Automated transport and storage systems for road transport companies

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Abstract. The technologies of automated transport and storage systems’ work for motor transport enterprises, placement, storage and parts release from the warehouse, as well as labor organization in the warehouse are considered. The calculation and design of the warehouse is given.

Introduction
The work performed in different warehouses is approximately the same. This is due to the fact that for different logistics processes, the functions performed by warehouses are similar: temporary placement and storage of inventories; providing logistics services in service system; material flows’ transformation. However, specific warehouses require their own work organization with their own characteristics, which depend on the purpose of the warehouse and its size. The work organization for large warehouse complexes is not suitable for a small, highly specialized warehouse. Transportation, storage and warehousing of foodstuffs requires different conditions and approach in contrast to industrial products [1-11].

The structure of the warehouse for automotive spare parts has a number of features that should be taken into account for the efficient operation of the warehouse. The spare parts warehouse is characterized by a wide range and heterogeneity of the sizes of the parts stored in the warehouse.

Theoretical section
Parts acceptance
Acceptance is an important part of the process. Acceptance is carried out by the responsible persons in accordance with the internal rules of the company.

Parts for the warehouse are accepted in terms of quality and quantity. Acceptance technology is determined depending on how the goods are delivered and packed. Acceptance by quantity is carried out by comparing data from the accompanying transport documentation (waybills, specifications, invoices, etc.) with the actual parts’ availability.

Acceptance by quality is performed according to the requirements of standards, contracts, technical conditions and accompanying documents. Products that have not passed mandatory certification are not subject to acceptance as well as parts with defects. If a non-compliance of the supplied parts with the company’s requirements is found, acceptance is suspended.

Parts are accepted by warehouse workers (storekeepers) unilaterally.
If a shortage or non-compliance of the goods with the company’s requirements is revealed, an act is drawn up with the signatures of the persons who carried out the acceptance. This act is sent to the supplier, it indicates the parts’ names, the invoice number, the type of shortage and the amount of missing goods.

*Parts placement and storage*

Parts that have passed acceptance are moved to storage areas to create the necessary parts stock in the warehouse. This technological operation is the basis for performing further functions of the warehouse technological process related to the rational supply organization of the company with spare parts.

The warehouse uses a rack method for storing spare parts. The parts themselves are in a container that has its own unique number (address), with the help of which, using the database of the system for accounting for parts in the warehouse, you can quickly determine the required cell in which the part required for release is located. Such targeting of storage provides operational management of warehouse stocks.

To maintain the proper quality and condition of the parts, the storage regime is observed. The warehouse is provided with control over maintaining the optimum air humidity and temperature. These microclimate parameters are controlled by ventilation and heating.

*Parts release from the warehouse*

To carry out repair operations or maintenance, it is necessary to provide the workers with the necessary spare parts and materials that are stored in the warehouse. Parts release is the distribution of parts from the warehouse directly for work and services.

In accordance with the established norms of the enterprise, the parts are distributed from the warehouse directly to the sites, but only to strictly defined employees who have the right to perform this kind of actions.

For release registration, a limit card can be used.

A quick search for the necessary parts is carried out by virtue of the warehouse accounting system database, which is based on bar coding. The part is written off from the warehouse automatically when scanning the barcode on the documentation and additional confirmation of the operation by the storekeeper carrying out the release.

After performing the above-mentioned operations, the storekeeper takes the required number of the specified parts from the specified cell and takes them to distribution, having previously completed all the accompanying documentation for the release.

*Labor organization in the warehouse*

First of all, with the introduction of a robotic loader, the warehouse organizational structure changes. If there is no need to work manually, the need for storekeepers disappears, the loader will do the work for them. But there is a need for periodic maintenance and adjustment of the loader; for these purposes, a person who will take the position of an operator-setter is needed. Otherwise, labor organization in the warehouse remains the same.

The duties of the commissioning operator include the following:

- monitoring the technical condition of the loader;
- carrying out scheduled maintenance and running repairs, as well as unscheduled repairs;
- software adjustments;
- manual control of the loader if it is necessary to transport goods outside the warehouse;
- loader monitoring;
- acceptance and placement of parts in the warehouse using a loader;
- filling out the accompanying documentation related to the loader.

*Parts acceptance*

The technological process of accepting the supplied parts remains the same, except that there are no storekeepers in the warehouse who previously accepted the goods. Now these responsibilities are assigned to the operator.
Calculation and design of a warehouse

In connection with the inclusion of a robotic loader into operation and, as a result, a change in the warehouse operation technology, it is necessary to calculate the overall parameters of the racks on which the containers will be stored.

When calculating the parameters, the dimensions of the container, which has dimensions suitable for the loading mechanism of the electric loader used in the warehouse are taken as basic. Accordingly, the cell should have the dimensions slightly larger than the overall dimensions of the container for free loading and unloading on storage racks [7-15].

Taking into account the robotic equipment operation in the warehouse, and, accordingly, the absence of a human factor, we can assume minimal errors when loading and unloading containers. In this case, it is possible to allow minimal displacement of the loading mechanism to the sides; and in order to increase the density of the warehouse layout, allow an increase in the storage rack cell relative to the overall dimensions of the container by only 20 mm on the sides (40 mm in total).

Then, the cell width will be:

$$B_c = B_{cont} + 40,$$

where $B_{cont}$ – is the container width, mm.

$$B_c = 1080 + 40 = 1120 \text{ mm}.$$

Free height for lifting the container should be slightly larger than the side gaps, first, for the ability to free load and unload the container when it is not fully loaded, and second, when filling the container with large-sized parts, there should be a space between the shelf of the storage rack and the parts exceeding the overall size of the container.

Then, the cell height will be:

$$H_c = H_{cont} + 85,$$

where $H_{cont}$ – is the container height, mm.

$$H_c = 915 + 85 = 1000 \text{ mm}.$$

The depth of the shelf corresponds to the depth of the container and is 920 mm. Thus, we get a rack cell with the following parameters: 900x1120x1000 mm.

Taking into account the dimensions of one cell of the main rack, it is possible to calculate the total number of the main storage racks’ cells that will be in the warehouse. With a height from floor to ceiling of the warehouse equal to 4900 mm, it is possible to fit the following number of cells in height (excluding the storage racks’ shelves height):

$$n = \frac{H_{wh}}{H_c},$$

where $H_{wh}$= 4900 – is the warehouse height, mm.

$$n = \frac{4900}{1000} = 4.9 \text{ pc.}$$

The resulting number 4.9 rounded down due to the impossibility of increasing the warehouse height. Then we get the number of cells in height, $n=4$ pc.

Taking into account the storage racks’ shelves height and the height of the resulting number of cells, we obtain the following value for the main storage racks’ height:

$$H_a = n* (H_c + h_{sh}),$$

where $h_{sh}$ – rack shelf height, $h_{sh}$=50 mm.

$$H_a = 4*(1000 + 50) = 4200 \text{ mm}.$$

Taking into account the storage racks’ length in the warehouse and the width of one cell, the calculation of the number of cells of the main racks is as follows:
\[ N_{mr} = \frac{(a + b + c + d) \cdot n}{B_c}, \]

where \( a, b, c, d \) – denote the main racks’ length, mm (Figure 1).

\[ N_{mr} = \frac{(4480 + 13440 + 5600 + 10080) \cdot 4}{1120} = 120 \text{ pc.} \]

Thus, the width and height of the cells of the additional racks are the same with the width and height of the main racks’ cells, the difference is only in depth. It follows from this that for additional racks it is necessary to select the containers with the following parameters: 560x1080x915 mm. In turn, the cell of the additional rack will have the following parameters: 560x1120x1000 mm.

In this case, the number of additional racks is calculated using the following formula:

\[ N_{add} = \frac{e \cdot n}{2 \cdot B_c}, \]

where \( e \) – is the additional rack’s length, mm.

As a result, a total of 168 cells with the containers are available for storing spare parts in the warehouse, of which 120 are large and 48 additional containers are smaller.

For fast and energy efficient operation of a robotic electric loader, the passage width should be sufficient for free maneuvering around the warehouse, as well as for loading and unloading goods. In this case, the steering control of the loader allows it to turn on the spot 90°. Based on this, for free maneuvering and performing operations, the loader needs a passage width a little more than its overall length. If such a maneuver is impossible, it is possible to use the U-turn algorithm in several steps; to execute this algorithm, the collision and route orientation parameters are included in the loader software.

Based on the above-noted parameters of the loader and its overall length, which is 3210 mm, we obtain the following dimensions of the passage width (Figure 2):
Parts’ placement and storage

Upon completion of the parts acceptance, they should be sorted into places. This process is carried out using a loader. The electric loader receives the address of the container into which the sorting will be carried out and brings it to the point of acceptance and release. For storing parts, large plastic containers of various sizes are used on runners (Figure 3).

Figure 2. Loader passage width

Figure 3. Plastic container for storing spare parts

These containers have a volume of up to 700 liters and can withstand dynamic and static loads on the bottom of up to 1000 kilograms. They also have a long service life with proper handling and are suitable for transportation by loader and do not overload the racks and loader with their own weight, unlike similar metal containers.

All containers available in the warehouse have a certain placement order. First of all, the containers are determined by two criteria:

1. mass;
2. Demand. These criteria were not chosen as the main ones by chance, the heaviest and most demanded containers are located as close as possible to the release point, this is done to reduce the load on the loader, save energy and increase the distribution speed of the necessary goods. In accordance with these criteria of containers, the racks in the warehouse are divided into three zones for placing the containers (Figure 4):

![Figure 4. Layout of disposition areas on storage racks](image)

1. Disposition area for heavy, medium and light high-demand containers;
2. Disposition area for heavy, medium and light medium-demand containers;
3. Disposition area for heavy, medium and light low-demand containers.

Within these zones, the distribution of containers by weight is also carried out, according to the principle, the further from the acceptance and release, the easier. Weight designation is numerical and looks like this:

1 – heavy;
2 – average weight;
3 – light.

The demand for containers is also divided into 3 groups, but indicated by letters:

X – high-demand;
Y – medium-demand;
Z – low-demand.

Further distribution is made based solely on the contents of the container. All containers are distributed according to specific parts and their belonging to specific groups. Membership in a group is indicated by the letters (A, B, C, etc.), and belonging to a particular part is indicated numerically (1-valves, 2-pistons, etc.). This distribution includes the following parts’ groups:

A – engine;
B – body (all attachments such as lights, handles, wiper blades, etc. are stored in a warehouse);
C – transmission;
D – running gear;
E – steering control;
F – brake system;
G – electrical equipment;
H – cooling system.

The result of such parts sorting by containers is the following example of a unique code for each container with spare parts (Figure 5):

![1ZA136]

**Figure 5.** Unique cipher of the container

After deciphering this designation, it turns out that the container is heavy (1), contains little-dimanded (Z) engine parts (A), namely camshafts (136).

**Parts release from the warehouse**

Parts are also released to persons who have the right to receive them from the warehouse, but the receipt process changes radically. The warehouse is fully automated and does not require human participation to carry out the release process. To obtain the necessary spare parts, the person to whom the release will be made comes to the pick-up and drop point with accompanying documentation, which contains a list of spare parts to be dispensed and there is a barcode for each part, which has the detailed information in which the container it is located for the loader. This information is read by the scanner and sent wirelessly to the loader via WI-FI. To locate the necessary container in the warehouse at the received address, RFID technology is used [16-20].

RFID – it is a technology that uses radio waves to transmit information. This system consists of tags (data keepers), a reader, an antenna (to amplify the signal) and a system that processes data.

The reading distance of an RFID tag will vary depending on the equipment and environment used, and is customizable based on needs. Data in the form of a cipher (Figure 5) is recorded on the RFID tag. The data received from the scanner and the data from the tag are compared by the loader and the route to the container with the necessary spare parts is determined. Following the algorithms, the loader loads the container and takes it to the acceptance point, where the customer picks up the necessary part.

**Accounting for material assets in the warehouse**

With the general automation of the warehouse, the processes of accounting for material assets are partially automated. So, when ordering goods from a warehouse according to the process described above, the barcode carries, in addition to the container address, information about the order, and specifically the number of released parts, their code numbers, recipient data. All data is automatically recorded by the computer when releasing and the details are entered into the database as shipped (released).

**Summary**

As a result of this work, the calculation and the warehouse design has been carried out, the plan for the storage racks arrangement has been calculated, the width of the passage for the loader has been determined, the containers’ disposition areas have been highlighted and a unique marking code for each container with spare parts has been proposed.

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