResearchBib Impact Factor: 8.848 / 2023
THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY
VOLUME-3, ISSUE-3

each element of the set B = $\{B_1, B_2, \ldots, B_n\}$ to match numerical weights or priorities. In the case of a hierarchical presentation of problems, a matrix is made to compare the relative importance of the criteria of the second level with respect to the general goal of the first level (the root of the hierarchy), and then the same matrices of pairwise comparisons of the next level are built with respect to the elements of the previous one.

Pairwise comparisons are performed in the ratio scale according to the point system, which is given in Table 1.

Table 1: Pairwise comparisons

Mark, k	**Definition**
1	The same importance
3	Moderate advantage
5	Substantial advantage
7	Significant advantage
9	Very great advantage
2, 4, 6, 8	Intermediate values (used in transitional situations)
1/k	Inverse values

The main task of the AHM is to determine the global priorities of alternatives, that is, their priorities relative to the root of the hierarchy. At the same time, the results of expert surveys in the form of matrices of pair wise comparisons at all nodes of the hierarchy, except for leaves – alternatives, are used as initial data.

For illustration, consider an example. The customer wants to choose a car. As a result of the analysis, the following criteria were identified that should be considered: prestige, cost, specific fuel consumption, comfort, reliability, maximum speed, dimensions, maintenance costs, warranty obligations.

Further consideration makes it possible to choose three models as "candidates" and present the problem in the form of a hierarchy. The initial set of criteria after analysis was narrowed down to such essential ones:

Q_1 – comfort; Q_2 – reliability; Q_3 – speed; Q_4 – cost; Q_5 – prestige; Q_6 – service; Q_7 – guarantees; Q_8 – fuel consumption. With the help of a survey of experts, the following matrix of pairwise comparisons was built for level 2 - criteria.

The hierarchical structure of the task of choosing a car is shown in Figure 4.

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889
ResearchBib Impact Factor: 8.848 / 2023
THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY
VOLUME-3, ISSUE-3

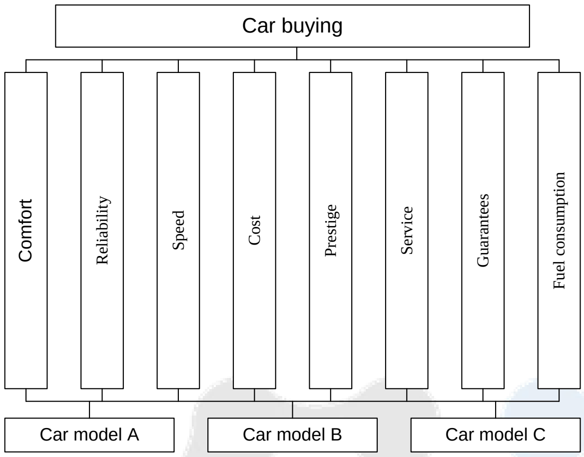

Figure 4: Hierarchical structure of the car selection problem.

Table 2: Matrix of pairwise comparisons of criteria

Criteria	**Q_1**	**Q_2**	**Q_3**	**Q_4**	**Q_5**	**Q_6**	**Q_7**	**Q_8**
Q1	1	5	3	7	6	6	1/3	1/4
Q2	1/5	1	1/3	5	3	3	1/5	1/7
Q3	1/3	3	1	6	3	4	6	1/5
Q4	1/7	1/5	1/6	1	1/3	1/4	1/7	1/8
Q5	1/6	1/3	1/3	3	1	1/2	1/5	1/6
Q6	1/6	1/3	1/4	4	2	1	1/5	1/6
Q7	3	5	1/6	7	5	5	1	1/2
Q8	4	7	5	8	6	6	2	1

After that, comparing three cars (A, B, C) in pairs for each of the criteria (level 3), eight matrices (for each of the criteria) of size 3×3 (by the number of alternatives to choose) were obtained.

Let's evaluate the sequence of the expert's statements and the determination of local priorities of the hierarchy.

Let's calculate the local priority vectors, consistency index, and consistency ratio for the matrix of pairwise comparisons of criteria (Table 2) and matrices of pairwise comparisons of alternatives A, B, C according to criteria Q_1–Q_8 (Table 3).

We present below the results of determining the priority vector, consistency index, and consistency ratio for the matrix of pairwise comparisons of criteria (Table 4). The priority vector is obtained because of calculating the main eigenvector followed by its normalization.

The obtained value of the consistency ratio is too high, but we will consider it acceptable. In relatively large matrices (n = 7,8,9) achieving a high level of consistency is problematic, but in this case the increased risk due to inconsistency should be considered.

Table 3: Matrices of pairwise comparisons of alternatives A, B, C by criteria

1					**2**				**3**				**4**		

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ResearchBib Impact Factor: 8.848 / 2023
THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY
VOLUME-3, ISSUE-3

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	/6				/7		/8		/8		/4				
	/8	/4							/6						
5				6				7				8			
										/2	/2			/7	/5
	/5		/3		/8		/5								
	/4				/6									/3	

Table 4: Determination of consistency of criteria matrix.

Criteria	**Q_1**	**Q_2**	**Q_3**	**Q_4**	**Q_5**	**Q_6**	**Q_7**	**Q_8**	**Vector of priorities**
Q_1	1	5	3	7	6	6	1/3	1/4	0,173
Q_2	1/5	1	1/3	5	3	3	1/5	1/7	0,054
Q_3	1/3	3	1	6	3	4	6	1/5	0,188
Q_4	1/7	1/5	1/6	1	1/3	1/4	1/7	1/8	0,018
Q_5	1/6	1/3	1/3	3	1	1/2	1/5	1/6	0,031
Q_6	1/6	1/3	1/4	4	2	1	1/5	1/6	0,036
Q_7	3	5	1/6	7	5	5	1	1/2	0,167
Q_8	4	7	5	8	6	6	2	1	0,333
								l_u	0,238
								l_0	0,169

Let's calculate the corresponding characteristics for a set of tables of the next level – evaluation of alternatives.

As for the interpretation of the results, in this example, fuel consumption is the most important factor in choosing a car, comfort is second, and speed is third. In a real situation, based on the results of such an analysis, it would be possible to discard insignificant criteria and repeat the expert's survey, but for illustrative purposes, all were left.

Global priorities are calculated at the next stage of AHM – hierarchical synthesis. For this purpose, to identify the composite, or global, priorities of cars, we will perform a reverse course: from the penultimate level, we move to the root of the hierarchy, collecting vectors of local priorities in a matrix and multiplying them by vectors of local priorities of immediate ancestors, until we reach the root of the hierarchy.

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ResearchBib Impact Factor: 8.848 / 2023
THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY
VOLUME-3, ISSUE-3

Table 5: Calculated values of local priorities for alternatives

Q_1	**A**	**B**	**C**	**Vector of priorities**	**Q_2**	**A**	**B**	**C**	**Vector of priorities**
A	1	6	8	0,754	A	1	7	1/5	0,233
B	1/6	1	4	0,181	B	1/7	1	1/8	0,005
C	1/8	1/4	1	0,065	C	5	8	1	0,713
			l_u	0,068				l_u	0,124
			l_0	0,117				l_0	0,213
Q_3	A	B	C	Vector of priorities	Q_4	A	B	C	Vector of priorities
A	1	8	6	0,745	A	1	1	1	0,333
B	1/8	1	1/4	0,065	B	1	1	1	0,333
C	1/6	4	1	0,181	C	1	1	1	0,333
			l_u	0,068				l_u	0
			l_0	0,117				l_0	0
Q_5	A	B	C	Vector of priorities	Q_6	A	B	C	Vector of priorities
A	1	5	4	0,674	A	1	8	6	0,747
B	1/5	1	1/3	0,101	B	1/8	1	1/5	0,06
C	1/4	3	1	0,226	C	1/6	5	1	0,193
			l_u	0,043				l_u	0,099
			l_0	0,074				l_0	0,17
Q_7	A	B	C	Vector of priorities	Q_8	A	B	C	Vector of priorities
A	2	1/2	1/2	0,2	A	1	1/7	1/5	0,072
B	2	1	1	0,4	B	7	1	3	0,65
C	2	1	1	0,4	C	5	1/3	1	0,278
			l_u	0				l_u	0,032
			l_0	0				l_0	0,056

In the given example, this procedure is reduced to assembling a matrix of vectors of local priorities of alternatives according to the criteria (s = 2):

$$P_1^{(1)} = \begin{pmatrix} 0.754 & 0.233 & 0.745 & 0.333 & 0.674 & 0.747 & 0.200 & 0.072 \\ 0.181 & 0.055 & 0.065 & 0.333 & 0.101 & 0.060 & 0.400 & 0.650 \\ 0.065 & 0.713 & 0.181 & 0.333 & 0.226 & 0.193 & 0.400 & 0.278 \end{pmatrix}$$

A vector of local priorities relative to the root of the tree:

$$x_1^{(1)} = \begin{pmatrix} 0.173 & 0.054 & 0.188 & 0.018 & 0.031 & 0.036 & 0.167 & 0.333 \end{pmatrix}^T$$

The transport sign is used for the convenience of its recording. Then:

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889
ResearchBib Impact Factor: 8.848 / 2023

$$p_1^{(1)} = P_1^{(1)} \times x_1^{(1)} = \begin{pmatrix} 0.0396 \\ 0.341 \\ 0.263 \end{pmatrix}.$$

Since the value is updated, the algorithm's work on it is completed. Therefore, according to the overall indicator (despite the worst indicators according to the criterion of fuel consumption), car A is chosen, because other indicators are better compared to competitors.

Practical realization of proposed system

Figure 5 shows the initial view of the web application.

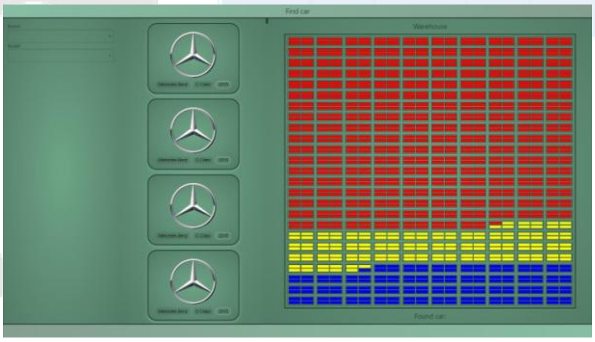

Figure 5: The initial view of the web application

From Figure 5 we can see that the structure of the page is accessible and convenient. It is divided into three sections, namely: brand and model selection (on the left), search results (in the center), the layout of cars in the warehouse (on the right). Each section is a separate software component that performs its role.

The first three stages are the main ones for working with the database. Next will be only the use of data from it. For this we use the keyword SELECT. The first request that will be processed by our server will be as follows – SELECT * from warehouse; – will return us a collection with all the cars in the database. Further, requests may have additional parameters, conditions under which we will select the data we need from the table. For example, to select Volvo cars, we will write the appropriate query – Select * from warehouse where make='Volvo';. We will choose other parameters according to this principle.

Setting up the server is the next step. The server, as described above, allows the user to send requests to the database management system and receive data from it in response. The program file of our application is quite simple and clear.

First, we specify the data of our database, namely the port on which MySQL is based, the name of the database itself, the desired table, and the user's input data – name and password. After a successful connection, we, so to speak, establish a communication channel between the user and the database.

After that database setup, we can run the server and client side. In two separate directories, you need to run the npm i command, which will install all the necessary packages to work. After that, run the npm start command in the same terminals. As soon as the client part is closed, an additional tab with our system will open in the browser.

Suppose that the user wants to find the position of a car with the following parameters:

– brand – Volvo;

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THE MULTIDISCIPLINARY JOURNAL OF SCIENCE AND TECHNOLOGY
VOLUME-3, ISSUE-3

– model – V40;

– year of graduation – 2016;

– engine power in horsepower is 245.

Let's perform the following steps and follow the change of the user interface. Select the Volvo brand in the car parameters selection section (Figure 6).

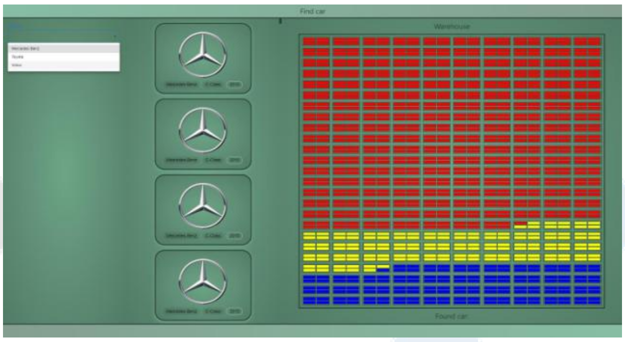

Figure 6: Choosing a Volvo brand car

Select the desired model from the drop-down list (Figure 7).

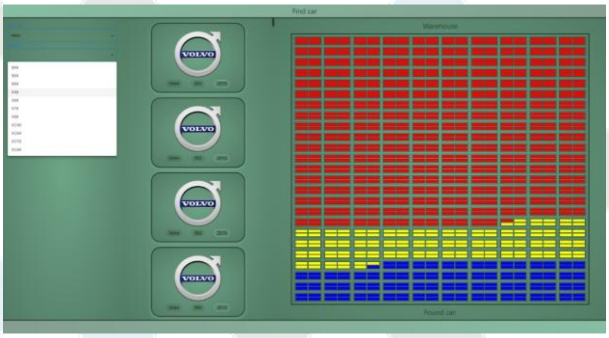

Figure 7: Selection of the appropriate model of the Volvo brand

As you can see, we received several cars with the specified parameters. Now, to specify a specific car with the required engine power, we select the first car and see its position in the warehouse in the form of a white rectangle. Also, more detailed characteristics of the car are described in the section under the composition scheme (Figure 8).

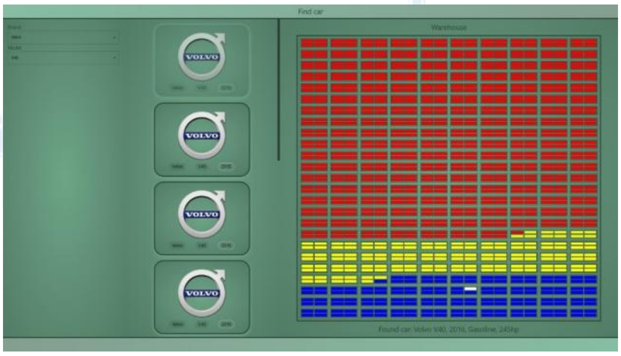

Figure 8: Selection of the desired car, display of its position in the warehouse and additional characteristics

To find out the position of the car in the warehouse, it is enough to move the mouse cursor over the white rectangle, after which there will be an additional window in which the location is encrypted (Figure 9).

ISSN: 2582-4686 SJIF 2021-3.261,SJIF 2022-2.889
ResearchBib Impact Factor: 8.848 / 2023

Figure 9: Position of the car in the warehouse and description of additional characteristics

Conclusion

The main modern management methods in warehouses, their differences, and advantages were described. Relevant characteristics, images for each method are given.

In the course of the work, software development of an automated system of logistics processes in warehouses was proposed. A warehouse that can hold up to 1,000 cars was taken into account. The car data was stored in a MySQL database. To work with data, a special server based on NodeJS was implemented, which processed user requests and responded appropriately with the appropriate data.

The visual part of the application, simple and clear, was also implemented.

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