Research Article

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Optimal Placement Method of RFID Readers in Industrial Rail Transport for Uneven Rail Traffic Volume Management

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Abstract: The issue of operative data reception on location and movement of railcars is significant the constantly growing requirements of the provision of timely and safe transportation. The technical solution for efficiency improvement of data collection on rail rolling stock is the implementation of an identification system. Nowadays, there are several such systems, distinguished in working principle. In the authors’ opinion, the most promising for rail transportation is the RFID technology, proposing the equipping of the railway tracks by the stationary points of data reading (RFID readers) from the onboard sensors on the railcars. However, regardless of a specific type and manufacturer of these systems, their implementation is affiliated with the significant financing costs for large, industrial, rail transport systems, owning the extensive network of special railway tracks with a large number of stations and loading areas. To reduce the investment costs for creation, the identification system of rolling stock on the special railway tracks of industrial enterprises has developed the method based on the idea of priority installation of the RFID readers on railway hauls, where rail traffic volumes are uneven in structure and power, parameters of which is difficult or impossible to predict on the basis of existing data in an information system. To select the optimal locations of RFID readers, the mathematical model of the staged installation of such readers has developed depending on the non-uniformity value of rail traffic volumes, passing through the specific railway hauls. As a result of that approach, installation of the numerous RFID readers at all station tracks and loading areas of industrial railway stations might be not necessary, which reduces the total cost of the rolling stock identification and the implementation of the method for optimal management of transportation process.

Keywords: RFID; railway transport; railway nodes; industrial rail transport; uneven rail traffic volume; management; mathematical model; linear programming

1 Introduction

The key trend of global transportation system development is the concentration of freight traffic at transport corridors and an intensive implementation of terminal technology. Transport technology systems and industrial transportation systems are one kind of terminals, in addition, to provide origination and absorption of rail traffic volumes, they ensured the immediate transport service of consumers – transport clients. With the increasing power of rail traffic volumes at transport corridors, the role of transport technology systems is very important to ensure timeliness of transportation for small and medium-sized cargo owners. In the case of railway nodes and transport technology systems, it leads to the complication of structure of handled trains and to the increase of shunting operations for trains’ rearrangement [1].

The noted trends are the most clearly apparent in the context of the railway transportation market development in Russia and form a competitive environment in this sphere. By 2011, the whole wagons fleet was transferred to the private operating companies. With the increasing total number of railcars owned by the operating companies, there has been no increase in traffic. However, there has been the increase of freight turnover. The main cause is the uncoordinated efforts of operating companies to manage the rolling stock fleet and utilization of the irrational railcars. As a result, the proportion of empty runs and
turnaround time of railcars are increased, reducing the reserve capacity and processing ability of railway stations and spans. The lack of transport capacity allows operating companies to acquire new railcars which exacerbate the situation. Current situation leads to the quality (timeliness) reduction of rail freight transportation (Figure 1) [2, 3].

As a result of mentioned phenomena the complexity of railcars’ structure takes place, since at railway nodes and industrial transport systems it must take into account features of railcars’ handling owned by different rail operators (Figure 2). It seriously affects the tasks for railcars’ management at railway nodes [4].

The traditional methods of operational transportation management on industrial rail transport were developed for freight traffic management with the relatively stable power and structure. Application of these methods in the changed circumstances leading to the significant increase of railcars’ dwell time on the special railway tracks, turnaround time of private railcars and difficulty of safety monitoring. Furthermore, management decisions are a little more complicated because of the insufficient information support of the transportation process [5].

To improve the efficiency of information service in the basis for management decisions at industrial rail transport, it is crucial to ensure the necessary efficiency of data collection about the location of rail rolling stock on the special railway tracks. The technical solution of this problem is the introduction of an identification system for rolling stock.

The identification and positioning systems should ensure identification of controlled objects; optimal positioning accuracy; optimal frequency of update data. Nowadays, in transport and industry, there are several systems have been applied to the identification of moving objects using different technologies and different working principle [6, 7]. The most common groups of technology are local positioning systems which include optical (including infrared) and ultrasonic systems; satellite navigation systems – GPS, GLONASS, Beidou (Běidˇou), Galileo and others; radio frequency identification technology - RFID (Radio Frequency Identification). The detailed comparative analysis of the technologies and systems is presented in [8].

The RFID or radio frequency identification is the technology using radio-frequency electromagnetic radiation for reading/writing information on the small device – tag, label or transponder. The task of the RFID systems is the storage of information with the possibility of its easy reading. The tag may contain information about object type, value, weight, temperature, owner, etc. The RFID system consists of three basic components: a reader (transmitter/receiver); an antenna; radio frequency tag with the integrated antenna, receiver and transmitter.

The automatic data reading systems of the moving rail rolling stock are used in the information management systems and intended for automatic fixation of the locomotives, freight and passenger railcars, railcars-mechanisms through pre-selected reader points [8]. At the present time, the widest system of automatic rolling stock identification on national railways is the «Palma» system [9].

To implement the measures for the introduction of rolling stock identification system on the special railway tracks of industrial enterprises it would be required to purchase stationary and mobile readers with the long-range and active RFID tags for their own rolling stock as well.
However, the introduction of identification systems in large industrial enterprises equipped with the extensive network of railway tracks with a large number of stations and loading areas is difficult because of considerable financial expenses, irrespective of the type and manufacturer of the RFID systems. For example, installation of the full set of data reading points from the onboard sensors of automatic identification system for rolling stock at railway nodes – AIS «Palma» for railway nodes with the deployed length of railway tracks more than 700 kilometers and composed of more than 30 railway stations would require the one-time costs of 12 million Euro [10].

To reduce investment costs for establishing the rolling stock identification system at the railway nodes, authors proposed the method of how to select the place of readers’ location, based on the idea of priority placement of these devices on the railway tracks and crossover tracks, where freight traffic flows are passed with unstable and uneven structure, power, and rail traffic volumes with a complex structure as well. The parameters of such volumes are difficult to predict at the present level of information systems’ development on the transport of industrial enterprises. This results in the delay of handling such flows at railway stations of a node.

The selection of prioritization to equip railway tracks at transport nodes characterized by the both complex structure like on railway tracks and processed traffic volumes, it proposes implementing the application of developed mathematical model and methodology.

2 The mathematical model statement formulation of optimal location of RFID from railcars at railway nodes

We assume that on the transport network describing the railway junction, there is \(i = 1, 2, \ldots, M\) places of potential RFID readers’ location from the onboard sensors which installed on railcars. RFID devices record the data about rail traffic volumes \(l_{ij}\), where \(i\) is the conventional number (index) of the flow, characterized by the type of cargo, railcar, railcar owner, etc. \(i\) is the place (station) of the flow origin, \(j\) is the location (station) of flow reduction. Each traffic volume flow \(l_{ij}\) is characterized by non-uniformity values in the place of its origin \(\mathcal{K}_{ij}\) and in the place of their reduction \(\mathcal{K}_{ij}^{l}\). Totally, \(L\) flows pass on a network.

As a result of RFID devices location in a special place, an effect forms in the size \(E_i\). We are supposed that the relative value of this effect will proportional to the non-uniformity factor of rail traffic volume. This assumption based on the fact that a great value of non-uniformity factor of rail traffic volume is in line with increased uncertainty and the larger amount of management information about the movement of these volumes. Therefore, the more non-uniformity value of the total coefficient of all rail traffic volumes registered by RFID devices, the more effect is achieved as a result of its utilization.

Then, the relative value of effect resulting from placement of one RFID device on the \(i\)-th place will be determined as an effectiveness ratio of one RFID reader placement to the total (maximum) efficiency of RFID system installed in each of the \(M\) places.

The efficiency of the \(i\)-th RFID device is defined as the sum of non-uniformity factors for all outgoing and incoming flows for the specific location (non-uniformity factors are summarized at the place of their origin and at the place of each flow reduction) and calculated by the formula:

\[
E_i = \frac{\sum_{j=1}^{M} \left( K_{ij}^{l} + K_{ij}^{l} + \sum_{l=1}^{M} \left( K_{ij}^{l} + K_{ij}^{l} \right) \right)}{\sum_{j=1}^{M} \sum_{l=1}^{M} \left( K_{ij}^{l} + K_{ij}^{l} + \sum_{l=1}^{M} \left( K_{ij}^{l} + K_{ij}^{l} \right) \right) \times 100\%} \tag{1}
\]

The placement of each unit of the RFID devices is involved with one-time costs equal to the \(c_i\). It is necessary to determine the minimum value of the total investments in the equipping of transport network of the RFID devices whereby a specified level of control efficiency for rail traffic volumes is provided.

We denote that \(x_i = 1\) is the decision about RFID device placement at the \(i\)-th place of the transport network, thus \(x_i = 0\) will be the refusal to place the RFID device at \(i\)-th place.

Then the objective function of optimal placement of RFID readers by criterion of minimum investment cost can be written as follows:

\[
C = \sum_{i=1}^{M} c_i x_i \rightarrow \min \tag{2}
\]

The following restrictions were imposed upon the variable \(x_i\) of the objective function:

- the restrictions on the achievement of the specified level of the effectiveness of rail traffic volumes management, \(E_{\%}\)

\[
\sum_{i=1}^{M} E_i x_i \geq E_{\%} \tag{3}
\]
• the restrictions on placement redundancy of RFID readers is the condition that the location of the RFID device in the place of rail traffic volumes origin breaking away from the placement of this device at the point of rail traffic volume reduction, and vice versa

\[ x_i + x_j \leq 1, \quad \text{for } i, j, \quad \text{if } l_{ij} \neq 0 \quad (4) \]

and

\[ x_i \in Z(\text{integers}) \quad (5) \]

• the additional restrictions on a parameters’ change of rail traffic volume in the process of their movement. Restriction (4) may be established not for all locations connected by at least one flow since the route extension of flow movement results in the increase of deviations of its parameters from estimated parameters in place of its reduction. As a criterion for the restriction inclusion in the model (4) for each pair, \( ij \) is encouraged to use the difference value of non-uniformity factors in the places of flow origin and reduction. Then the restriction (4) will be rewritten as follows:

\[
\begin{align*}
\delta (x_i + x_j) &= \delta 1, \quad \text{for } i, j, \quad \text{for } l_{ij} \neq 0; \\
\delta &= 1, \quad \text{if } |K_{ij}^l - K_{ij}^s| < K \max; \\
\delta &= 0, \quad \text{if } |K_{ij}^l - K_{ij}^s| \geq K \max.
\end{align*}
\]

\( \delta \) = 1, if \( l_{ij} \neq 0; \)

\( \delta \) = 1, if \( |K_{ij}^l - K_{ij}^s| < K \max; \)

\( \delta \) = 0, if \( |K_{ij}^l - K_{ij}^s| \geq K \max. \)

The reverse issue is formulated as follows. It is necessary to determine the maximum level of effectiveness of the RFID system achieved in investing of the specified amount of funds.

The objective function of utility maximization problem will be written as:

\[ E = \sum_{i=1}^{M} E_i x_i \to \max \quad (7) \]

The following restrictions were imposed upon the variable \( x_i \) of the objective function:

• the restriction on the available investment resources, \( C \)

\[ \sum_{i=1}^{M} c_i x_i \leq C; \quad (8) \]

• the restrictions on placement redundancy of RFID readers and the restriction on change of parameters of the flow in the process of their movement were similar to the direct task – (5) and (6).

To convert the value of relative efficiency to an absolute value it is proposed to make use of the efficiency indicators of RFID devices recommended by the system manufacturer [9] taking into account the actual cost of specific railway tracks: reduction of empty movement coefficient and, consequently, the dwell time of railcar by 2.4%; the development of additional transportation and increase of the handling capacity on special railway tracks by 1.6%; cost reduction of railcars’ repair when implementing the repairing system on mileage, by 2.5%.

The phasing of the RFID readers’ placement on the special railway tracks at industrial enterprises or transport node is determined according to the purpose for each stage. In the case of need to provide the specified level of efficiency, the direct problem of optimization of RFID devices’ placement is solved with the result that the required level of investments is determined.

If there is the plan of annual investments in the development of the rolling stock identification system, the inverse problem is solved and the maximum achievable efficiency level is determined at such costs.

### 3 The example of model calculation

The scheme of an estimated transport network and rail traffic volumes between vertices of a network is presented in (Figure 3). Calculate the values of the efficiency of RFID readers’ placement (the numerator in the formula (1)) for each \( i \)-th place (vertex of transport network):

for 1-st vertex: \( 1.5 + 1.6 + 2.4 + 2.4 + 1.2 + 1.2 + 1.8 + 1.8 = 13.9; \)

for 2-nd vertex: \( 1.8 + 1.8 + 1.3 + 1.4 + 1.5 + 1.6 = 9.4; \)

for 3-rd vertex: \( 1.3 + 1.5 + 1.7 + 1.6 + 1.6 + 1.2 + 1.2 = 11.3; \)

for 4-th vertex: \( 1.2 + 1.6 + 1.4 + 1.3 = 5.5; \)
for 5-th vertex: \( 1.6 + 1.7 + 1.3 + 1.5 + 2.4 + 2.4 = 10.9 \).

We calculate the total (maximum) efficiency of the network equipping of the RFID devices (the denominator in equation (1)), as the sum of the \( E_i \) for all \( i \)

\[
M \sum_{i=1}^{M} \left( K_{ij}^l + K_{ij}^b + \sum_{j=1}^{M} \left( K_{ij}^l + K_{ij}^b \right) \right) =
\]

\[
M \sum_{i=1}^{M} E_i = 13.9 + 9.4 + 11.3 + 5.5 + 10.9 = 51.
\]

We calculate the values of relative efficiency for each vertex of the transport network by the formula (1): \( E_1 = 13.9/51 = 0.27; E_2 = 9.4/51 = 0.19; E_3 = 11.3/51 = 0.22; E_4 = 5.5/51 = 0.11; E_5 = 10.9/51 = 0.21 \).

If the costs of the placement of one RFID reader \( c_1 = 6000 \) euros, the objective function of direct issue (2) is given by the formula:

\[
C = \sum_{j=1}^{5} 6 \cdot x_j \rightarrow \min.
\]

We assume that is required to provide a 40% efficiency level in the control of rail traffic volumes. Then the constraint (3) can be written as

\[
0.27x_1 + 0.19x_2 + 0.22x_3 + 0.11x_4 + 0.21x_5 \geq 0.4.
\]

We write a system of restrictions (4) for each pair of transport network vertices connected at least by one flow (flow \( l_{15} \) is a transit for vertex 4, hence, restrictions for vertex’s pairs 1-4 and 4-5 are not included in a system of restrictions)

\[
\begin{align*}
1 + 2 & \leq 1; \\
1 + 3 & \leq 1; \\
1 + 5 & \leq 1; \\
2 + 4 & \leq 1; \\
3 + 5 & \leq 1; \\
4 + 3 & \leq 1.
\end{align*}
\]

The solving of the constructed model by the simplex method shows that the required effect is achieved by installation of two RFID devices on vertices 2 and 3. An objective function of inverse problems (7) is given by the formula:

\[
E = 0.27x_1 + 0.19x_2 + 0.22x_3 + 0.11x_4 + 0.21x_5 \rightarrow \max,
\]

and the restriction (8)

\[
\sum_{i=1}^{5} 6 \cdot x_i \leq 12.
\]

The solving of the inverse problem gives the same result as a direct one because the available funds are enough for the installation of two RFID devices. If 6,000 euros were allocated for the installation of one RFID device, the result of solving the inverse problem is the most effective placement is in the point 1 that has the relative effect of 27%.

Further improvement of the developed mathematical model connected with the introduction of a system of restrictions (4) and (6) correction coefficients before the unknowns. Through such correction factors, the requirements could be specified to the placement of RFID devices, for example, the requirements of cargo and railcar safety.

The developed model calculations are carried out for the real railway node, comprising 37 industrial railway stations, the total length of railway tracks is more than 800 km. The daily rail traffic volume on arrival in this railway node up is to 2,000 of railcars. To perform the calculations on the developed model, free access program LP-Solve IDE v.5.5.2.0 was selected [11]. A selection of this program had initially been guided by a large dimension of the solved problem - even in the case of rail traffic volumes’ modelling between stations without separation of the cargo type or the railcar type, restrictions’ number of the form (4) is 280 restrictions. In the case of the rail traffic volumes’ separation of the jets by cargo type or the railcar type, restrictions number rise up to two ranks.

To record the conditions of the problem (input data of a model), there are several formats used in program LP-Solve IDE, particularly their own «LP» format which represents a text file. An example of recording in the format of the LP model described in the previous paragraph is shown in Figure 4.

The last line (No. 12) accords with the restriction (5) defining, in this case, that required variables are binary (can take the values 0 or 1). Instead of the variables’ type...
«bin», it is also possible to specify the «int» type (integers), that gives the same result with restrictions in lines 6–11.

4 Assessment method and variants’ selection of the RFID systems

The enlargement of the developed method for assessment and placement variants’ selection of the RFID readers from railcars at railway nodes includes two stages. At the first stage, an analysis of node structure, the collection of data on the traffic volumes between the railway stations of a node, the calculation of the non-uniformity factor of the rail traffic volumes are performed. At the second stage, optimization calculations are carried out on the developed mathematical model, the tree construction of equipping options for hauls by the RFID readers and the selection of the optimal sequence (phasing) of the variants’ realization.

The recommended sequence of the works on calculation and evaluation of the technological scheme for variants’ location of the RFID readers includes the following steps.

1. To select the purpose of the implementation of a data collection system from the rolling stock at railway nodes. The purposes might be the maximization of the amount of recorded data of all railcars at the node; the maximization of the amount of the recorded data for uneven rail traffic volumes; the maximization of the amount of the recorded data of the massive rail traffic volumes; the minimization of costs on establishing the system.

2. To select the tasks solved in the process of the implementation of a data collection system. The main task is the registration and control of all types of railcars’ movement in the node. In some cases, it might be the task of control and management of the certain type of railcars, the railcars with a certain kind of the goods, the railcars belonging to a specific owner, etc. The selection of a task established the composition of the analyzed data of rail traffic volumes, as well as the procedure governing the composition of plans’ variants of the RFID devices’ placement.

3. The formation of the statistical samples of the daily number of railcars in the rail traffic volumes between each pair of the railway station of a node. Data can be taken from the information system of rail transport.

4. To calculate the non-uniformity factors of each rail traffic volume between each pair of the stations at railway node) and the matrix formation of non-uniformity factors of incoming and outgoing rail traffic volumes for each pair of stations. An example of the matrix coefficients is shown in Figure 5. First row and first column of the matrix contains the conditional numbers of the railway stations of a major node. As can be seen from the following fragment, the non-uniformity factors of rail traffic volume may differ by more than five times. The rail traffic volumes characterized by the large values of the non-uniformity factor have a complex structure and low frequency. The hauls where these kinds of rail traffic volumes must first be installed by the RFID readers.

5. To calculate the costs for the placement of RFID devices on each station. The costs are determined by the value of RFID devices and the hauls’ number adjacent to the station. It is envisaged that each haul installed by one RFID device.

6. The formation of an objective function of the model is the costs’ minimization for the placement of RFID devices (2). The formation of the model restrictions determining the scheme of special railway tracks (restriction of the form (4)). The formation of model restriction on the effective placement of RFID devices at the stations. An efficiency is determined as the ratio of the non-uniformity factors of rail traffic volumes of a concrete station to the total value of the non-uniformity of all rail traffic volumes of the railway node calculated by the formula (1) (restriction of the form (3)). The example of the mathematical model of optimal placement of the RFID devices for the investigated real railway node in LPSolve IDE program is presented in Figure 6.

7. The formation of a fundamental «tree» of equipment options for hauls by RFID readers. The structure of the tree is determined by the tasks that data collection system is expected to meet. For example, it is possible to outline in the separate branches the variants of the railcars’ data collection belonging to the enterprises of a node and located inside the node (local railcars, railcars of factory park), the railcars circulated on the network of mainline railways, as well as the mixed variants – data collection from all railcars.

8. The performance of calculations on the mathematical model for determining the optimal number of RFID devices for each variant of input data according to the developed principal «tree» of variants.
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Figure 5: The fragment of the matrix of non-uniformity factors of the rail traffic volumes between the railway stations of a node.

![Figure 5: The fragment of the matrix of non-uniformity factors of the rail traffic volumes between the railway stations of a node.](image)

Figure 6: The example of mathematical optimization model of RFID devices’ placement at railway transport node comprising 37 industrial railway stations.

The completion of the «tree» solutions by data about costs of the haul’s equipping by RFID devices and the resultant effect. The creation of the several solutions forming a sequence (phasing) of the readers’ implementation due to the fact that the solution of the developed mathematical model is the optimal equipping of a limited number of hauls. These hauls are already not taken into accounted and excluded in the scheme of the transport network in the next solution of a model. The example of the «tree» of equipment options at railway node by the RFID devices is shown in Figure 7. The costs of equipping are determined depending on the optimum number of RFID devices, the value of a size is calculated by the formula (1). The positive or negative numbers on the branches of the «tree» variants are the difference between costs and effect. In (Figure 7), the variants of data recording from railcars arriving at the node from external network are highlighted in light color, dark color is the railcars circulating inside the node.

9. The determination of the optimal sequence (phasing) of hauls’ equipping with the RFID readers at rail node by dynamic programming method, as the minimum total costs throughout the period of the
Variant 0 (existing)

**Variant 1.1**
costs: 340 149
effect: 13 688

**Variant 1.2**
costs: 218 616
effect: 4 934

**Variant 2.1**
costs: 148 532
effect: 19 892

**Variant 2.2**
costs: 101 647
effect: 23 725

**Variant 2.3**
costs: 45 455
effect: 55 350

**Variant 2.4**
costs: 45 455
effect: 55 350
- 9 895

**Variant 3.1**
costs: 96 358
effect: 24 871

**Variant 3.2**
costs: 42 179
effect: 76 413
- 34 234

**Variant 3.3**
costs: 65 638
effect: 88 041
- 22 403

**Variant 3.4**
costs: 72 261
effect: 177 146
- 104 885

**Variant 3.5**
costs: 53 595
effect: 264 100
- 210 505

**Variant 4.1**
costs: 46 179
effect: 25 187

**Variant 4.2**
costs: 20 566
effect: 188 256
- 1 67 690

**Variant 4.3**
costs: 65 638
effect: 88 041
- 22 403

**Variant 4.4**
costs: 72 261
effect: 177 146
- 104 885

**Variant 4.5**
costs: 53 595
effect: 264 100
- 210 505

Stage 1

Stage 2

Stage 3

Stage 4

**Figure 7:** The example of the equipment options’ «tree» of rail node by RFID readers.

**Table 1:** The optimal sequence (phasing) of the options.

<table>
<thead>
<tr>
<th>The selection priority (sequence number)</th>
<th>Sequence variants</th>
<th>Assessment sequence (Euro): costs (plus), effect (minus)</th>
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<tr>
<td>0</td>
<td>1.2 $\rightarrow$ 2.3 $\rightarrow$ 3.4 $\rightarrow$ 4.5</td>
<td>-33 374</td>
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<td>263 058</td>
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<td>1.1 $\rightarrow$ 2.1 $\rightarrow$ 3.1 $\rightarrow$ 4.1</td>
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The determination of an optimal frequency may be performed according to the criterion of the maximum total effect or to the maximum of the net discounted income. The optimal sequence includes the following options for the considered example (Figure 7) 1.2; 2.3; 3.4; 4.5 (Table 1), i.e., involves the placements of RFID devices on the hauls first and foremost, which has uneven rail traffic volumes arriving at the node from an external network (on average by 2 thousand railcars per day). Such a sequence could achieve at the end of the fourth year of the project the effect (not discounted) amounting to $33 374 euros.
5 Discussion

A prospective direction of this research, in the authors’ opinion, is the development of the technology of integrated management of data obtained from RFID devices and the creation of simulation models for operational forecasting the operational situation – train and shunting operations in rail nodes. The challenge of RFID systems is to provide simulation models of separate railway stations with the real-time data about the rail traffic volumes. Based on these reliable data, simulation models generate the predictions of the parameters of train and shunting operations. These predictions will be adjusted and refined as and when the new data from RFID devices becomes available. As a result, the detailed account of operations with rolling stock produced in the railway nodes is provided.

This combination of technical and organizational solutions can significantly reduce the costs of the creation of railcars’ movement control system, and it creates preconditions for the methods and models implementation of optimal management of the transportation process in the framework of intelligent transport systems on rail transport.

6 Conclusion

As a result of the analysis of existing positioning systems for rolling stock, authors concluded that to face the challenges of railcar identification problems at railway stations and on the railway tracks of industrial enterprises, the most perspective are the systems based on the utilization of the RFID technology. This is due to a number of reasons. The most significant should include: the existence of a large number of buildings, facilities, various metallic structures that debar the application of the of navigation systems (GPS, GLONASS, Galileo); operation of the rolling stock in adverse conditions (dusty air, an existence of pollution sources, etc.), thereby reducing the efficiency of the optical railcar identification system; starting to cycle a large number of private railcars within the major railway nodes, that making more effective their equipment by the onboard sensors containing various types of information on railcar; the implementation of different operations at railway node for their effective accounting, it is desirable to provide data about these operations to the rolling stock.

The equipment of a railway node with an extensive network of railways and a large number of stations and freight fronts with the RFID devices requires considerable one-time costs. To provide the maximum efficiency of data recording on the railcars at railway nodes with limited investment resources, it is proposed the phasing equipment of interstation hauls with the RFID devices. In the first place, it is proposed to equip interstation hauls which have the rail traffic volumes with the maximum value of non-uniformity factor. The effectiveness of this approach is due to the fact that the parameters of stable and uniform rail traffic volumes are predicted with sufficient accuracy based on data from the existing information systems on the railway transport. Therefore, the additional registration of such flows through the RFID devices is not always as effective as the uneven flows with complex structure. The lack of reliable information and predictions about the uneven traffic volumes complicates their operational management, that, ultimately caused delays in their processing, increases the delivery time, reduces the indicators efficiency of a rolling stock utilization. The paper contains the formula to calculate the efficiency of RFID devices depending on the value of non-uniformity of the registered rail traffic volumes.

To determine the optimal placement of the RFID devices of data capture from railcars on the interstation hauls in the railway nodes, the mathematical model that maximizes the effect of the installation of RFID devices has been developed. In the developed model, it takes into account the restriction on the redundancy of RFID devices placement, i.e. the condition that location of the RFID device in the place of rail traffic volume origin allows to eliminate the placement of this device at the point of rail traffic volume decreasing, and vice versa. Furthermore, it is proposed to consider an additional restriction on the change of parameters (non-uniformity factor) for rail traffic volumes in the process of their movement. It is anticipated that the route extension of the flow leads to an increase of the deviations of its parameters from the estimated deviations in place of a decrease of the rail traffic volume.

This paper proposes the calculation example of the developed model and the results of calculations on the model for the railway node with the flattened length of the railway tracks more than 800 km, handled up to 2 thousand railcars per day and includes 37 railway stations.

The method of phasing equipping of interstation hauls with RFID devices based on the formation of the equipment variant «tree» according to the tasks of primary registration of various types of railcars, as well as the priority placement of RFID readers in optimal places. It is proposed to select the optimal sequence for variant realization with dynamic programming method.

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