Number of Loaders Optimization Serving the Warehouse Complex of Logistic System Taking into Account Their Repair

G.I. Nechaev, I. A. Tararychkin, M. E. Slobodyanyuk
East-Ukrainian National University named after Volodymyr Dahl
Address for correspondence: Ukraine, 91057, Lugansk, kvartal Gagarina 14V|113,
e-mail: slobod777@gmail.com
tel: +380 953 299992; fax: +380 642 412150

Summary: The article shows the structure of the autoloaders service cycles, describing the execution sequence of various repairs. It explains what allows realization of the optimal scheme of service management. The sequence of autoloaders output in repair is introduced bringing into service within one interrepair cycle and requirements to organizational management of autoloaders on different freight fronts.

Key words: logistic system, warehouse, optimization of transport, material flows.

JEL: R40.

One of the major logistics problems is optimization of loading and unloading mechanisms in different areas of a warehouse complex. Its solution is connected with costs minimization on processing material flows in the logistics system and should take into account not only mechanisms used in work, but also being in planned maintenance (PM).

The PM of transport machines promotes their no-failure operation and execution of their planned maintenance work. According to the existing transport standards, the number of autoloaders being under repair at one and the same time should not exceed 10 % from the total number of those serving a warehouse complex (1, 1989, pp. 264, 2, 2007, pp. 400). However it is difficult to fulfill such requirement in practice, and the number of autoloaders being under repair at one and the same time can reach 25-30 %. Such a peak in servicing loaders result not only in increase of operating costs, but also breaks the uninterrupted work of the warehouse as a whole. The structure of the autoloaders service cycles, describing the execution sequence of various repairs is shown in Figure 1 (2, 2007, pp. 400).

K – capital repair
T – running repair

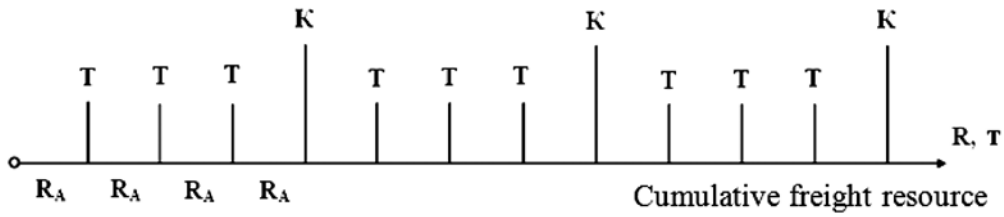

Figure 1. The sequence of autoloaders repair service

Hereinafter the term "optimal" is related to such a scheme of service management in which no more than one autoloader is in a running or capital repair, and during one interrepair cycle the repair of all loaders of the warehouse complex is provided.

Realization of the optimal scheme of service management allows:

- to minimize the number of loaders serving the warehouse;
- to provide uninterrupted repair works without taking out of service a great number of loaders at one and the same time;
- to preplan and provide uninterrupted delivery of service parts for loaders;
- to provide the minimum size of manufacturing areas which are necessary to be intended for a repair bay;
- to minimize the number of the service personnel.

The aim of this work is to determine the conditions under which the achievement of the optimal scheme of autoloaders' service management is possible.

Hereinafter the following notations are used:
n – number of freight fronts of the warehouse complex, piece;
S – quantity of loaders used on each of the freight fronts, piece;
N – total number of loaders used on all freight fronts, piece;
Q_Σ – daily volume of processed freights on all freight fronts, t/d (tons/day);
$П_T$ – real daily loading on one loader, t/d;
T_T – standard duration of one loader service at running repair, d (days);
T_K – standard duration of one loader service at capital repair, d;
R_A – a standard for the freight resource for one autoloader within one interrepair cycle, t;
$T_Ц$ – duration of the interrepair cycle, d.

The total volume of freights processed by a complex per twenty-four hours:

$$Q_\Sigma = П_T \cdot S \cdot n \text{ [t/d]}.$$

Calculated duration of the interrepair cycle:

$$T_Ц = \frac{R_A}{П_T} \text{ [d]}. \quad (1)$$

During this period of time all loaders should pass a capital repair on the condition that the complex functioning does not stop, only one loader should be taken out of service, and its work is carried out by a changeable loader from the previously formed reserve.

Considering that $T_Ц > T_К$. S . n and using the formula (1) we get:

$$Q_\Sigma \leq \frac{R_A}{T_К} .$$

If we accept the following standard values [2]: R_A = 36000 t and $T_К$ = 14 d for used autoloaders, the realization of the formulated optimal scheme appears essentially possible for warehouse complexes with freight volumes:

$$Q_\Sigma \leq \frac{36000}{14} = 2570 \text{ [t/d]}. \quad (2)$$

Thus, the number of autoloaders used in the warehouse, for which the organization of repair service at an optimal scheme is possible, depends on their real average daily loading $П_Т$ and is determined by taking into account the dependence (2) according to data in Figure 2.

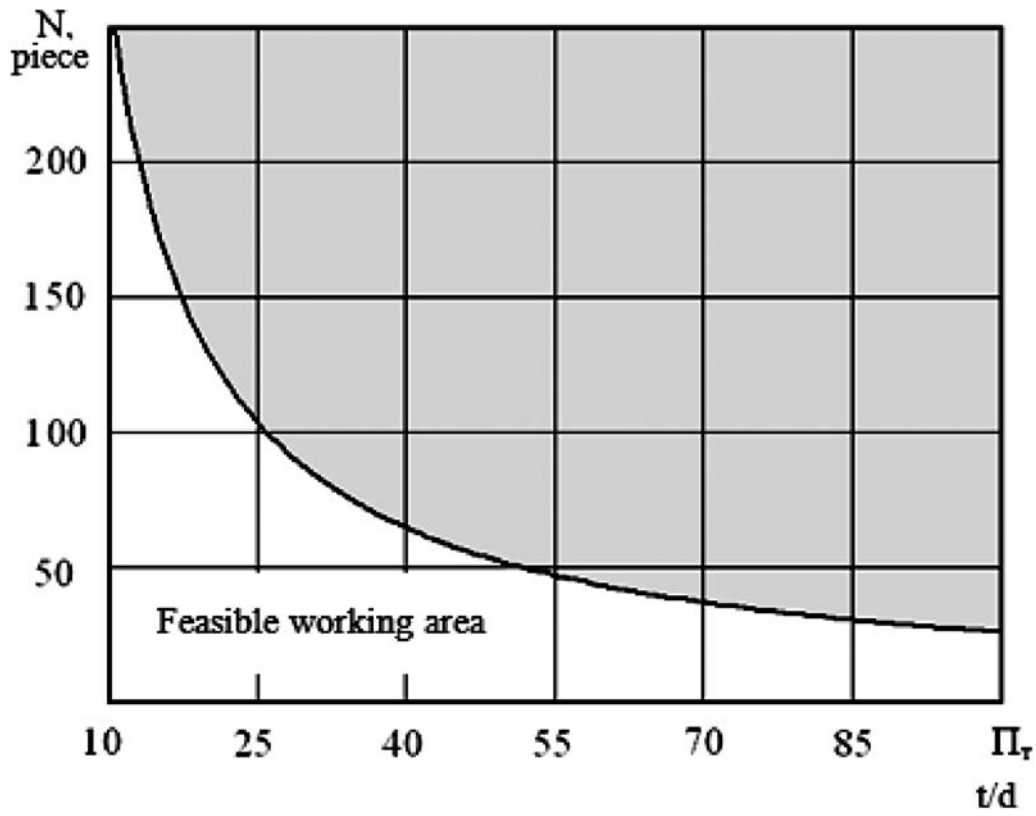

Figure 2. The scheme of admissible number of warehouse loaders definition

The sequence of autoloaders output in repair and bringing into service within one interrepair cycle

Structures of the output and further bringing into service units of equipment for running and capital repairs may be different because of the existing differences in standard time ($T_K >> T_T$). Therefore, scheduling repair operations on the basis of compatibility conditions must be done concerning the case of capital repair uppermost.

Let's define the time t_1 between bringing into service of the last loader serving j front and output in capital repair of the first loader on j + 1 front (Figure.3):

$$t_1 = \frac{T_Ц - T_K \cdot S \cdot n}{n - 1}.$$

The duration of the cycle $T_Ц$ is defined by the formula (1). The structure of the scheme of loaders' output in running repair will be different. In order these schemes to be mutually compatible it is necessary for loaders appointed to each freight front to establish an additional time slice $t_0 = T_K - T_T$ between bringing into service the previous one and output in repair of the Figure 4.

Besides, the time slice $t_0 + t_1$ should be provided between bringing into service the last loader appointed to **j** front and output in repair of the first loader appointed to j + 1 front.

Using the proposed schemes provides the compatibility of output in repair procedures of autoloaders for all freight fronts, at transition from mid-life to capital repair and the opposite. Let's notice that the main condition of the suggested approach realization is the necessity of maintenance of equal freight resource exhaustion by different loaders for identical periods. In this case the rate of freight resource exhaustion $\varepsilon = \frac{R_A}{T_Ц}$ for each of the loader during all operating period remains constant.

The schedule of freight resource exhaustion by separate autoloaders during the transition from

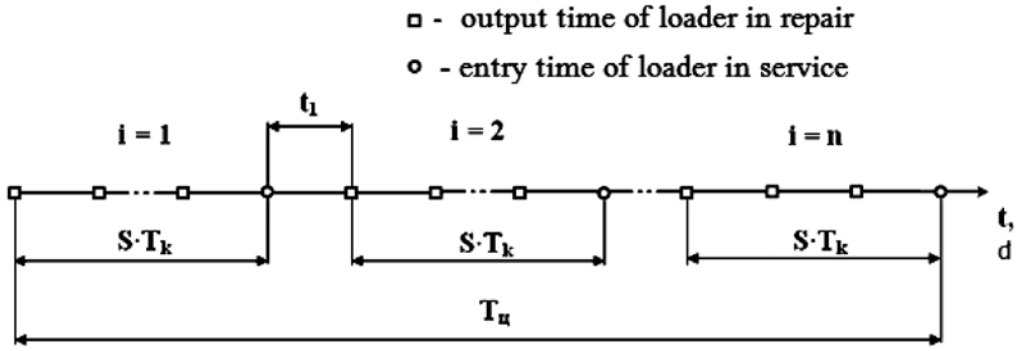

Figure 3. The scheme of autoloaders' output in capital repair

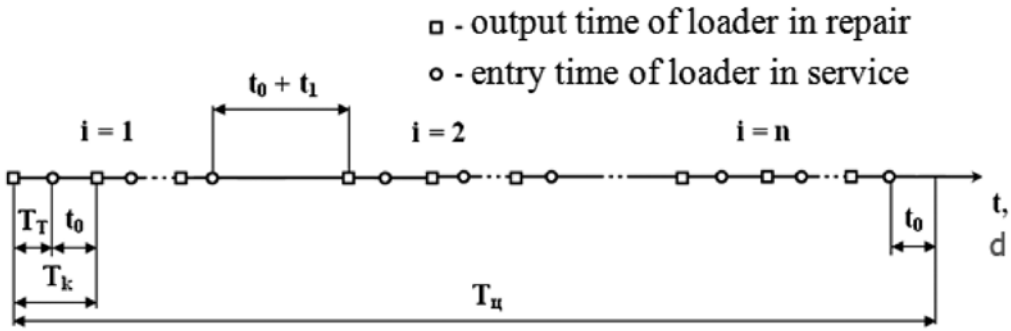

Figure 4. The scheme of autoloaders' output in running repair

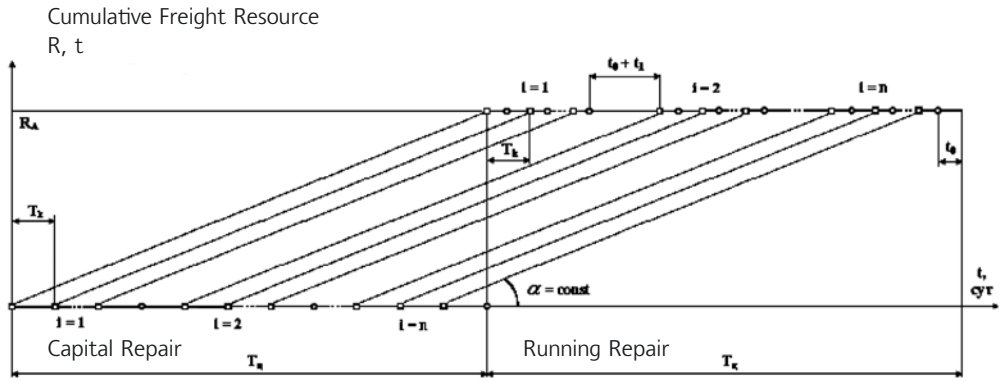

Figure 5. The scheme of capital repair and running repair

capital to running repair is shown in Figure 5. The value ε characterizes an inclination angle of rectilinear segments describing the process of freight resource exhaustion (ε = tgα), therefore further examining the questions connected with the optimal PM system work should be coordinated with the practical organizational management on separate freight fronts.

Requirements for organizational management of autoloaders on different freight fronts

Let's assume that *S* loaders work on *n* freight fronts at the same time. Then $Q_i = S\ П_m$ tons of freight will be processed on every *i* front per 24 hours. Thus, one of the necessary conditions for organizational management according to the suggested optimal scheme is the maintenance of equal volumes

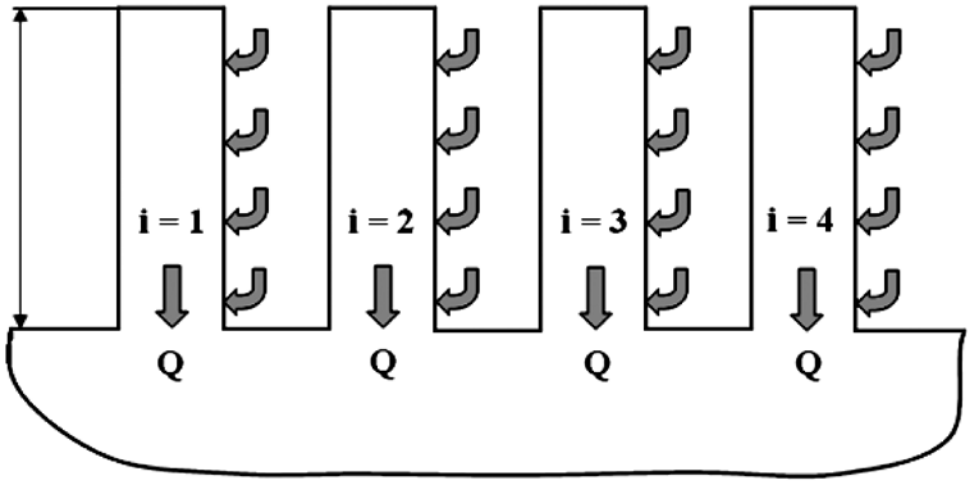

Figure 6. The scheme of freight fronts in a warehouse complex with approximately equal throughput

of daily freight handled on each front:

$Q = Q_i = Q_\Sigma/n$ (i=1, 2, …n).

In practice this condition can be satisfied in the event that separate freight fronts have equal length and serve approximately equal freight flows (Figure 6).

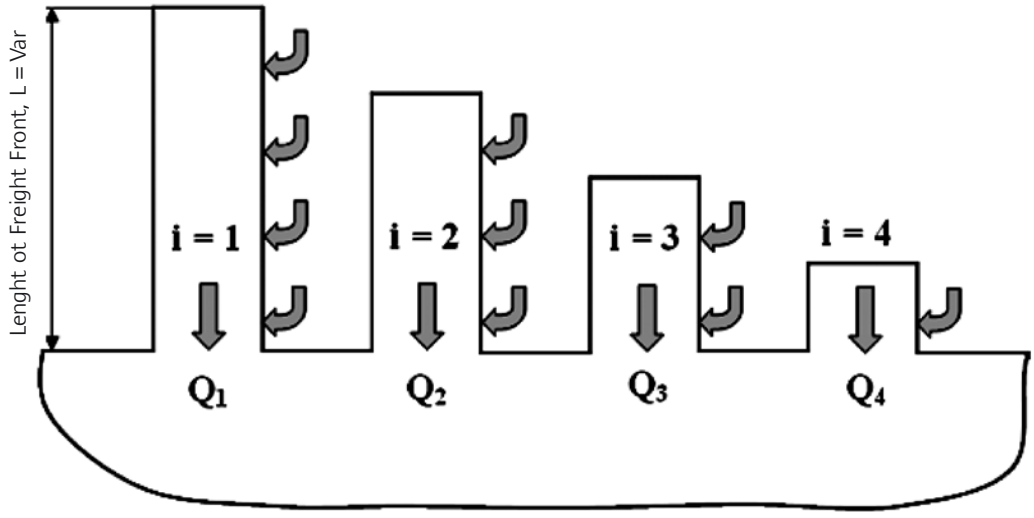

Figure 7. The scheme of freight fronts in a warehouse complex with linearly changing throughput

However the suggested scheme of the repair service organization appears comprehensible also in the case that throughput of separate fronts is different. In practice it may be connected, for example, with length change of various freight fronts (Figure 7).

Let's number the freight fronts in descending order of throughput so that the first of them ($i = 1$) has appeared loaded to the maximum ($Q_1 = Q_{max}$), and the last one to the minimum ($Q_n = Q_{min}$). If the number of fronts is even, and Q_i changing from front to front occurs under the linear law, the volume of processed freights is:

$$Q_{\Sigma} = \frac{Q_1 + Q_n}{2} n = \frac{Q_{max} + Q_{min}}{2} n \ [t/d].$$

For the maintenance of a constant rate of freight resource exhaustion by all loaders, they are reasonable to be co-operated in $n/2$ groups per $2S$ pieces the extreme freight fronts, for example the first and the last one, the second and the penultimate, etc.

Thus the fronts co-operated with identical daily volume of processed freights $Q_{max} + Q_{min}$ will be served by $2S$ loaders each. And the loaders working on co-operated fronts should change between them every day for the maintenance of a constant rate of freight resource exhaustion which will be identical for all loaders in this case.

Literature

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